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19-22 September 2022
BARCELONA

SEFI 2022

50th Annual Conference of The European Society for Engineering Education

19-22 September, Barcelona, Spain

Towards a new future in engineering education, new scenarios that European alliances of tech universities open up

PROCEEDINGS

50th Annual Conference of The European Society for Engineering Education

19-22 September, Barcelona, Spain

Towards a new future in engineering education, new scenarios that European alliances of tech universities open up

SEFI 50th Annual Conference
Universitat Politècnica de Catalunya · BarcelonaTech (UPC)
19 –22 September 2022

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This book contains the contributions accepted for presentation at the 50th SEFI 2022 Annual Conference, which was held in Barcelona on 19-22 September 2022.

We are moving fast towards new scenarios in engineering education. Not only is technology strongly influencing education, human and social factors are also at the core of essential ways of shaping a new future for universities.

How can we shape the future of learning and teaching?

We can have a say, as we have comprehensive experience in all relevant elements that influence learning. We share our passion for education. We have the will to accompany teachers and new academics on the road to engineering education. We have all the SEFI Special Interest Groups working hard on key topics.

Let us share our vision for the future and the new scenarios that open up and bring together the transformative capacity of universities and teachers.

The focus of the proceedings also explore the new scenarios that European alliances of tech universities open up for the future of engineering education.

The organizers would like to thank all authors for submitting their contributions, as well as the supporting organizations for their help in making SEFI 2022 possible.

Furthermore, we are delighted to announce that in addition to ISBN, we will include a Digital Object Identifier (DOI) for each accepted paper at this year's conference. We hope that you appreciate this important step forward, we believe having a DOI is an excellent advantage for researchers

The UPC and its Institute of Education Sciences have just celebrated 50 years in teaching and education. The SEFI and the UPC are thankful for everyone's participation in this project.

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Santiago Silvestre *(Co-Chair SEFI Conference 2022)*

Ariadna Llorens *(co-Chair SEFI Conference amb Director of ICE UPC*

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SEFI is the largest network of higher engineering education institutions (HEIs) and educators in Europe. Created in 1973, SEFI is an international non-profit organisation aiming to support, promote and improve European higher engineering education, enhancing the status of both engineering education and engineering in society.

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SEFI formulates ideas and positions on engineering education issues, influences engineering education in Europe, acts as a link between its members and European and worldwide bodies, contributes to the recruitment of good students whilst always promoting an international dimension in engineering curricula.

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The cooperation with partner and sister engineering organisations in Europe and in the world is also one of our priorities.

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TOWARDS A NEW FUTURE IN ENGINEERING,

NEW SCENARIOS THAT EUROPEAN ALLIANCES OF TECH UNIVERSITIES OPEN UP

We are moving fast towards new scenarios in engineering education. Not only is technology strongly influencing education, human and social factors are also at the core of essential ways of shaping a new future for universities.

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The focus of the conference also explores the new scenarios that European alliances of tech universities open up for the future of engineering education.

The UPC and its Institute of Education Sciences have just celebrated 50 years in teaching and education. Therefore, at this 50th SEFI annual conference, the SEFI and the UPC are pleased to invite everyone to participate.

Theme of SEFI 2022

"Towards a new future in engineering education", new scenarios that European alliances of tech universities open up.

- Conference Tracks

1. Entrepreneurship Education.
2. Artificial Intelligence in Education.
3. Student Engagement. Building Communities and Coordination.
4. Industry and Companies liaison. Regional Involvement and Innovation.
5. Mentorship and Tutorship.
6. Fostering Engineering Education Research.
7. Sustainability. Sustainable Development Goals.
8. Ethics in Engineering Education. Social and Service Learning, Cooperation for Development.
9. Virtual and Remote Labs.
10. Navigating Open Learning Environments (Moodle and others).
11. Mathematics at the heart of Engineering.
12. Physics and Engineering Education.
13. Architecture Education.
14. Challenges of new European Universities (Joint Programmes, Flexible Study Pathways, Student Mobility, Metacampus, Co-teaching, Co-creation with students, ...).
15. Attractiveness of Engineering, Gender and Diversity.
16. Curriculum Development, Engineering Skills, Lifelong Learning. (Including skills and competences, transition to labour market, self-awareness, management of self, creativity and innovation, management competences, employability, competitiveness, professional development, career planning, principles and values).

Contributions on any other topic on Engineering Education are also welcome.

KEYNOTE SPEAKERS

Monday 19 September 2022

New scenarios that European alliances of tech universities open up

Lourdes Reig Puig

Vice-rector for International Policy

Universitat Politècnica de Catalunya (UPC), Spain

Lourdes Reig Puig has a degree in Biological Sciences from the Universitat Autònoma de Barcelona, a doctoral degree in Marine Sciences from the Universitat Politècnica de Catalunya and a master's degree in Scientific, Medical and Environmental Communication from the Universitat Pompeu Fabra. She has been an associate professor attached to the Department of Agri-Food Engineering and Biotechnology and affiliated with the Barcelona School of Agri-Food and Biosystems Engineering (EEABB) since 2003.As a researcher she is part of the Centre for Agrifood Economics and Development (CREDA-UPC-IRTA). Her research field is aquaculture, in which, as the technical director of an aquaculture facility for eight years, she focused on production before starting her activity at the UPC. She has spent mobility periods at the University of Washington (Seattle, USA) and the Lower Saxony Fish Health Control Centre (Hanover, Germany). She was a visiting professor at the University of California (Davis, USA) and the Technical University of Denmark (Copenhagen). She is the author or co-author of more than 30 publications in indexed and non-indexed journals and around 100 conference papers. She has participated in numerous national and European competitive research projects and technology transfer contracts. She is currently the director of the Maritime Network of Catalonia (BlueNetCat).In the area of management, she was the academic secretary (2005-2007), the assistant director of Promotion and International Relations (2008-2010) and the director (2011-2015) of the Barcelona School of Agricultural Engineering (ESAB, now EEABB). She coordinated the interuniversity master's degree in Aquaculture (2006-2010) and was the vice-rector for International Relations (2015-2017).

Wednesday 21 September 2022

Gender mainstreaming in Engineering Education

Alicia García-Holgado

Assistant Professor

Computer Science Department

University of Salamanca, Spain.

Alicia García-Holgado received the degree in Computer Sciences (2011), a M.Sc. in Intelligent Systems (2013) and a Ph.D. (Cum Laude) (2018) from the University of Salamanca, Spain. She is Assistant Professor at the Computer Science Department since September 2021 and member of the GRIAL Research Group of the University of Salamanca since 2009, where she currently leads the research line "Social Responsibility and Inclusion". She is a Researcher of International Impact at the Universidad Nacional San Agustín, Arequipa (Peru). She is also a member of the Women in Computing Committee of the Spanish Computing Scientific Society and sub-coordinator of the CLEI (Latin American Centre for Computer Science Studies) Community for Latin American women in computing. Her research is related to the development of technological ecosystems for knowledge and learning processes management in heterogeneous contexts, and the promotion of diversity and inclusion in STEM, with a particular focus on engineering and technology. She has participated as technological support and coordinator in a large number of regional, national and international research projects. She is currently part of the coordinating team in the W-STEM project, a capacity building project funding by the European Union (https://wstemproject.eu), and researcher in the CreaSTEAM project, both focused on creating inclusive spaces in education and reducing the gender gap in STEM.

Thursday 22 September 2022

The Future of Engineering Education in a Post-pandemic World

Arnold Pears

Professor and Department Head

Department of Learning in Engineering Sciences

KTH Royal Institute of Technology, Sweden

Arnold Pears BSc(Hons) 1986, PhD 1994, La Trobe University, Melbourne, Australia. Appointed to Professorial Chair, Department of Learning in Engineering Sciences, KTH Royal Institute of Technology, Stockholm, Sweden, 2018. Uppsala Served in the University Academic Senate, Programme Director for the IT Engineering programme, and served multiple terms as elected member of the educational advisory board of the Faculty of Technology and Natural Sciences. Currently supervises 4 PhD students and leads the KTH participation in projects funded by the EU and NordPlus. He coordinates KTH participation in 2 Swedish Reseach Council funded graduate schools. He has published more than 40 journal articles and more than 150 refereed conference papers. Citations: 1861, H-index: 19, Google Scholar 14/12/2020

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PAPERS

RESEARCH PAPERS

DESIGN AND EVALUATION OF A CHEMISTRY SUBJECT IN AN ENGINEERING DEGREE

Almajano, MaríaPilar
Chemistry Engineering Department, Universitat Politècnica de Catalunya

Darbra, Rosa Mari
Chemistry Engineering Department, Universitat Politècnica de Catalunya

Lalueza, Joana
Chemistry Engineering Department, Universitat Politècnica de Catalunya

Conference Key Areas: *Student Engagement*
Teaching methods
Keywords: *Flipped classroom; continuous assessment; leadership; self-study*

doi:10.5821/conference-9788412322262.1150

ABSTRACT

The beginning of a new Degree at UPC was the opportunity to design a Chemistry subject from the start. It was designed under the criteria of focusing the process on student learning, following the indications of the last meeting of the European Higher Education Area in Rome, November 2020.

The objective of the design was to comply with the regulatory requirements and incorporate the learning outcomes that were already defined in other engineering areas, as well as to facilitate the learning of students who had not studied chemistry in high school (between 20 and 30%).

To this end, videos have been created with embedded questions, tests, summary preparation criteria, various cooperative work methodologies, ... to which part of the subject's grade (10%) has been assigned in order to facilitate student commitment to weekly completion.

Each academic year (3 normal and one in confinement have been developed) an assessment has been made with the students, both of the methodology and the material. In all cases, they reflect that continuous work and immediate or very close feedback is one of the points that has helped them the most in their process. They have also commented (in each academic year) on possibilities for improvement in which they have been directly involved and have helped to bring it to completion.

The material is currently ready to be made public on the University website and accessible to all students.

1 INTRODUCTION

1.1 Preliminary and regulatory aspects

The design of a subject for a new degree, respecting the indicators set by the ministry, is a challenge for the team of professors and entails a prior extensive search, as well as a consensus on the contents.

The Engeneering and Economics Degree (EnEcD) was born as a fusion of an Engineering Degree (EnD) and an Economics Degree (EcD). The contents of the Official Gazette of the State of Spain (BOE in Spanish) are respected. Nevertheless, the 10.5 ECTS present in Chemistry EnD (divided into two courses) are encompassed by 6 ECTS (one course), respecting the competences.

The regulations only indicate Specific Competence (SC4): ability to understand and apply the principles of basic knowledge of general Chemistry, Organic and Inorganic Chemistry and their applications in Engineering. The Learning Outcomes (LO) are:

1. Able to predict physicochemical properties based on the composition and structure of a compound.
2. Able to correlate the physicochemical properties of pure substances or mixtures with the composition and molecular and electronic structure of the components.
3. Able to solve problems analytically or numerically.
4. Able to know the use of the material and the equipment found in a chemical laboratory.

Other contents:

1. Fundamental concepts of Chemistry. Structure of matter and chemical bond.
2. Basic relationships between the structure of organic and inorganic substances and their physical properties.
3. Reactivity of organic and inorganic substances. Engineering applications.
4. Chemical laboratory, laboratory material and security.
5. Basic chemical laboratory experiments.

In addition, the faculty of the subject incorporates general skills that are specified in aspects of methodology. For this reason, in both theorical and practical lessons as well as in exams take place discussions regarding possible solutions, aspects such as versatility, initiative, adaptation to new situations, creativity, critical reasoning, ability to communicate, understanding of statements, justification of reasoning, autonomous and critical reasoning, consolidation of habits of self-discipline, self-demand and rigor, identification of the key factors of a problem, proactive attitude, continuous improvement, among others.

With all of the above mentioned, the topics, contents and LO are decided. This information is collected in Table 1.

An important point to consider is the initial heterogeneity of the students. Since a percentage of them –between 20 and 40% – do not study Chemistry in high school, they do not understand the basic concepts upon arrival at university.

After discussing "the framework topics" –the learning objectives – the learning methodology and continuous assignments are chosen. The specific learning evidence supporting this choice can be found in the perspective of the "constructive alignment" of Biggs and Tang [1].

1.2 Reflections on the methodology of Chemistry

In the last 20 years the concept and planning of Flipped Classroom has gained popularity at all levels of education and in all areas of knowledge, from the humanistic to the technological, including Chemistry. What is important is not the name of the methodology used and following fixed rules, but to build a framework of active learning [3]. The design of a discipline through this methodology has been extensively studied, specifically regarding the benefits it brings to student learning. The effectiveness in improving student performance is no longer discussed, because it is evident with numerous studies that contrast it. It is worth highlighting an article by Reid, in Milwaukee, in which a global meta-analysis of student satisfaction on the flipped classroom is made, compared to traditional methodologies. They highlighted that flipped classroom had a weak-moderate positive effect on student satisfaction [4]. A recent experience (2019) with positive results in the teaching of Chemistry was carried out at the University of Sydney. They took advantage of the opportunity offered by the renewal of the curriculum to move part of the subject into the “inverted model”. Tutorials, videos and questionnaires were prepared so that students could work outside the classroom in the time not shared with the Lecturer. Moreover, guided work was planned, in pairs, in which the procedures were discussed and both the students and the Lecturer actively participated. The most remarkable aspects of this study are, on the one hand, the students' satisfaction with the learning resources and, on the other, the results, measured as final grades, which were statistically superior to those obtained in "more traditional" learning situations. The number of failures was similar or even lower [5].

Two studies analyzed the situation of an entire branch of Chemistry at country level. The first was held in Poland in 2009: It focused on Analytical Chemistry. However, it does not indicate or advise any type of methodology [6].

Table 1: Correlation between required legal content, learning outcomes and defined topics

BOE content	Designed content	Topic (Chemistry)	Learning Outcomes
CE4 - Ability to understand and apply the principles of basic knowledge of general Chemistry –Organic and Inorganic Chemistry– and their applications in engineering.			
Fundamental concepts of Chemistry. Structure of matter and chemical bond.	*Le Chatelier* 's principle Bond. Molecular structure Hybridization Chemical kinetics	Topic 2	Able to predict physicochemical properties based on the composition and structure of a compound. Able to correlate the physicochemical properties of pure substances or mixtures with the composition and molecular and electronic structure of the components. Able to solve problems analytically or numerically.
Basic relationships between the structure of organic and inorganic substances and their physical properties.	Hybridization. Link. Molecular structure Functional groups in Organic Chemistry and main reactions	Topic 2 Topic 3	Able to predict physicochemical properties based on the composition and structure of a compound. Able of correlate the physicochemical properties of pure substances or mixtures with the composition and molecular and electronic structure of the components.
Reactivity of organic and inorganic substances. Engineering applications.	Acid-base equilibrium Precipitation and complexation equilibria Oxidation-reduction equilibrium. Main reactions in Organic Chemistry	Topic 1 Topic 4 Topic 5 Topic 3	Able to solve problems analytically or numerically.
Chemical laboratory, laboratory material and security.	Specific laboratory sessions and self-study videos	Experimental practices	Able to solve problems analytically or numerically. Able to know the use of the material and the apparatus found in a chemical laboratory.
Basic chemical laboratory experiments.	Specific laboratory sessions and self-study videos	Experimental practices	Able to solve problems analytically or numerically. Able use the material and the apparatus found in a chemical laboratory.

The second, from 2017, was published collecting the difficulties of teaching Organic Chemistry in Russian universities. As a consequence of this meta-study, global recommendations were made to all universities, but more in line with the type of knowledge to be imparted than with methodologies [7] .

Fautch, from York College of Pennsylvania, wonders whether the flipped classroom is effective in small groups for teaching Organic Chemistry. He concludes that the students who worked with the flipped classroom felt "more comfortable" with Organic Chemistry and even became passionate about the subject, which leads him to conclude that the flipped classroom is an effective tool for teaching Organic Chemistry [8] .

In 2016, Eichler and Junelyn Peeples of the University of California-Riverside and of Claremont University Consortium, respectively [9] comment on the large proportion of Lectures in the areas of knowledge of Science, Technology, Engineering and Mathematics that continue to use the so-called master classes or expository classes, focused on what the Lectures does.

One aspect to be highlighted, due to the effort it can save teachers who want to use this methodology, is the use of videos from Khan Academia, which greatly simplifies teacher preparation. In addition, small guides and a support book are provided.

2 METHODOLOGY

2.1 Chemistry design for engineers

With all the background described, the faculty designs the subject, focusing on student learning and student autonomous work. Hence, there are two key aspects to be considered: (1) integrate the constructive alignment in the contents, methodologies and evaluation; (2) unite the three aspects from which Chemistry can be approached (macro, micro and symbolic) in the development of problems in the classroom and outside it. Figure 1 shows a global scheme of this development.

2.2 Contents

In the fifth iteration, which is the one presented here, Chemistry has been distributed in five topics. Three of them are associated with the first semester and two of them with the second semester of the previous grade.

The topics are the following ones:

Theme 1. Acid-base equilibrium (5 sessions + 1 continuous evaluation).

Theme 2. Descriptive Chemistry (4 sessions):

Bond. Molecular structure. Hybridization. Chemical kinetics. Le Chatelier 's principle.

Theme 3. Introduction to Organic Chemistry. Basic organic reactions (4 sessions and mid-term exam).

Theme 4. Precipitation and Complexation Equilibrium. Heterogeneous systems (5 sessions).

Theme 5. Oxidation-reduction equilibrium (5 sessions + 1 continuous assignment).

Presentation by teams: 1 session ; and Lab Practices: 2 sessions

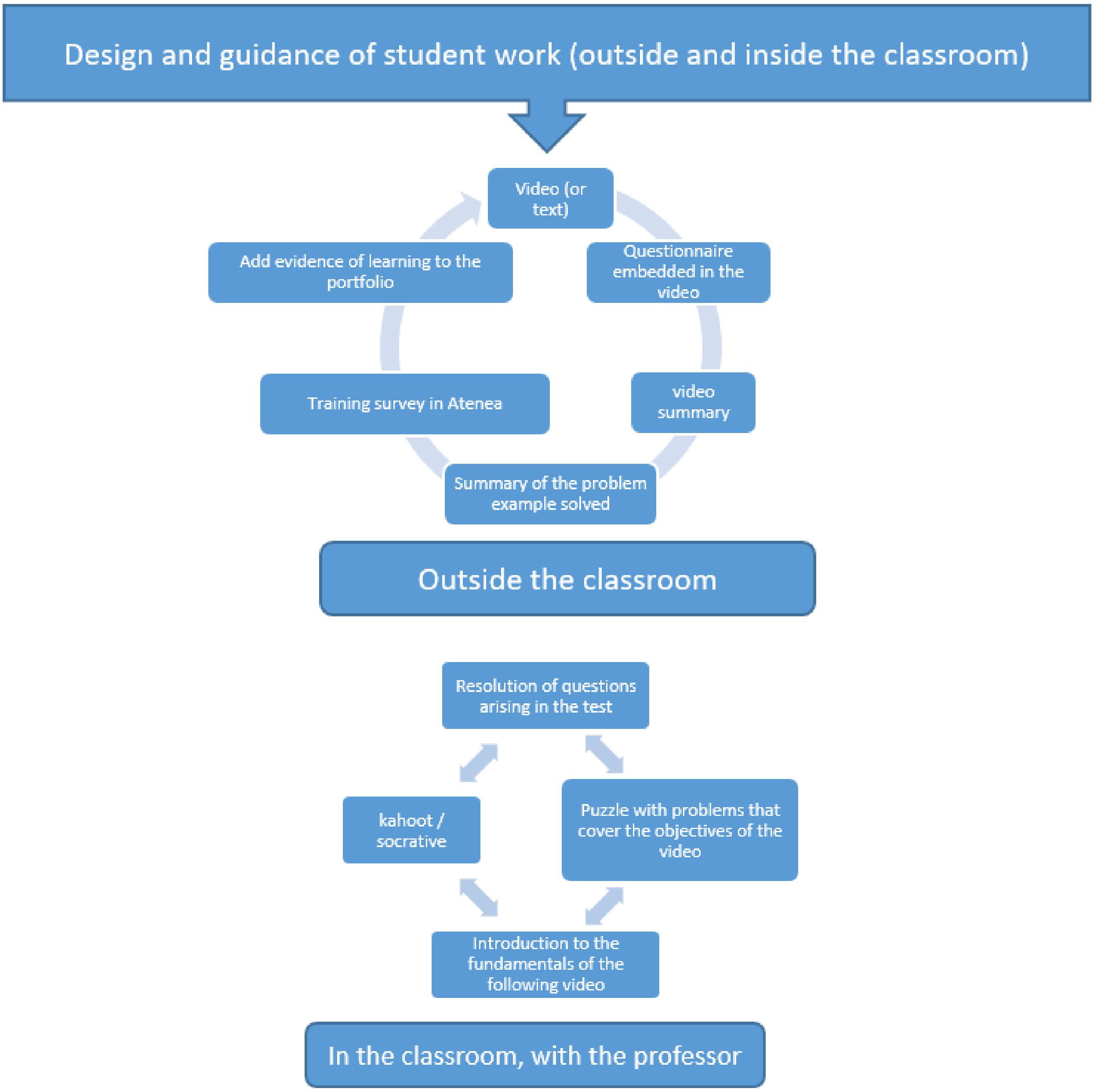

Fig. 1. Global scheme of planning inside and outside the classroom

The global evaluation is based on Eq.1:

10%CA1 + 10%CA2 + 25%mid-term exam + 10%(Portfolio+tests+lab practices) + 35%final exam (Eq.1)

being CA: continuous assignment.

The portfolio must be done weekly; the weekly deliveries must be reflected, especially summaries, exercises done in groups, the reasoning, the evidence of learning...

For this reason, it has been decided to evaluate the portfolio as a continuous work of the course, which will be posted on Moodle platform and can be consulted at any time, especially useful for those students who struggle with exams. As the tests are "self-corrected", the professor’s time is optimized and so it can be spend teaching.

With the idea of bringing together the three aspects from which Chemistry can be analyzed (macro, micro and symbolic) the statements of some problems have been changed. For example, transforming a typical pH calculation problem in a buffer solution with certain data into a laboratory video in which the same data is explicit in the footage, with a final question mark on the pH meter screen.

3 RESULTS

3.1 General comments

Figure 2 represents the evolution of grades throughout these 4 academic years. No student failed the subject during the first year, with 1 during the second year and 5 in both the third and the fourth. Nevertheless, the most remarkable feature is the increase in good grades as the methodology of the subject improves due to the enhancement of the aspects collected in the surveys with the students.

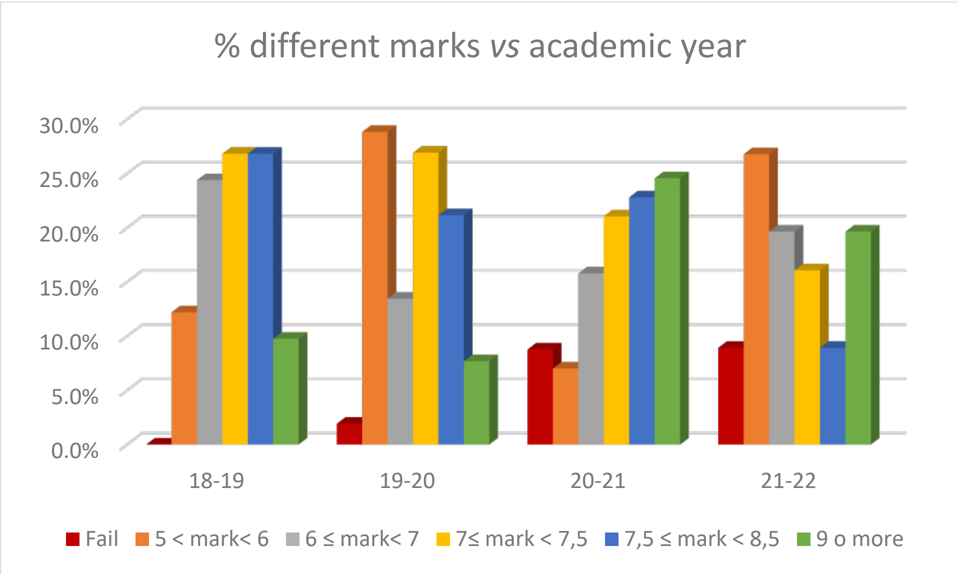

Fig. 2. Grade distribution (number of students vs intervals) in each academic year

The EnEcD entry mark requirement was 12.102/14 (18-19), 12.024/14 (19-20), 12.516/14 (20-21), 12.548/14 (21-22). These data indicate that it is a degree highly requested by students, which implies that only the best among those who have applied for it can enter. This allows for a high level of rigorousness that, for the most part, the students can keep up with. The decrease in the entry mark requirement from the first to the second year is due to an increase in the number of places.

In general, the marks obtained by the students are slightly higher (with non-significant differences except for the last academic year) than those obtained in the rest of the subjects. Nevertheless, learning satisfaction (manifested in the different surveys that have been given to the students) and the class attendance is much higher.

3.2 Course 18-19

It is perceived that after the half-term exam there is a general discouragement, not focused on Chemistry but on EnEcD. One of the advantages that active methodologies bring is continuous teacher-student contact, which allows for conversations that facilitate understanding of student behavior from a more anthropological perspective. For this reason, the possibility of personalized teacher-student tutoring is proposed to improve performance. 74% of students make use of academic tutoring.

An anonymous survey was carried out to the students, and the possible improvements for the following course were obtained:

a. Improvement and standardization of the documentation given to students.

b. Homogeneous weekly structuring, without work delivery between classes with only one day in between.

c. Elimination of deliveries of solved problems prior to joint work with the teacher.

d. As a strong point of the first definition of the subject, the students are able to work in group, which they value positively and consider that it helped them to get into the degree itself and to resolve their doubts.

e. Another positive aspect are class presentations made by students, carefully prepared by them and that allow to teach theoretical aspects in a more attractive and dynamic way.

Administrative questions via email student-professors are constant. It is decided to create a document with Frequently Asked Questions (FAQ) that will be explained on the first day and will be posted on Moodle Platform.

3.3 Course 19-20

As in the previous course, an anonymous survey was passed through Google Forms in which students had to reflect on the aspects that had helped them in learning and those that they believed could help them if present. One of the most valued aspects was the introduction of laboratory practices, and, again, group work. They value doubt-resolution classes very positively (73%) and they think that it played a role as far as passing the exam is concerned. Nevertheless, they still claim to better plan work outside the classroom (57% of students).

3.4 Course 20-21

Laboratory practices are expanded and re-planned so volunteer students (with good performance and previous laboratory experience in high school) act as mentors. This is the year of lockdown, so it had a different structure (which is not the subject of this paper). Most of the classes were online, with the exception of laboratory practices, which were obviously face-to-face. It should be noted that attendance at online classes (mostly problem solving and doubts) was between 70% and 95% (far superior to the rest of the subjects in which the percentage of connected students did not exceed 40%).

The rest of the planned asynchronous activities are maintained: (1) viewing of videos to which embedded questions have been incorporated; (2) weekly tests. The first two exams (first continuous assignment and half-term exam) were carried out online. To avoid student cheating in the exam, the time frames are adjusted downwards and random problems are generated. The next two exams were done face-to-face.

The average mark is 7.3, almost one point higher than the previous year, even though the data of the entry students were very similar. These results, which are slightly higher from those obtained in previous courses, are attributed to the fact that exams were carried out online and also to the fact that there was an increase in motivation compared to other subjects that entail greater dedication, both due to the interaction in the laboratory practices such as continuous feed back with students.

3.5 Course 21-22

The survey of the previous course reflects that the improvements introduced have been successful. For this reason, the improvements introduced focus on the aspects that the team of teachers perceive as improvable, since the students value the methodology and continuous evaluation very positively.

The subjective perception was that, in general, the subject was difficult to keep up with. However, the objective data, the grades, show that they are quite consistent with those obtained in pre-pandemic academic courses.

Class attendance was one of the poorest in this subject, around 70%. Nevertheless, it is a good result compared to the rest of subjects (it does not reach 40%). Often, those who miss classes the most present a higher level of disengagement and with the worst grades, so it is difficult to influence their learning process.

It is important to notice that all the improvements were developed with the students' help.

4 SUMMARY AND ACKNOWLEDGMENTS

This paper is not conceived as a final product, but as a step that reflects the planning and monitoring intended to be continued in the subject. The design of a subject must be dynamic and adapted to upcoming situations.
Highlights:
1. The content that students work on when they are not synchronous with the Lecturer must be fully designed. This content incorporates individual and group activities. Specifically, twelve videos have been prepared and many other ones have been selected (many of them from Khan Academia). In addition, documents, self-study tests and templates for weekly summaries have been written.
2. Self-assessment and continuous assessment have been integrated into the design of the subject, increased the number of tests taken in previous years and incorporating videos and new learning material instead of traditional learning.
3. Initial lessons of key concepts of chemistry taught in high school have been planned, to give response to the need of basic knowledge for those students who have never studied chemistry before. This is crucial for students to be able to keep up with the subject optimally.
4. Perhaps, the most important conclusion is that the implementation of a subject by Flipped Classroom requires much more effort and hours of work on the part of the

faculty than the definition of a subject focused on the explanations of the professor, and it is difficult to do in less than four years.
5. A qualification of the subject has been foreseen that counts the continuous effort collected in the electronic portfolio, as well as two continuous assignments (of a conceptual nature and similar to the self-study tests), a half-term exam and a final one that will have to show the mastery of macromolecular and symbolic chemistry and the ability to resolve everyday life situations.
6. The methodology has been used almost equally during the quarantine and results were similar. Nonetheless, the number of exceeding students rose slightly compared to previous years.
This document focuses on the design of a chemistry subject, in which the learning outcomes have been chosen and, based on them, all the necessary material has been designed using the flipped classroom methodology. The entire methodology is applicable to any subject, both newly designed and those that want to be redesigned.

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SERVICE-LEARNING IN ENGINEERING: ANALYSIS OF STUDENTS EXPERIENCES IN DEVELOPMENT COOPERATION

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ABSTRACT

For several years, engineering students from the Escola Politècnica Superior d'Enginyeria de Manresa have been participating in development cooperation projects as activities of the non-governmental Organization Mining for Development, with the support of the Center for Development Cooperation of the UPC. Activities were carried out in several mining sites in South American countries, mainly in Bolivia and Peru. Although the motivation for the students may have been initially a desire for adventure and volunteering, the experience turned into meaningful learning, as intended by the faculty leading the project.

This paper presents the findings of a study carried out to analyze how these experiences contributed to the learning of engineering students, within the framework of what is known as service learning. The study is based on the reports written by the students at the end of the experience and interviews conducted afterward when the experience had been fully internalized.

The characteristic elements of service learning have been identified. In addition, the analysis revealed how the experiences had a significant impact on subsequent learning, even beyond the initially intended objectives.

1 INTRODUCTION

Engineering is naturally associated with the solution of society's problems, so it can be seen naturally as a profession at the service of society in multiple fields: structures, industries, electronics, robotics, telecommunications, biotechnology, etc. It is not surprising that it is an ideal field for the cultivation of methodologies such as problem-based learning, challenge-based learning, or service-learning methodology.

However, while some educators view "service learning" (SL) as a new term that reveals a rich, innovative, pedagogical approach for more effective teaching, others view it as simply another term for well-established experiential education programs. For years, education researchers and practitioners struggled to determine how to best characterize SL. In 1979, Robert Sigmon defined SL as an experiential education approach that is premised on "reciprocal learning" [1]. In Sigmon's view, SL occurs only when both the providers and recipients of service benefit from the activities.

In the USA, higher education experienced tremendous growth in SL courses during 1990. This growth was supported by the Corporation for National and Community Service [2]. Service learning was seen as a "method under which students learn and develop through active participation in thoughtfully organized service experiences that meet actual community needs, that [are] integrated into the students' academic curriculum or provide structured time for [reflection, and] that enhance what is taught in school by extending student learning beyond the classroom and into the community..." (Corporation for National and Community Service, 1990). The National Society for Experiential Education, which for years has focused on various types of experiential education programs, broadly defines SL as "any carefully monitored service experience in which a student has intentional learning goals and reflects actively on what he or she is learning throughout the experience." (National Society for Experiential Education, 1994).

For example, Engineering service-learning and Humanitarian Engineering (HE) programs at The Ohio State University have been in existence since 1979 [3]. Another well-known SL program is Engineering Projects in Community Service (EPICS), that was initiated at Purdue University in the Fall of 1995, [4]. It was extended to many engineering service-learning projects in other universities, being the largest and longest-standing in the U.S., and/or into international experiences providing engineering services and solutions to the developing world, e.g. through cooperation with Engineers Without Borders (EWB). See [5] for updated information.

Regarding institutionalizing plans, it is worth noting that Bringle and Hatcher described in 1996, cf. [6], a Comprehensive Action Plan for Service Learning (CAPSL): planning, awareness, prototype, resources, expansion, recognition, monitoring, evaluation, research, and institutionalization.

Currently, engineers have a significant opportunity to help solve many of the world's greatest challenges. Getting involved in humanitarian engineering does not necessarily require a total change in career or lifestyle but can still have a major impact. Thus, engineering is in the spotlight with a key role in reports on Society development and challenges. See for example UNESCO report (2010), [7] or the National Academy of Engineering's (NAE) Grand Challenges, [8].

In consonance with this global context, some initiatives of SL carried out at the Universitat Politècnica de Catalunya (UPC) are presented. Section 2 is devoted to presenting the context at UPC, namely the Centre for Development Cooperation and the Manresa School of Engineering, where the SL activities we deal with in this study are designed. Section 3 details the methodology used for the analysis. Section 4 contains the results of the analysis of students' experiences, identifying the phases of service-learning and showing the relationship between students' experiences and competencies.

2 KEY AGENTS AT UPC

2.1 The Centre for Development Cooperation

The Centre for Development Cooperation (CCD) was created at the UPC in 1992. It coordinates programs related to development cooperation with the participation of UPC's social volunteers such as students and teaching staff. The cooperation programs aim to fight against poverty, inequalities, and exclusion in the form of values so that other realities can be implemented both globally and locally. The actions carried out aim to contribute to improving people's lives. Moreover, for the students of the UPC who participate, it becomes an apprenticeship that helps to train future professionals to have a more just and sustainable commitment to the planet.

The CCD organization is present in all teaching centers of the university and coordinates and gives support to development cooperation activities. The funding for the different projects comes from institutional contributions such as educational cooperation agreements and voluntary contributions from students or part of the teaching staff's salaries, collected in the so-called 0.7% campaign. It is also open to external funding such as companies and entities whose objective is the development of specific projects. During their university studies, future engineers working in cooperation and development projects not only acquire technological knowledge but also learn social values that are very remarkable once they enter the professional and working environment.

2.2 Projects from EPSEM

The Manresa School of Engineering is the school of UPC located in the city of Manresa. Students can enroll in bachelor's degrees in several Automotive Engineering areas, such as Automotive, Industrial Electronics and Automatic Control, ICT Systems, Mechanical, Chemical, and, last but not least, Mineral Resources and Recycling. It is the only university center in Catalonia where you can study the Bachelor's degree in Mineral Resource and Recycling Engineering, several Master's degrees related to Natural Resources and Mining Engineering, or the Natural resource and Environment graduate program, all of them inside civil engineering area. Among their responsibilities are the control and use of explosives in civil works projects. Like all engineering, but in this one even more so, social commitment and ethical values are very important.

The degree is organized into four years, and eight semesters. The number of students per course is not very high and the relationship with teaching staff is very good. They have dedicated laboratories with advanced equipment and a group conscience is generated, which facilitates interaction between students from different courses.

During the regular semesters, fieldwork is carried out, with visits and internships at sites in the area. In the summertime, when there is no schedule, extra opportunities to be in other mining areas around the world are offered to students. But this is not just an internship, but a real cooperation project as mining activities or, in general, the extraction of natural resources is an important issue in developing countries, especially in Latin America. In many cases, there are problems concerning environmental pollution such as the use of mercury for gold mining, the health of the workers, or economic conditions that hinder the efficient extraction of resources. Cooperation projects mainly serve to deliver improvements in sustainable mining, safe working environments, and improvements in mining performance. Thus, these projects are a real service-learning experience.

The projects involve the participation of professors, who travel with the students. The CCD provides some funds and some training course.

3 METHODOLOGY

The analyzed sample contains nine cooperation and development projects carried out at EPSEM in the field of mining and natural resources, in the years 2016-2021. All of them have been developed at mining sites in Bolivia and Peru. Because of the covid pandemic, in 2020 students did not travel there, but worked by using samples from the previous year, and keep in touch with university staff there.

For each project, a previous report was prepared, to plan the activity and to ask for financial support and the authorization of the university. The duration of the stay oscillates between 25-50 days in summer. The more technical part of the experience, related to content learning is included in the final degree project or projects belonging to subjects for the following semester. In addition, the students write a personal assessment report of the experience.

We analyzed 18 reports written by 13 participants, as 5 of them participated for 2 consecutive years. The following table lists the reference number of the projects, containing the year, and how many reports of each project were considered, indicating how many come from females or males. All the projects considered were led by Professor Pura Alfonso, who also traveled with the students.

Table 1. List of projects and reports analyzed

Project	Num. reports	female	male
P-2016-O013	2	1	1
P-2016-U006	2	1	1
P-2017-O014	1	1	0
P-2017-O013	2	1	1
P-2018-U017	2	1	1
P-2018-O026	1	1	0
P-2019-B005	4	0	4
P-2020-B006	3	0	3
P-2021-G007	1	0	1

To conduct a deeper analysis, an interview was conducted with three students corresponding to three different situations to follow up on the experience after some years:

- student A (male, aged 21), undergraduate student, between 1st and 2nd experience,
- student B (male, aged 23), master student, 2 years after the 2nd experience,
- student C (female, aged 28), graduate student, 5 years after the 2nd experience.

4 ANALYSIS OF STUDENTS EXPERIENCES

4.1 Phases of student involvemnet

The sample of students assessment have been analysed to check the progress of student involvement in SL. Five phases have been identified, according to the student development model provided by Delve, Mintz, and Steward [9]. We quote student fragments for each phases:

a) *Exploration* (naive excitement)
“Once we got to the mining area, I saw that the situation was much worse than I could have imagined”. “It has been a unique, enriching, and highly recommended experience”. “Lack of basic services such as running water, solid electricity, decent housing, and good roads, among others”.

b) *Clarification* (on values)
“Workers are at great risk, as safety measures are minimal in the mine, in many cases, it is a lack of knowledge as they have done so all their lives and do not see so much danger, so it is necessary to work to make them aware of the risk they are taking”. “Many of these problems are caused by extreme poverty, which means that the population does not have enough resources to have a good education”.

c) *Realization* (insight into the meaning of service)
“I have taken samples and will be testing these samples which will help the miners to know more about the material and learn how to make them myself, so I think it has been very positive for both parties”.

d) *Activation* (participation)
“You learn to see things from a different point of view and to make decisions in order to carry out projects with very scarce resources”. “Personally, it has been my second year traveling to the same villages and I have been able to see the first improvements, especially in terms of organization and awareness of issues such as health and safety”. ”The part of collecting samples allows to see of the way that works, what dimensions covers the exploitation and also allows to know in first person the experience of the own workers of the cooperatives”.

e) *Internalization* (the service experience influences career and life choices)
“Sharing my day-to-day life with classmates from here and with partners from there is also a lesson for me”. “I think the project can have good continuity and that the relationship we started this summer can continue for years to come. I believe that we can contribute to a more sustainable development of this area, but I hope that with the work we are doing soon we will not have to cooperate again in this area”. “I’m glad I was able to relive this experience where I was able to learn a lot again and become aware of what’s really important”.

4.2 Service Learning and the competences

Within the framework of EHEA, the need for greater development of transversal competencies in Higher Education is a topic of interest. Service-learning, as a methodology centered on students’ experience, can play a significant role.

Several authors as Fuertes et al. [10] studied how SL influenced the interpersonal skills requested by the community. Researchers recognized that it could be worked through experiential and practical methodologies in the learning process so SL could play a key role, also when employability is considered [11].

On the one hand, focusing on the importance that SL attaches to the reflection on experience, SL can contribute [12] to the development of the analysis and synthesis skills among university students in an era of great complexity and uncertainty. Also the impact of SL in other competences, interpreted as psychoeducational variables of university students variables, are studied in [13].

On the other hand, the work of students in SL is considered to be one of the most appropriate ways to develop ethical and civic competencies [14]. As an example, they remark that at the UNED, these competencies are related to the application of democratic values linked to fundamental rights and equality. They also refer to the statements by Universitat Autònoma de Barcelona "to promote values, behaviors and sustainable practices that guarantee gender equality, equity and respect for human rights”. At the UPC, and other catalan universities, similar statements are also found, even at their statutes, prior to the formulation of the EHEA.

An empirical approach to the influence that transversal competencies (soft skills) may have on the degree of employability of university students has been conducted in [11]. They found differences between the students who participated in experiential activities and those who did not, in favor of the former and explored theoretically whether the pedagogical approach of SL might contribute to a better connection between transversal competences and employability.

Our study on the students’ reports and the following up on the students participating in the projects also confirm a good correlation between the student’s perception of their skills, after the development of the projects, and external evaluation, from employers, internships, employers, etc.

5 ACKNOWLEDGMENTS

Service learning projects considered in this paper were carried out with the support of the teaching staff of the department of Mining, Industrial and ICT Engineering, and funding from the Centre de Cooperació pel Desenvolupament (CCD-UPC). Also, the NGO Mineria per al Desenvolupament contributed to the development of the projects. Our gratitude to them to make it possible. We also thank all the participants and students involved in the projects, especially those collaborating in this paper sample.

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SERVICE-LEARNING EXPERIENCE THROUGH OUTREACH AND ENGAGEMENT WITH SCIENCE AND TECHNOLOGY MUSEUMS

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ABSTRACT

The paper describes and analyzes the service-learning experiences of various engineering students in two science and technology museums, over the years 2020, 2021 and 2022. The experience was based on the design and implementation of education and outreach activities and scaffolding material was provided.

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Student learning was significant not only in terms of content but also in terms of generic and transversal competencies. In addition, this service-learning model shows a good potential to address some of the problems in engineering today, such as the declining interest in engineering among school students. Thus, it can be a win-win model for all the agents involved: museums, university, the student himself and society in general.

1 INTRODUCTION

This paper aims to analyze some effects of engineering students' experiences in science and technology museums, within the framework of service-learning, as the kernel of a study on improvement of teaching and innovation.

This section first describes what is meant by service learning and how it is applied in the field of engineering. On the other hand, we place the reader in the context of this experience with a brief description of the agents involved, museums and the Manresa School of Engineering and their relationship with each other. The second section includes a brief description of the activities carried out by the students, the relationship with other service-learning experiences and the goals and methodology of our study. The results are presented in the third section followed by brief conclusions.

1.1 Preliminars on Service-learning in engineering

Last decades, service-learning has been considered in higher education as an active learning strategy to be applied to many areas consistent with the change of paradigm in education from a focus on teaching to a focus on learning. It is a pedagogy integrating academic learning with community-based work, with a two-fold focus: learning for the student and service to the community. It can be defined as "a form of experiential education in which students engage in activities that address human and community needs together with structured opportunities intentionally designed to promote student learning and development. Reciprocity and reflection are key concepts of service-learning" [1].

Engineering has a vast potential for service learning, and several models of engineering service learning have been presented in the literature, discussing the benefits and outcomes of the program. A well known program is Engineering Projects in Community Service (https://engineering.purdue.edu/EPICS), EPICS program, initiated at Purdue University in 1995. It is described by Kirsch [2]: "(it) empowers students to work with local service organizations to apply technical knowledge to implement solutions for a community's unique challenges. In this way, EPICS in IEEE not only assists communities in achieving their specific local improvement goals but also encourages students to pursue engineering for community improvement as a career.

1.2 The Museum of Geology, a university museum

The Museum of Geology "Valentí Masachs" was founded in 1980 by Dr. Valentí Masachs. It was started with his private collection of fossils and minerals as well as collections from other founding members of the museum. In 1993 showcases of mineral applications were added.

The museum is part of the Universitat Politècnica de Catalunya (UPC), and it is therefore a university museum, like other museums around the world. It is located on the UPC campus in Manresa, connected to the classrooms and laboratories, and it is strongly linked to the university in its day-to-day research and teaching. It also serves students and teaching staff from all levels of education and it is a channel of connection between the university and the education system. The museum is also open to the general public.

The museum collection increased over the years thanks to the work of its directors, faculty and students who contributed to it through their research. At present, the museum has a collection of about 5000 minerals, 2000 rocks and 3000 fossils.

1.3 The Manresa Technical Museum

The Technical Museum of Manresa is located in the old water tanks of the city, with a capacity of 12,000 m³ of water. The museum was founded in 1993 on the initiative of the municipal company "Aigües de Manresa SA", Manresa City Council and the Museum of Science and Technology of Catalonia. Since 1992 it is part of the Science and Technology Museum System of Catalonia, and since 26 November 2004, it has been integrated into the Manresa Science Heritage Park. The Museum is also part of XATIC, the "Xarxa de Turisme Industrial de Catalunya" and the Water Museums Global Network.

1.4 The UPC Manresa School of Engineering

The Universitat Politècnica de Catalunya (UPC) is a public institution of research and higher education in the fields of engineering, architecture, sciences and technology. It is one of the leading technical universities in Europe with a widespread presence in Catalonia, through nine campuses. Manresa School of Engineering is the campus located in the city of Manresa, offering several Bachelor's and Master's degrees. The list of Bachelor's degrees covers several fields, namely Industrial Electronics and Automatic Control Engineering, Mechanical Engineering, Chemical Engineering, ICT Systems Engineering, Mineral Resource Engineering and Mineral Recycling. Students can also enroll in Master's degree in Natural Resources Engineering, Master's degree in Mining Engineering, Master's degree in Mining Engineering and Master's degree in Geotechnical Engineering, all of them very related to the Museum of Geology referred above.

2 ACTIVITIES IN THE FRAMEWORK OF SERVICE-LEARNING

2.1 Brief description of the activities

Both museums, the Museum Valentí Masachs and the Technical Museum of Manresa receive a large number of visits from primary and secondary school students throughout the academic year. Students enrolled in engineering degrees are encouraged to guide the visits and give workshops. The variety of degrees taught at EPSEM allows museums to match activities and students taking into account students' profiles. The experience is based on the design and implementation of education and outreach activities. Learning materials were provided. Training sessions are conducted by faculty to enforce students' knowledge and students' skills, in order to ensure learning for the student, and the quality of the service. Design and creation of new workshops is a challenge for the students too.

Actually, specialized training sessions have been designed, putting together sessions by leisure professionals and experts in museography and technology, face-to-face sessions in the two museums, and practical sessions in exhibition activities. Two editions have been implemented. It is worth mentioning that these were highly valued by the participants. There were no known structured descriptions of recommended training to support students to develop this kind of activity. Thus, the design, program and the two editions experience can be of interest.

Some final undergraduate and master's degree projects (TFE, in Catalan) are also related to the two museums. Thus research, development of theoretical frameworks and creation of manipulative material such as prototypes are carried out by engineering students under the supervision of several professors.

Students are also involved in collaboration projects of the museums with secondary schools with special needs. For instance, some students collaborated with the secondary school IES Guillem Catà, through the Museum Valentí Masachs to design and equip a small museum of mineralogy in the school to enable hands-on and active learning. In addition, the students participate in cooperation and development projects at the international level, mostly related to sustainability and social projects, one of the main areas of dissemination of the Museum of Geology Valentí Masachs. They are also involved in some cases of TFE.

In the context of this article, research was conducted for information on similar experiences. Most of the known examples of service-learning in engineering correspond to the model of project design, or the model of development and cooperation in another placement, International or not, which should not be confused with International volunteering or internships.

But some examples similar to our activity can be also found. A course where college students work with elementary school students is studied in [3], including a description of lessons learned and best practices. In [4], projects for 35 different undergraduate core courses are summarized, including for example the design and construction of displays to illustrate various technologies for middle school students. Several features are studied there in the context of USA universities. This paper wants to contribute to the study of some particular features in our context, in order to develop a further study in engineering service-learning experiences in universities in Catalonia.

2.2 Setting the goals of the study and the methodology

In this paper, the goal is to survey students' perceptions of their learning, referred to content and competencies, show connections to particular subjects, and collect data on the impact of academic and social projection of students through Science and Technology museums.

The main focus will be the generic competencies in UPC undergraduate curricula, cf. [5]. Our main hypothesis is that this service-learning experience has a positive impact on the achievement of competencies. It is a student-centered study, so the survey instrument is designed to be answered by students. Besides the students' perception of competencies achievement, it is intended to measure the influence of service-learning activities on students' perspectives about engineering, their career interests, and social consciousness.

The methodology consists of: (a) the careful design of a questionnaire, with valid and reliable questions, including a test and a revision; (b) the distribution of it to the population we are interested in, namely students who have been involved in outreach activities in museums; (c) data cleaning analysis, and interpretation, (d) completion of the survey with some personal interviews.

The questionnaire combines open-ended and closed-ended questions, in order to get both qualitative and quantitative responses. It is structured in several parts. The first part collects the data prior to the museum's activity. The second part collects quantifiable information on the name of the workshops in which the activity was carried out, the school year, the amount of schoolchildren involved, etc. The third part takes care of the relation with academic subjects related with the activities. The fourth part focus on their perception of improvements in general competencies. The fifth part collects the personal and professional impact. Finally, the last one reflects on the social commitment of the university and its relationship with STEAM. See figure 1.

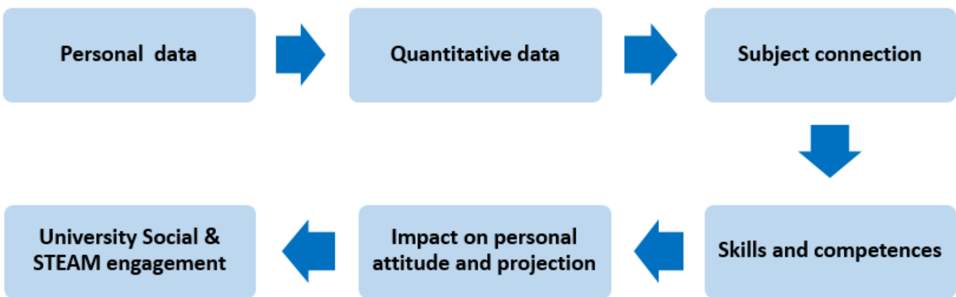

Fig. 1 . Structured parts of the questionnaire

The questionnaire can evolve to be used as a tool to encourage students to reflect on learning, a very important step to make meaning of the experience, cf. [6]. Open-ended questions and interviews can be used for further refinement of the form.

3 RESULTS

The questionnaire was distributed to students who have been involved in outreach activities in museums. After getting the responses, data cleaning allowed us to identify and remove responses from people who either didn't match our target audience (not students, or involved in museums not related to science and technology). Final sample included ten students, six males and four females, from four different engineering degrees, who participated in outreach activities in one of the two museums, related with their degree. We will denote them S1, S2, ... S10, following the order of seniority of participation, from February 2016 to the present.

Information was completed with three personal interviews: (S3) a master's student enrolled in the museum program two years ago, who is still collaborating; (S10) an undergraduate student, currently enrolled in the museum program; (S9) a former student enrolled in the program who is nowadays a teacher at secondary school.

Students responses to the questionnaire confirmed impact on subjects learning, even after finishing them. Connections with several subjects (at least three each) were stated. They admited to change their opinion about some subject value (increasing it) and discovered some contents that they have overlooked and decided to review to be more confident about, and they were more interested in the course they were studyng at the time the activity at museum was developed. For example the question: "Did the questions the students ask you and the chance to explain them some answers increase your learning?" got a 70% of the answer "yes quite often".

In terms of competencies, as expected, "Efficient oral and written communication" is the one that students are most aware of having improved with the experience in the museum. S10 states explicitly in two occasions: "explain concepts that you already know are very beneficial. It allows you to improve your skills to express concepts clearly and concisely", or "I have learned to better communicate my ideas, capture the attention of the audience, when explaining concepts, the way you do it, etc.".

But there are also other competencies that, from the student's point of view, have improved thanks to the museum activity, namely: Entrepreneurship and innovation, Sustainability and social commitment, and even Gender perspective. Figure 2 shows the comparison of results of the value given to the development of four generic competencies, derived from the regular subjects courses or from the service-learning experience. For the other competencies, there were no significant differences.

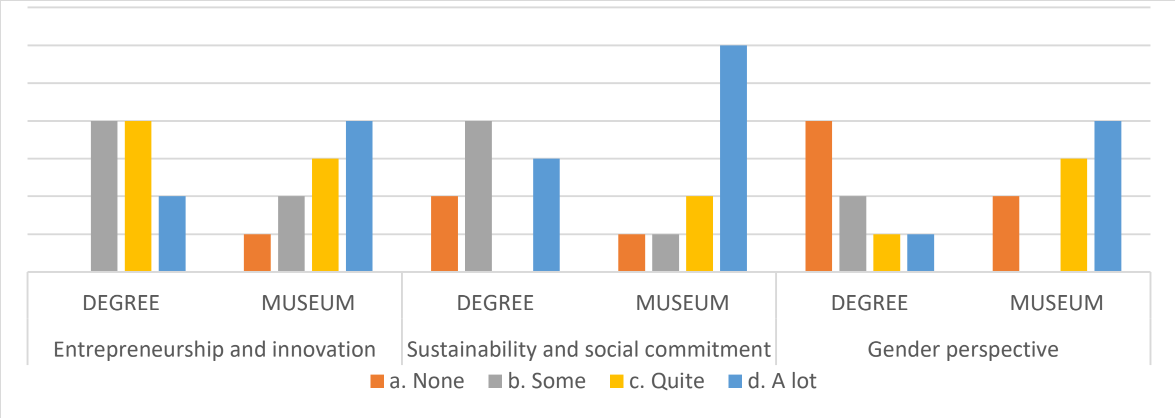

Fig. 2. Student's perception of competencies development derived from the subjects course or the service-learning experience.

As for the impact on their personal career, a clear example is S9, who says, "Literally, my job at the museum helped me find a career and ended up being the determining factor for what I now have a job that I love."

Open-ended questions revealed some ignorance about service-learning label for experiences, with the exception of some development cooperation projects, with a learning scheme. It is not clear how these experiences are offered to students, as in some cases they are only linked to optional subjects or final degree o master projects. Regarding the interest of students in these activities, a paradox similar to that cited in [7] is observed. Some students had taken part in voluntary activities related to the leisure of young children and teenagers or had taken part as a child (of course without an explicit relationship with science and technology). For them, the discovery was that they could relate it to STEAM and, in particular, to what they were studying. But the majority were students who had not been involved in such activities before. For them, the discovery has been twofold, and their learning has opened up new opportunities for them. More specifically, it has been crucial for S9, which is currently a high school teacher, and for S3, which is now targeting it.

While the activity may be more interesting to students who are familiar with the world of leisure, they often develop this facet in communities not related to university campus and do not spend time looking for such opportunities in connection with university degrees. On the other hand, students who did not participate in this type of experience confess that they discovered it thanks to the teachers who proposed it to them. It is therefore important to study the role of the teacher as well in terms of the extension of social engagement.

The interaction between students and faculty is very important for the evolution of service-learning proposals. On small campuses, such as the Manresa School of Engineering, formal and informal communication can be very helpful to significantly improve their development and analysis.

After the experience, students are much more aware of the importance of spreading their interest in engineering. They can be good STEAM ambassadors, closer to teenagers and children. Thus, apart from the win-win of student learning and the service to museums and schoolchildren, it is the whole society that will indirectly benefit.

Finally, it would be interesting to test if there is a significant positive relationship between engagement in outreach service-learning and a reduced likelihood of dropout, in the same direction as several studies on the significant positive relationship between engagement in extracurricular activities and dropout in high school (cf. [8]).

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HYBRID ENGINEERING EDUCATION RESEARCH: THE CHALLENGES & BENEFITS OF AN EMERGENT METHODOLOGY.

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ABSTRACT

Engaging students of any discipline in meaningful and constructive research about their university experience can be challenging[1]. During the Pandemic maintaining a balanced approach to sampling and data collection when conducting pedagogical research proved to be more than a little problematic, with many students seemingly experiencing ‘online fatigue’. Moving slowly out of the Pandemic, the issues have changed, with students now hesitant to participate in face-to-face research. This short concept paper discusses the practical and theoretical challenges encountered in undertaking Engineering Education Research (EER) at a time of unprecedented social and educational change. In focusing very much on methodology this paper does not report on the emergent findings of the study discussed but instead focuses on the methodology itself.

1. INTRODUCTION

Starting with an overview of the organisation in which the study is set, this paper discusses a current project aimed at promoting a culture of scholarship and evidence-based learning and teaching across all undergraduate and postgraduate programmes within a UK Russell Group University Department of Engineering & Management.

Starting with a short precis of the literature, attention is drawn to three student-focused areas prioritised by the project team: The quality of the student experience: Blended learning: Student engagement. Following this, a reflexive account of the use of hybrid research to promote scholarship is given whereupon the paper critiques the use of an online platform as a contemporaneous structured **and** reflective unstructured data collection tool (Miro, 2022[2]).

The virtual and traditional strands of a current hybrid research approach are discussed and the benefits and challenges of using tools such as *Miro* for data collection considered. In reflecting upon some of the unforeseen challenges of engaging students in hybrid research, the paper contributes to current debates about how EER is emerging as a new research discipline in its own right.

2. BACKGROUND

One of the largest applied engineering faculties in the UK, WMG has a long history of applied research, working alongside global and local employers to produce innovative solutions to contemporary real-world engineering challenges[3]. Alongside this, a steady, but increasingly strong history of high quality, practical engineering and applied management education has emerged; producing graduates able to impact the workplace from the date of employment, whilst also being equipped to deal with the unknown problems of the future.

Like elsewhere, over the past two years or so, the Covid19 pandemic has affected a paradigm shift in how education is provided offered within WMG. Almost overnight, the

Spring of 2020 saw a c-change in how all aspects of education were provided and managed. Previously 'tried and tested' pedagogies were suddenly not available for use as, like elsewhere, WMG switched all of its education provision to being 100% online. Over two years later, as the globe begins slowly but surely to emerge out of the Pandemic, both colleagues and students find themselves metaphorically blinking in the *light of day*. Whilst some are reluctant to re-enter the classrooms and labs, others cautiously are embracing the return.

In this unprecedented situation, the notion of 'hybrid learning' has emerged. Differing from blended learning in that many 'live' lectures are contemporaneously provided online **and** face-to-face in the classroom, questions of how students' are experiencing the 'new normal' in engineering education have arisen. Tasked with evaluating students' perceptions of learning after lockdown, National Student Survey (2021)[4] results were used to identify and prioritise which programmes to evaluate as a priority.

In seeking to empirically critique what continues to be a fluid pedagogical picture, it soon became clear that capturing the student experience, whilst traditionally tricky, is now even more difficult – with many students reluctant to engage in conversations and some avoiding attending university in person. With a need to capture the views of as many students as possible the idea of a 'hybrid methodology' was born.

Aimed at providing as many students as possible with the opportunity to engage anonymously either online or in person in the evaluation, the decision was taken to use an online 'learning platform', *Miro* to explore the student experience. This paper focuses primarily on the process of developing and using an 'online' contemporaneous research tool. It highlights the benefits and drawbacks of 'hybrid research' and reflects upon how this approach may be used in future.

3. THE LITERATURE

Prior to considering how to accurately capture the breadth and depth of students' and colleagues' perceptions and experiences as we emerge out of the pandemic, a short literature review was undertaken. With the aim of thematically determining where the study should focus three key themes were explored:

- **The quality of the student experience**: Much has been written about the quality of the student experience, both in traditional, face-to-face scenarios and also with regards to online and blended learning[5,6,7,8]. Whilst acknowledging that the concept of 'quality' is in-itself much debated, the researchers' turned their attention to the need to holistically capture students' lived experiences. Conducting research at the end of the pandemic saw a number of unforeseen practical problems including a reluctance to engage with any face-to-face live activities. Manifested by what appeared to be an innate shyness in many students an initial call for participants did not heed any respondents. At a time when the vast majority of 1st and 2nd year undergraduates have not undertaken any written examinations to get into university, and postgraduate students have completed their undergraduate education alone in their bedrooms, the question of how *liveliness* of the university environment was impacting individual student's academic and social behaviour arose before the study had even started.

- **The Challenges and Benefits of Blended Learning**[9,10]: With the term 'hybrid' learning emerging out of the Pandemic, the literature review identified a range of challenges and benefits in the area of Blended Learning. A number of key areas for exploration emerged out of the literature including the need to investigate: *how* learning technologies are used at university level, particularly in the area of active learning: *what* previous technologies used in the university had proved to be successful in engendering learning and which ones had not: *why* some platforms, whilst multifunctional and able to support a range of learning approaches, were used by colleagues to simply 'dump' lecture notes and readings: *how* to better engage students in online learning.

- **Improving Student Engagement**[11,12,13]: Learning technologies have traditionally attracted both positive and negative student responses, with student engagement key to pedagogical success. The incept of mandated online learning during the pandemic saw virtual engagement increase as students had little or no choice but to engage with the various learning platforms. Yet ironically, as society is emerging out of the pandemic, students have become comfortable in their study rooms and bedrooms. Used to being able to listen to a lecture whilst perhaps not fully engaging, the question of how we can better engage learners is perhaps more pressing than ever.

As previously acknowledged, at the beginning of the study students' reluctance to engage in 'on-campus' learning was manifest by difficulties in finding participants willing to take part in qualitative research. Thus, in considering how to investigate the student experience of the past two to three years, the need for a hybrid methodology arose.

4. HYBRID EDUCATIONAL RESEARCH: AN EMERGENT METHODOLOGICAL APPROACH

Having been tasked with critically analysing student perceptions' across the undergraduate population, two of the research team initially planned to undertake a *traditional* qualitative Action Research study following a methodology based upon Grounded Theory[14]. Whilst the initial intention was to run face-to-face focus groups and interviews with students to look at the issues raised in the National Student Survey (2021), it quickly became apparent that whilst conceptually guided semi-structured interviews are indeed a tried and tested method of gaining a depth of insight of the student experience, this year's undergraduate cohorts were very reluctant to meet face-to-face and also unwilling to discuss their concerns verbally in any forum.

Difficulties in accessing the student voice using traditional methods resulted in a number of alternative approaches being considered, including online group interviews and individual face-to-face meetings (both online and face-to-face). Such approaches were quickly put to one side as some undergraduate students made it clear that they felt very uncomfortable talking in front of their peers, whilst others simply did not want to come onto campus. The primary reason for such reluctance appeared not only to be a fear of Covid, but also a lack of group cohesion and familiarity across each of the cohorts. Used to working alone and having made friends only with a very small group of peers, students simply did not want to engage in any type of activities where they needed to talk in front of each other.

Having used Miro successfully in teaching the research team took the decision to adapt this learning technology and use it for research. Numerous practical questions about how to maximise participation whilst assuring student confidentiality were dealt with within the tool itself, which automatically pseudonymised the participants as they logged in.

Three key *concepts* were written onto the Miro Board and a series of semi-structured questions asked verbally around each concept. These concepts were: Student Perceptions of Learning & Teaching: How learning is organised: The overall student experience.

Facilitated by two of the research team, with one colleague talking and the other taking notes, students were provided with the opportunity to answer the various questions 'live' online. Like traditional focus groups, additional questions were included as matters arose during the discussions. Similarly, the students, able to read each other's comments reacted in real-time, indicating approval or disagreement through the use of a 'thumbs up' or 'thumbs down' e-mojis, whilst also adding in comments about their own experiences and thoughts. Although there was no need for students to talk or to identify themselves, one or two chose to do so, however, the majority remained anonymous; typing their thoughts onto Miro under the guise of an artificially created pseudonym. This technique worked remarkably well, eliciting a greater breadth and depth of data than would usually be acquired during a focus group. Additionally, the use of a 'voting tool' formed the basis for a further discussion – providing all of the participants with an opportunity to give immediate feedback on a give question or topic.

4.1 Using Miro as a Research Tool: Was it a Success?

In total, three focus groups were conducted in February and March 2022 with 32 participants selecting to join the discussions 'live' and a number of students engaging over a period of three days following each focus group whereby the individual boards were left open with no live facilitator (56 different comments were left on the open boards, although the anonymous nature of the approach means that the number of students could not be determined). Overall, the approach proved successful, gaining an unusual breadth **and** depth of data directly from the student participants. The sample was controlled by sending the link to each cohort separately with students required to use their login details to gain access.

On reflection, some of the most notable benefits of using this 'in the moment' research technique were:

i. Students were able to type in their thoughts, feelings, reflections, and comments anonymously – meaning that some went into depth whilst others raised issues that it would have been difficult to discuss in a more traditional group (for example, the demographic mix of the groups reflected the wider student body of different ethnicities, genders and disabilities and enabled the students to anonymously raise sensitive issues indicative of their demographic background).

ii. The contemporaneous nature of the 'live' focus groups meant that problems were quickly identified, reported to senior management, and action taken almost immediately. Having a written record of students' own words added to the evidence base, enabling programme and faculty management to take informed decisions and, more importantly, to be seen to be listening to the student perspective.

iii. The online methodology and managerial response gave some students the confidence to participate in further, in-depth interviews and focus groups. Whereas the initial call for participants to take part in 'face-to-face', live research had not elicited a response, students actively approached the research team after the Miro sessions asking to be heard in person.

Conversely, in addition to the above benefits, two unforeseen problems with the technique arose – one during the focus groups, the other during the short period when the boards were left open:

i. Whilst the online nature of the technique meant that the students were able to participate anonymously, the Miro boards were hosted on MS Teams. This meant that whilst the students' comments were anonymous, the research team were theoretically able to identify which students participated in the live discussions. It is important to note that the decision was taken not to record the MS team discussion as it went live (whilst the Miro boards were recorded). Likewise, no record was made of student names or any other details.

ii. Leaving the Miro boards open for two-three days following the live events was deemed to be important as only around 1/3 of each cohort had participated in the live events. This proved to be a little risky, as a small number of the less mature students selected to write inappropriate comments on the board. Fortunately, the boards were checked frequently by one of the researchers who, whilst reluctant to remove anything, took the decision that inscriptions which could potentially undermine the very real issues raised by the majority would be damaging to the whole process and so removed inappropriate content as soon as it was noticed.

Having participated in the online research some of the students requested to further explore the issues with the research team face-to-face. A number of different tools were utilised including:

i. In person focus-groups using purposive sampling techniques provided women students and those from ethnic minorities with the opportunity to further explore some of the more sensitive issues raised in the online forum.

iii. Individual one-to-one interviews utilising a blanket sampling technique meant that all students in each of the cohorts had the opportunity to participate further. This technique enabled male and female students who felt they would like to further discuss the various issues to do so in a confidential and supportive manner. Interviews were held in the university and online with four students.

With regards to the research approach issues of academic validity have been dealt with as a matter of some importance. The questions were guided by both the literature and by the researchers' individual observations and insights. The findings of both the hybrid and face-to-face research have been recorded contemporaneously and grounded theory methodological approaches will be used to conduct a rigorous analysis. The use of 'live virtual anonymous focus-groups' using Miro proved successful, although leaving the boards open for students to 'drop in and comment' afterwards was not as useful as it was hoped. A few immature students left comments, not connected to the study, but aimed at causing mischief.

This work is very much ongoing. The emergent study findings have been reported both to senior management and to the teaching team on the programme concerned. Additionally, three 'feedback-feedforward' sessions have been held with the students to inform them of the findings and to explain what changes are being made.

5. CONCLUSION: HYBRID RESEARCH – DOES IT WORK?

The use of the Miro board as a research tool proved to be an appropriate and worthwhile methodological approach. The ongoing nature of the study means that the approach will continue to be used in ongoing research being conducted across the undergraduate body of students, with contemporaneous records kept and more traditional approaches used to follow up. Whilst this first attempt at 'hybrid educational research' has provided successful a number of ethical and practical questions have yet to be addressed, particularly in relation to the potential for identifying participants logging on through MS Teams.

In conclusion, whilst the suitability of the approach for more detailed or sensitive research has yet to be tested, there is little doubt of the potential of this approach as a way to engage students in contemporaneous educational research using a media that they are happy to work with. Engineering Education should, by its very nature, be forward-thinking and innovative; Engineering Education Research (EER) needs to reflect this. As an emergent academic field of study those of us working in EER, whatever our background, need to be seen to be leading the way in developing and testing new pedagogical methodological approaches and tools. Miro is one single tool, there are many other virtual platforms and non-digital tools that we have access to. The question this paper leaves us with is *"How can we make sure engineering* *education is empirically grounded whilst making best use of emergent technologies and thinking?"* This question is, of course, for future consideration … …

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Integrating Sustainable Competences and Green Skills in the Hungarian Environmental Engineering Education

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ABSTRACT

Engineering plays a crucial part in responding to the biggest challenges of our era, including the transition toward a green economy by meeting the Sustainable Development Goals by 2030 and by achieving net-zero carbon emissions by 2050. Engineering education could be the leading actor in preparing engineers for these complex tasks and spread the necessary green knowledge, interdisciplinary skills, and competences to pursue a sustainable future. Hungary's education system has improved significantly in the last decade, considering the Central Eastern European region. A new national higher education strategy in 2014 set new directions for its development in many aspects, including an emphasis on soft skill development in the curricula. The Hungarian higher education system was characterized for decades by memorizing facts and figures; therefore, the effective integration of soft skill development is a slow process. In our study, we first provide a systematic review of the international and national literature to identify fundamental sustainability skills and competences for engineering. We also examine the Hungarian higher education frameworks and the skill-related output requirements in the environmental engineering programs. In the second part of the research, we present a qualitative study of in-

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depth interviews with Hungarian experts with different academic profiles and a focus group study with environmental engineering students about their views on green skills. Our results show that the concept of green skills is slowly spreading in environmental engineering university communities in Hungary; however, the effective implementation into the curricula will require some more time and work.

INTRODUCTION

1.1 General Introduction

Pressing actions are needed to reach the targets set by Sustainable Development Goals by 2030. Sustainability and climate change-related goals are complex issues where conventional answers are not adequate enough. New skill sets and toolkits are needed to face these challenges successfully. As per target 4.7 of the Sustainable Development Goals (SDGs), all learners need to acquire the knowledge and skills to promote sustainable development by 2030. Education has a crucial role in the green transition as it allows students to improve their competences and collect the necessary knowledge, skills and attitudes to take action for sustainability (1). Education systems worldwide need to integrate sustainability skills and competences into their agenda to accelerate the transition to a fairer, greener economy and society.

Environmental and Sustainability Education (ESE) has been in the highlight for the last decades. The need to include sustainability education in the educational curricula is now widely recognized globally. UNESCO dedicated a decade for Education for Sustainable Development between 2005-2014 followed by the Global Action Programme (GAP) on Education for Sustainable Development (2015-2019) (2). As part of the Green Deal, the European Commission issued the European Sustainability Competence Framework – GreenComp in 2022, serving as guidance for both learners and educators (3).

Engineering plays a crucial part in solving sustainability challenges and fostering the implementation of sustainable transition. It has also been in the focus of ESE research, among others in the Barcelona Declaration from the Engineering Education for Sustainable Development Conference in 2004 (4). The much-needed shift towards sustainability in engineering has been acknowledged theoretically; however, the implementation is not an easy task - the mindset of university leaders, professors, and those of students needs to be changed.

1.2 Research Background and Research Questions

The current paper is built on previous quantitative research from 2021 conducted in Polish and Hungarian universities (5). The research sought to answer whether green skills development appears in the environmental engineering undergraduate programmes, and if yes, how. It also examined the main barriers of implementation. A questionnaire was compiled about the integration possibilities of green skills in the environmental engineering BSc programs separately for students and professors reaching a total of 257 people in January 2021.

Both lecturers and students were open to green skills development based on the answers. They identified environmental awareness, professional knowledge, and practice as the most important green skills. Soft skills (flexibility, adaptability, creativity, group work, communication skills, empathy, etc) were less often classified as green skills by respondents.

Since the European Commission issued the GreenComp in 2022 identifying the main sustainable competences for all, we considered conducting a qualitative study to ask the opinions of both professors and students about green skills. The aim of the research is to examine how sustainable competences could be integrated into the environmental engineering programmes. Our hypothesis is that even though non-technical skill development is a legal requirement in the Hungarian environmental engineering programmes, there has not been enough emphasis on its successful implementation. The main research question we formulated is: How can we integrate sustainable competences and green skills into the curricula of environmental engineering programmes?

2 METHODOLOGY

The first step of the research project was to conduct a brief literature review in the fields of the usage of the words: 'sustainable competences' and 'green skills' and to see the legal requirements for learning outcomes of the Hungarian Environmental Engineering BSc programmes.

Environmental engineering programmes were chosen since they can be considered the closest to the topic of sustainability, and maybe the most open for the integration of sustainable competences. Students and professors for the research were chosen from the Budapest University of Technology and Economics (BME), since that is the oldest and most prestigious engineering university in Hungary.

In the practical part of the research, semi-structured interviews were conducted within the framework of qualitative research. The discussion was based on a pre-compiled thematic questionnaire, which was handled freely during the discussion. The selected academics for the in-depth interviews play important roles in the Environmental Engineering programme: directors of the entire programme or one of the specializations, and actively teach the students. The interviews were conducted in January 2021 and in April 2022, the first one online, the second one in person. Both interviews took around one hour, and they were recorded, and later on transcripted.

We also conducted a focus group with a group of students from the Specialisation in Environmental Management of the Environmental Engineering BSc programme at BME. Seven students participated in the focus group discussion in the framework of the course Complex Environmental Management Practices in April 2022.

General inductive approach (11) was used as the qualitative research analysis. The raw data (the transcripts of the interviews, and the notes from the focus group discussion) was read several times by both authors, and the emerging themes were identified and conclusions drawn as a results of several discussions between the authors.

3 RESULTS

3.1 Literature Review

In the respective literature, several terms are used to describe the necessary abilities for sustainability: green/sustainable and skills/competences. "Green" is a term that is derived from the green economy concept, and it is mostly used in relation to employment and employability (6). The term sustainability is widely used in both job and education relatedly. The difference between skills and competences is that usually, skills represent only a part of competences since competences include knowledge, skills and attitudes – as per the educational definition. However, green skills or skills for sustainability are often used instead of competences in policy and scientific works (7). Higher education institutions should implement sustainability competences into their agenda to prepare their students with the necessary green skills to be employable for green jobs.

The European Commission's science and knowledge service, the Joint Research Centre (JRC) published GreenComp - The European Sustainability Competence Framework in 2022. It defines sustainability competences as a group of skills, attitudes, and knowledge. It provides a common understanding of these competences both for students and educators. The report identifies four main competence areas and 3-3 competences within each area (Table 1).

Table 1. Competence areas and Competences of GreenComp (3)

GreenComp competence areas			
1. Embodying sustainability values	**2. Embracing complexity in sustainability**	**3. Envisioning sustainable futures**	**4. Acting for sustainability**
Valuing sustainability	Systems thinking	Futures literacy	Political agency
Supporting fairness	Critical thinking	Adaptability	Collective action
Promoting nature	Problem framing	Exploratory thinking	Individual initiative

In the Higher Education System in Hungary, the document ‘Shifting of Gears in Higher Education Mid-Term Policy Strategy’ (8) is the first policy to provide guidance in Hungary for universities on the actual application of practical education for the 21st century. It emphasized the importance of transversal skills that increase employability, such as entrepreneurial skills, digital skills, and foreign language proficiency. It also highlighted the competences that describe general characteristics such as the competences of critical thinking, independent but cooperative problem-solving, civic knowledge, digital literacy, etc. Some of these fields can be connected with the GreenComp competences such as critical thinking and problem solving correspond to the competences from embracing complexity competence area, and the active citizenship characteristic corresponds with the acting for sustainability competence area. This strategy paved the way for universities to introduce education innovations and practical education.

The learning output requirements for environmental engineering programmes are defined by law (18/2016) with detailed information of the expertise, professional abilities, attitude, autonomy, and responsibility areas. The following general skills are mentioned as a requirement for environmental engineers: environmentally conscious behaviour, demand for lifelong learning, good communication skills using technical terminology, ability to solve professional problems, digital capabilities, and openness to cooperation (9). The introduction of these learning outcomes is a significant development in the Hungarian higher education system (10).

3.2 Interviews

Throughout our interviews and focus group discussion, we focused on the possibilities and barriers of the implementation of sustainable competence development in the higher education institutions. We identified four main themes of the discussions, presenting the results around these topics.

The concept of sustainability has become widely used in the last decade.

One of the professors highlighted that the spread of the sustainability concept resulted in the word entering everyday vocabulary on a rhetorical level without people knowing exactly what it meant. Often only the environmental aspect is understood by it; there is no complex understanding of the concept sometimes even at academic level. According to the other interviewee, even though the concept of sustainability is widely spread, it is not integrated in engineering programmes except for the environmental engineering training. Both professors mentioned the concept of saving as an example – it is a fundamental concept of sustainability, still the teaching programmes do not convey that. Both professors highlighted the students' often experienced inadequate knowledge in natural sciences – without which it is hard to discuss these complex issues.

Sustainable Competences/Green skills in the environmental engineering programmes

Both professors brought examples from their teaching practices regarding practical education tasks that support green skills development during their courses. These tasks work well because they reflect on a real-world problem, such as representing an issue the local municipality or simply discussing simple everyday actions from a sustainability point of view. One of the professors mentioned that lately other professors started to see that specific skills could/should be implemented in the everyday teaching practices. Professors already have to identify the skills, knowledge, and attitudes as the output requirements for each course - unfortunately, this task is experienced by most university lecturers as a considerable burden. There is no energy to redesign lessons unless it is mandatory (eg: redistribution of classes).

Both professors agreed that certain soft skills could be a booster for sustainability, e.g., the art of debate, good communication, and networking abilities. These are more and more present in the courses but typically as part of the assessment – these skills are not taught.

According to one of the interviewees, integrating sustainability skills should not be through separate sustainability courses but built-in elements of all courses, even in mathematics, physics, and statistics as topics of certain tasks.

Multidisciplinary and interdisciplinary education

Both professors agreed that the introduction of multidisciplinary and interdisciplinary projects is very much needed in the environmental engineering courses. However, both found it too hard to implement - it would take too much energy to compile a challenge-based interdisciplinary course.

Encouragement for university professors to integrate sustainability skills

Both professors emphasized the importance of training and guidelines about innovative pedagogical methods that could support professors to move away from the frontal teaching. Lecturers need to be educated about green skills in an engineering context. One of the professors highlighted the importance of thematic calls as an incentive for researchers and lecturers to deal with green skills development. The other professor emphasized the role of networking. The implementation of green skills is currently more a characteristic of the younger generation. Having opinion leaders network with highly respected older generation of academics could support the sustainability initiations within the university.

3.3 Focus Group

We invited seven students from the Specialisation in Environmental Management of the Environmental Engineering BSc programme at BME to take part in the focus group study. Out of the seven students there were 1 female and 6 male participants. 4 of the students already worked beside their studies (as chef, manager, or intern). First, we were interested in how much they live a sustainable lifestyle by asking questions about their everyday sustainable habits. The whole group tries to avoid plastic waste and waste generation in general, and they collect waste selectively. Only 4 out of 7 students try to reduce printing, avoid using cars and buy second-hand products. The least spread actions were reducing eating meat and the usage of smart appliances in their homes. In this regards, this group can be considered better than average.

The first question was about the current teaching program's ratio of engineering and non-engineering skills / knowledge. The group agreed that currently, the non-engineering skills take about 30%-40% of their training. There was a small debate since some students thought the ideal would be around 50%, but others argued that 30-40% is also ideal.

The second question was whether it is the task of the environmental engineering bachelor's and master's programmes to support the development of green competences? Most of the group agreed that, yes, it is because the student's ultimate goal is acquiring these competences for their future jobs. In the management specialization, they feel that it is more typically present, but the technology specialization should not be neglected either.

The third question focused on how useful they find gaining sustainability knowledge during their engineering training. The students found it useful because it covers many areas as a horizontal issue. Engineers shape the physical environment and technologies; therefore, this knowledge is becoming more and more important nowadays, and it is needed for a deeper understanding of complex issues.

For the fourth question we asked the students to provide ideas based on the sustainable competences of the GreenComp on how their training programme could support these competences, and how they could improve these outside the university.

According to students, universities could support the skills and knowledge development as they teach sustainability as a complex system. Sustainability could also be represented by educators from different background fields, and through the appropriate use of resources, research work, case studies, and practical experience. Some students highlighted that universities could only inspire the attitude, but it ultimately depends on the individual student to utilize it. Both groups agreed that it is the students' responsibility to develop these competences for example in their extracurricular activities. They identified programs such as attending events, lectures, conferences, reading scholarly articles and journals, watching videos, and joining and supporting NGOs to improve their sustainability skills. Some of the students emphasized that the Environmental Engineering programme could benefit from more interactive courses, up-to-date knowledge and materials, and the development of pedagogical skills of the professors.

4 CONCLUSION

As a conclusion, we can say that our original hypothesis was right. Even though higher education laws in Hungary prescribe non-technical skills development in environmental engineering education, the interviews and the focus group study showed that these regulations are not fully implemented in many cases. There is a lack of training and a lack of resources and examples – many Hungarian educators are not prepared for the shift from traditional knowledge-centred frontal education. The redesign of university courses and giving place to pedagogical experimentation is not easy to implement.

The introduction of good educational practices into undergraduate education is a complex, systemic problem. It depends on many factors, such as the approach of the university management, the incentives given for curricula development, but also the instructor's personality, their economic situation, etc. The work with the student group, however clearly showed that the demand for this shift is real. Students had a clear view that sustainability skill development is a key factor for environmental engineers, and they expect the university to offer these to them.

To promote improvement both bottom-up and top-down approached are needed. The easiest, most effective ways as per our recommendation are to develop teachers' / lecturers' trainings, pedagogical guidelines, but also raising awareness through students' competitions. The institutional strategy in this respect could also support the transition. Furthermore, to understand better the local needs, we plan to do further research in the labour market in Hungary in the form of an alumni and labour market survey to better understand employer needs of green skill / sustainability competence.

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First year engineering students' internal and perceived expectations

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ABSTRACT

First-year students' expectations when entering the university play a central role in how they experience higher education. While there has been a significant number of studies on first-year students' experiences, much less is known about which role expectations play on a qualitative level. In this study, we will approach the question; How students' expectations of higher education shape and are shaped by their experiences of entering the university. By drawing on a qualitative thematic analysis of nine interviews with first-year students in an electrical engineering program, we found that students' expectations to themselves and perceived expectations from others, are key elements in experiencing the learning environment and culture at the university. Grounded in the empirical material and in light of the contemporary research literature on first-year students, learning environments and university

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pedagogy, we explore students' positions and aim to better understand the social mesh that they interact within during their first year at the university.

1 INTRODUCTION

Entering higher education is a major step for students and describes a significant transition in their personal and professional development. The transition into higher education is often accompanied with uncertainties and expectations. Students need to find their spaces and negotiate their role and social relations to other students and educators. On a disciplinary level, enculturation of students into engineering practices plays a central role [1]. In other words, students need to learn and assimilate knowledge, practices, and values of both disciplinary engineering cultures and social cultures surrounding their study program and the university in more general terms.

Furthermore, expectations first year students bring with them, either explicit or implicit, play a central role in how they experience higher education [2]. While there has been a significant number of studies on first-year student experiences, much less is known about which role expectations play on a qualitative level [3].

With this in mind, this study will be centred around the question; *How do students' expectations of higher education shape and are shaped by their experiences of entering the university?* We will explore this question by drawing on a qualitative thematic analysis of nine interviews with first-year students from the electrical engineering study program at the Norwegian University of Science and Technology (NTNU).

Grounded in the empirical material and in light of the contemporary research literature on first-year students, learning environments and university pedagogy, we argue that transitioning from high school to university can be challenging on many levels. By exploring students' positions, we want to better understand the social mesh that they interact within during their first year at the university.

In the discussion, we will draw upon social identity theory (SIT) and system justification theory (SJT) to provide a conceptual framework to understand students' experiences. SIT approaches identity processes as embedded in social meshes and describes how group behaviours are influenced by status differences, perceived legitimacy and overall in- and outgroups [4]. In addition, SJT provides entry points to how students justify the system and culture that they are part of [5]. We argue that a closer examination of how students' transition and adjust is of general interest for engineering education and that the findings from this study have both practical and research implications.

2 METHODOLOGY

2.1 Research context

The context of this study is a five-year integrated master's program in electrical engineering at NTNU called Electronic Systems Design and Innovation. This is a program that admits 120 students every year and is one of 17 five-year integrated engineering master's programs at NTNU. All of these are among the programs with the highest admission requirements in Norway, though with significant differences between the 17 programs.

Associated with the Electronic Systems Design and Innovation program is a student organization, Omega, that provides social and extra-curricular arenas for students. Omega is organized and run entirely by students on a voluntary basis and takes responsibility for welcoming new students to the study program through social events, parties, and inauguration rituals, being a social facilitator throughout the year, and creating connections between students and industry. With this in mind, many students experience Omega as a main social arena from day one at university. Omega is made up of various committees, which in total organizes almost all of Omega's activities.

The students can choose between different committees with different activities where for example some arrange social events, others brew beer, and some are a part of the board. The committees are tightly knit to the industry, both through sponsorships and arranging meetings between students and companies. In addition to Omega, there are various other technical student organizations, not connected to a specific program, that provide additional social arenas for students oftentimes centered around realizing a specific technical project, e.g. Formula Student.

2.2 Research design

To explore the question; How students' expectations of higher education shape and are shaped by their experiences of entering the university, we draw upon a qualitative case study approach [3] with semi-structured in-depth interviews. In total, twelve first year students were recruited and gave their informed consent to be interviewed. Eight individual interviews and one group interview with four students were conducted. The students were recruited amongst the entire student population and signed up voluntarily. The interviews lasted 45 minutes on average and covered group dynamics, sense of purpose and belonging, design thinking, diversity, culture, and interdisciplinarity. All interviews were conducted in Norwegian (the students' mother tongue), and later audio-recorded and transcribed. Only the sections used in the results were translated to English and students were given pseudonyms.

For the analysis, the interviews were pooled together and a thematic analysis approach [4] was used to identify, analyze, and describe patterns and themes within the data. The material was read and re-read to explore how students' expectations of higher education shape and are shaped by their experiences of entering the university. Through the iterative analysis process, we identified themes that emerged from the interviews. These themes were further explored by considering relevant literature and using it as an additional perspective to develop and deepen the thematic analysis. In this study, we will present three themes that emerged from the analysis: *finding themselves*, *discovering social arenas within their study program*, and *positioning their study programs in relation to others*.

3 RESULTS

Based on the qualitative, exploratory analysis, it is apparent that students' own expectations and perceived expectations from others, are key elements in how they experience their learning environment and the overall culture at the university. Their expectations influence how they view themselves and how they position themselves in relation to others in a complex social mesh of rituals, traditions, and hierarchies. The interviews also reveal a strong dynamic in how students negotiate their own positions and are enculturated into the university culture both disciplinary and social.

3.1 Finding themselves

Grounded in the empirical material, it is clear that the students hold strong expectations towards being at the university when transitioning from high school. Furthermore, these expectations are not necessarily fixed, explicit, or coherent and an apparent finding in the material is that students continuously contradict themselves throughout the interviews. While students commonly answered that they did not have any expectations, when talking about their experiences from entering higher education and being a student, they clearly build upon and draw from the expectations they hold themselves and those of others.

One area where this becomes obvious in the empirical material is relation to their choice to become engineers. Here, the answers varied from wanting to pursue a genuine interest, to utilizing grades, following in their parents' footsteps, and achieving status and power. Status and power were mostly indirectly expressed in comparison to other professions, where engineers were compared to professions which are usually associated with lower status and power. One student expressed the desire of status directly, but more as a confession than a statement.

> And a little bit due to status, I have to admit. It is a little bit like, if you can study engineering, you should (S7)

Another aspect of students' expectations that came up is that it can be tough going from being the best in your class to just being average amongst others who were also used to being the best. Becoming an electrical engineering student at NTNU requires relative high grades to be admitted. It appears that several of the students are struggling more with finding their place and building their professional identity around being one amongst many rather than being the smartest in a group. As a result of this, it turns out that they start perceiving themselves as average compared to everyone else.

> You are used to hearing that you are the best in your class. And known to others as the best. And then you come to a place where everyone has the same experience. Suddenly, you do not feel so smart anymore. You do not stand out anymore… it has to do with the fact that I was the smartest, and now I am not anymore. I am not used to struggling in school. It's not like I'm stupid, but it's hard. I planned to be a straight A student, but now I'm more like a "passed" student. Because now I've met people who are a lot smarter than me, I thought I was that person, but I'm not. (S1)

In addition, students are unsure about the social norms in the cultures around their study program. They try to find a balance between positioning themselves in a way where they are seen as neither the most nor the least intelligent.

Simultaneously, several of the students reflect on the positive aspects that come from not being "better" than everyone else. This includes using the other students as a resource, rather than competing against each other. The students point out that they do not see the point in competing against others who are on the same level as themselves.

> I have been able to use the other students more like resources now. Something that I did not feel before, before I came to the university that is. (S3)

3.2 Discovering social arenas within their study program

Upon entering the university, students start to navigate the social and professional landscape and try to find their way. The results reveal that an important part of this is becoming a part of the student organization at their study program and joining a committee. These committees appear to have great influence on the students' learning environments and overall culture. In all the conducted interviews, students have pointed out the significance of these committees. The statements made, suggest that the students perceive joining a committee as an expectation to be a part of the social life of a student.

There seems to be a plethora of information about joining a committee and what it means to join a committee. During the interviews, the students were asked about why they wanted to join and several students expressed that joining a committee was a way of getting access to important social arenas. Not being a part of a committee, can lead to the feeling of being left out.

> There was a lot of advertisement about the committees all the time. So, I don't find it strange that so many students wanted to join, when you are surrounded by this information all the time… it's a pity though, because there aren't enough places for everyone to join. So, everyone that wants to join, cannot. It is a pity because they will miss that social arena, especially since a lot of students want to join as well. (S8)

Another student reveals that joining a committee did not feel like a big deal at first, but in retrospect played a central role in the process of becoming a student. She explains that if you are not a part of a committee or the "right" committee, you are labelled as "outcasts".

> I wish I could change or influence the existing culture more. Or be more a part of it. I don't know if it is just me that has not participated enough. I didn't know that committees were such a big deal, like everyone portrayed them to be. I have applied for a committee, but I didn't know if you do not join a committee, you are practically nothing… I am in the revue committee and thought to myself "okay, this is cool". But no one views the revue as a legitimate committee. At the student organization ball, all the committees had their own table, but the revue group didn't even have a table. And the students who weren't in a committee at all, sat all the way in the back and were like "outcasts". (S1)

Yet another student reflects on her first days at the university, where it seemed like everyone had joined student organization committees quickly and without much thought. Not just one committee, but multiple ones. She later realized that this did not work for her and became a roadblock in her studies. She describes her impression when arriving at the Ada-day – a project to promote technological studies to recruit more women.

> When I arrived during the Ada-day, I got the impression that everyone had a student organization committee, a technical committee and did some other fun things and had time for hobbies in the side. And that they still had time to do the things they wanted to during the week. I found out after just to committees, that this didn't work for me. Where one of them didn't even take much work. I noticed that it was just mentally draining to just be a part of it, more draining than actually just doing the work that was required of me. Now I feel much more relaxed knowing that I can focus on my studies, without worrying about all the other stuff I should be doing. (S2)

3.3 Positioning their study programs in relation to others

When describing both the decision for choosing their study program and how they are experiencing it, the students draw heavily on comparing and positioning their study program in relation to other study programs. When choosing a study program, the common approach seems to be to choose based on your grades and aiming to be admitted to the study program with the highest possible admission requirement.

> There is an existing hierarchy within our society and university. It seems that people think that you should just swoop into your place (in the hierarchy). If you have a 6.2 GPA (grade scale= 1-6), then you are supposed to choose indøk (Industrial Economics and Technology Management, the engineering program in Norway with the highest admission requirements). If you choose something else, it will be like «what are you doing? You are not supposed to be here". Passing on the notion that if you do not max your GPA, it will be a waste. (S7)

Once at the university, several chose to portray their own situation by ranking their program compared to others, both technical and non-technical study programs. The students illustrate a hierarchy, where they have a specific place, not at the top, but not far from it. Even before being fully enculturated into the university culture, the students pick up on existing social norms that exist on how to talk, relate, and view other study program. There is a known "feud" between the technological and humanistic studies. One of the students shares a story from the beginning of the semester illustrating this.

> It might be because you don't have so much contact with people from the other study programs. I remember a situation from the initiation weeks at the university. We were at a student's house at a place in Trondheim. A person peaked through the window and asked where we studied. And I remember one girl lying about what she was studying, she said that she went to our university, because she knew that we went to this specific campus (with the technological study programs). It turned out that she went to BI (a private business school). So, this shows that there is a culture at our campus (Gløshaugen), that we are better than other studies. (S5)

When asked about where the notion of technological studies being "better" than other studies came from, the student points out that he has been told from former/senior students how the culture at NTNU and the electrical engineering program is and has always been. He emphasizes that these assumptions are unfortunate.

> It is mostly from people around you. Things I have heard from last year's students. It is unfortunate. There is no reason for walking around thinking that you are better than everyone else. I do not feel like I think like that. But you hear it from people. There have not been any bad vibes, it might be more as a joke. But then again, there is always some truth behind a joke. (S5)

Another student describes what she has encountered as a common attitude at the university. The description contains how the campus where the technology programs are at home is perceived as better than the campus for other study programs. Even within the technological studies, there is a known hierarchy. She points out that this feeling has grown stronger after being a part of the university culture for a while.

> I feel like there is an attitude at Gløshaugen (campus at the university), to start with- Gløshaugen is above all other places. This is where the hardest, toughest, smartest people study. Like a God-complex. And within, you have the really hard study programs. If you are just enrolled in a bachelor's study program you are just an engineer, not a sivil engineer… the industrial economy study program for example, is not perceived as having a very high status within Gløshaugen, but this study program has very high status elsewhere. This is a feeling I have. I did not think that it would be as strong as after I came here. I got this feeling after I came here, a lot more than when I applied. (S7)

4 DISCUSSION

Building on the empirical material, we will in the following discuss how students' expectations of higher education shape and are shaped by their experiences of entering the university. On a general level, based on the findings in this study, it is clear that the students' expectations before entering the university do not always align with their experiences after being admitted, which is in line with earlier investigations into first-year experiences [1]. Furthermore, it is apparent that their expectations of the university have a clear connection to their experiences from high school, including what they expect from themselves and others professionally.

The process of entering the university is a turbulent experience for students, where they have to realign their views of themselves to match their lived experience, a process that is shaped by their expectations, i.e. students who did not expect the social importance of the committees and feel left out when having problems joining or students who expected joining a committee would be socially important, but where the activities left them mentally exhausted.

From the interviews, it is clear that this process is tightly linked to students finding their role in the social hierarchy at the university. In the following, we will discuss three dimensions of this positioning process within the social hierarchy at the university: students' individual relations to each other, the role of social committees, and between study programs. First, when transitioning into university, the students need to reassess their own expectation of how they view themselves, including their own capabilities and knowledge, in relation to others in the same program. One of the students described it as "swooping into your place in the hierarchy". Previously, it has been found that this perception of oneself in relation to other students can affect behavior when collaborating in project courses, giving more meaningful tasks to the students that are perceived as more knowledgeable [5]. Second, the students need to position themselves in relation to other students in the same student organization, with a membership in a committee as both an indicator and a generator of social attractiveness, with strong existing assumptions that new students will want to join one. Third, the students need to understand what status their choice of study program gives them in relation to students outside their program. Lastly, the students reveal that the choice of applying to engineering somewhat motivated by status and the expectations of those around them, not necessarily meaning only their parents, but other people in their community as well.

According to social identity theory (SIT) [6], students will derive a positive self-concept from being a member of a group, thereby favoring their own in-group to create a higher self-esteem. Simultaneously, there is a clear hierarchy between groups, as illustrated in the empirical material where the revue-committee is described as an out-group amongst the committees. It is also apparent that students constantly compare their own study program and see it in relation to other study programs. Being enemies with other student organizations, is portrayed as a joke, and by doing this it is possible to create an in-group within the student organization. This recurring theme is apparently a known topic both within and outside the university.

The high status of the student organizations creates a situation where they seem to have monopoly on how and where student culture and learning environments are negotiated. Students perceive that they are required to spend a set amount of time on committee work, and most spend significant amounts of time on the social events connected to the committee. The more time they spend, the more influence the committee will hold over the members, in turn making the committee as an in-group even more important for the students' university experience.

Building on system justification theory (SJT) [7], we see the students justify the social hierarchy through ego justification, group justification, and system justification. Ego justification describes the process by which students feel better about themselves by viewing themselves as better than other students, both in their own program and other programs. Group justification captures how committees are perceived as valuable places to be and creating value for others, whereas differences between programs and campuses can be approaches on the level of system justification.

Furthermore, the empirical material gives the impression that attitudes, justifications and overall culture is being passed on from one generation to the next, even though the students reveal that there are many aspects of the culture they do not like. The strong rituals and norms within the student organization might hold on to predefined connotations and prejudices, which several of the students' descriptions illustrate.

In conclusion, the interviews reveal that the students have expectations to both themselves and to others when entering university, expectations that are quickly shaped by the process of finding one's place in the university's social hierarchy through maneuvering the strong established expectations already present in the programs, organizations, and committees, creating an experience predefined by the strong cultural norms of what it means to be a student.

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IS "DIGITAL EDUCATION" THE RIGHT WAY FORWARD? – OR IS, MAYBE, POSTDIGITAL EDUCATION WHAT IS NEEDED!

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ABSTRACT

The use of “digital tools” have usually played an important role in the transformation to “emergency remote teaching” during the pandemic. However, even before the pandemic there has been a strong pressure that education should become more “digital”. Nevertheless, we see several problems associated with the present discourse related to “digitalisation” of education. 1) It often unclear what is meant with “digital education”, 2) very narrow view of “digital tools” too mainly be tools for information and communication neglecting other uses of digital technology, 3) unbalanced focus on “digital tools” there other tools are either neglected or seen as inherently inferior and “old-fashioned”, 4) conflation between “digital” and “distance”, 5) adherence to either a technological determinism or a pedagogical determinism (technology is a neutral tool).

Engineering students’ courses of action have been videorecorded in design projects and in electronics labs at two universities. It can bee seen that students’ use a wealth of bodily-material resources that are an integral and seamless part of students’ interactions. They use bodily resources, concrete materials, “low-tech” inscriptions as well as “high-tech” (“digital”) inscription devices. Our results challenge that by hand – by computer and analogue tools – digital tools should be seen as dichotomies. Our empirical evidence suggests that students should be trained to not only be trained to work with “digital” tools but with a multitude of tools and resources. We, thus, advocate that a postdigital perspective should be taken in education where the digital makes up part of an integrated totality.

1 INTRODUCTION

1.1 Digitilisation of education

For about about thirty years there have been a strong focus on, and a pressure to increase the use of, computers and internet in education [1-4]. In later years the buzz words “digitilisation” and “digital education” have been coined to describe this trend. During the Covid-19 pandemic many universities and schools world-wide transformed to “emergency remote teaching”. This was enabled by the use of “digital tools” such as the internet, computers and other communication devices equipped with cameras and speaker/microphones leading to an even stronger focus on “digitilisation” of education.

Nevertheless, we see several problems associated with the present discourse related to “digitalisation” of education. 1) It often unclear what is meant with “digital education”, 2) very narrow view of “digital tools” too mainly be tools for information and communication neglecting other uses of digital technology, 3) unbalanced focus on “digital tools” there other tools are either neglected or seen as inherently inferior and “old-fashioned”, 4) conflation between “digital” and “distance”, 5) adherence to either a technological determinism or a pedagogical determinism.

The aim of this paper is to be somewhat provocative and raise questions and issues related to the “digitilisation” of (engineering) education for debate. The paper is organised as follows: In sections 1.2 – 1.6 we, as a background, describe in some more detail (than is done in this section) some of the problems we see as exhibited in the present discourse related to digitilisation of education. In section 1.7 we argue for a broad view of digitilisation and demonstrates that it, indeed, is nothing recent but has a long history and in section 1.8 we briefly introduce the consequences we see with a narrow digitilisation as presented in sections 1.2 – 1.6.

In many ways the paper is a conceptual one but we support our argumentation with empirical data collected using video recording of engineering students in action in a design project and in an electronics lab. How the data was collected and analysed is described in chapter 2 and two episodes from the data are presented as results in chapter 3. Finally in chapter 4 we briefly discuss our findings in relation to postdigital theories. As this is a conference paper with limited space it has only been possible for us to briefly discuss the issues we want to address and the questions we want to raise. We have also only included a limited number of references.

1.2 Unclear meaning "digital education"

There is a lack of conceptual clarity regarding what is meant by "digital education". In a very early paper [5] "digital education" was used to reference the training of the dexterity of a dentists' hands (remember the original meaning of digit as finger). In the 70:s when the first author was an undergraduate student in engineering "digital education" was the learning about digital electronics (seen as distinct from analogue electronics). Neither of these earlier meanings are in the foreground in present day discourse.

Nowadays two main meanings of "digital education" can be discerned in the discourse: "Digital education" (and synonyms such as e-learning, technology enhanced learning etc.) can used for educational approaches that make use of digital tools and technologies during teaching and learning such as online learning and blended learning. "Digital education" can also denote the education of the learners to enable them to use digital tools in a skilled and comptent way. For example University of Edinburgh is using the first definition (with the add on that it should be "innovative use") [6] while the European Union in its Digital Education Action Plan use both meanings [7].

1.3 Narrow view of "digital tools"

What is apparent in many reports is what a quite narrow view of "digital tools" are purported. These are commonly described as being tools for transfer of information (in a narrow sense) and communication, i.e. ICT (information and communication technology). Other uses of digital tools such as the use of digital technologies for taking measurements, making observations, displaying and visualising results from measurements and observations, controlling measurements, modelling and simulations are seldom mentioned. Figure 1 displays a typical view of the meaning of digitalisation [8]. Indeed, Walan [9] in a study of "digital technology in science classrooms" only describes digital technology as information and communication tools and in a study performed by Henderson et al. [10] the digital devices the students reported to have used in the previous four weeks were laptop or desktop computers, smartphones, tablets, and in a few cases a dedicated e-reader. Although 47.8% of the students in the study by Henderson et al. were medical, science or engineering students no other use of digital devices were reported.

Fig. 1. From a publication by The Swedish National Agency for Education describing how the agency is working to digitalise schools [8].

Despite the heavy use of digital technologies (see section 1.7) for observation, measurements, regulation and control in health sciences, natural sciences, and engineering this usage is neglected in many common descriptions as reported above. Indeed, many successful projects for the learning of physical concepts built on the use of computers, with attached sensors, to make (real-time) measurements in real experiments. Such experiments were introduced in the teaching of physics in the mid 1980:s (see, for example, references [11, 12]) and the first author have reported successful use of such (digital) technologies with Swedish engineering students [13-16]. However, contrary to the narrow view of Walan [9] Kyza et al. [17] presents a much wider use of (digital) technologies that include technologies for data collection and analysis.

A wider view, but not complete view of digital tools are discussed in section 1.7

1.4 Unbalanced focus on “digital tools”

The narrow meaning of digital tools embraced in many accounts described in previous section is problematic. This limited discourse is often further extended by digital tools beeing portrayed as something positive and “modern” as opposed to substandard, inferior and outdated pre-digital tools and techniques [4, 18, 19]

1.5 Conflation between "digital" and "distance"

It is common to describe distance meetings (using, for example, computers and software such as Skype, Zoom, or Teams) as "digital" meetings. This has resulted that in many cases there is a conflation between between "digital" and "distance" and, for example, that planning for distance laborations are discussed as making the labs "digital". This is *highly* problematic as many (on campus) labs in science and engineering already are digital in that sense that they make heavy use of digital technologies for performing (real) measurements, analysing data from these measurements, and controlling experiments.

1.6 Technological and pedagogical determinism

The topics of technological or pedagogical determinism actually are actually worth a paper in its own to be discussed in depth and have, indeed, been discussed by many authors. We have chosen to illustrate the issues involved by figure 2 taken from the works of Tim Fawns [20]. In short, technological determinism rests on the illusion that the use of a specific tool *pre-determines* the outcome. In our own research we have demonstrated that this is simply not true, but that the pedagogical design also matters [e.g. 16, 21]. On the other hand, in pedagogical determinism technology is seen as a neutral tool and the pedagogical method used *pre-determines* the outcome. In our own research we have demonstrated that different techologies, indeed, have the different affordances effecting what is possible for students to experience [e.g. 22]. In the debate and discourse regarding "digitilisation" of education both technological and pedagogical determinism can be found [e.g. 4, 20].

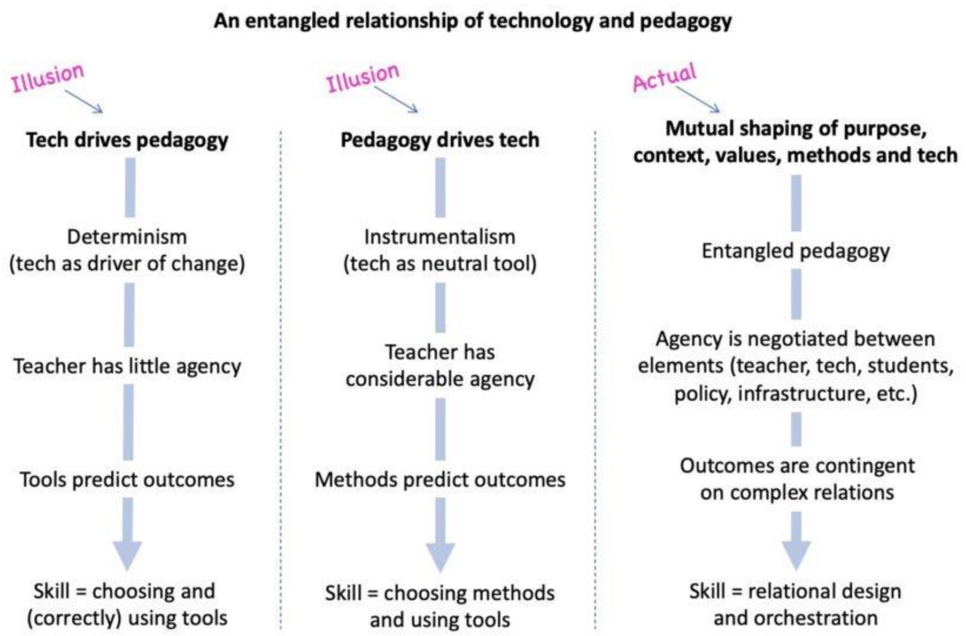

Fig. 2. An entangled relationship of technology and pedagogy (v3), CC BY SA, Tim Fawns, University of Edinburgh.

1.7 “Digitalisation” has a long history

In section 1.3 it was mentioned that often a rather narrow view of the meaning of “digital tools” are embraced. Commonly digital technology is described as a rather recent (and modern) technology and the digitalisation of society as a new phenomena. In part this is true for the aspects of digital technologies experienced by the general public. Indeed, that is seen by the public (and policy makers) is mostly digital tools as information and communication technologies. Most people are not aware about the amount, and features, of digital technologies that are operating behind the scenes and that are contributing to the well-beeing and affluence in modern society (at least in some parts of the world).

If we see digitalisation as meaning something that can be described by discrete, digital, units (as opposite to continuous, analogue, entities) it can be seen that “digitalisation” has a rather long history. One start is the invention in 1725, credited to Basile Bouchon, to use perforated tape to control looms for the veawing of ornamental patterns [23]. This idea was further developed over the following years and around 1805, using perforated cards, Jacquard was able to make the first really successful automatic weaving loom. As discussed by, for example, Randell [23] the control of the Jacquard loom inspired various developers of analytic engines manifested in 1944 with paper rools used to control one of the very first computers (Mark 1). Still, in 1973 when the first author as a first year engineering student learned programming (Fortran IV), punch cards were used to control the computer and execute programs.

There is, indeed, a rather continues line of development from the control of operating looms in 1725 by a rather primitive “digital technology” to the (automatic) control nowadays of our dishwashers, washing machines, heating, cars etc to the control of machinery, railways and even complete industrial processes. The difference is that the “card perforations” now are electromagnetically stored as zeros or ones (an intermediate step has been electrical sensing of card perforations). Digital electronics has enabled the control processes and things at a faster spead, larger scale, higher reliability and at a lower and lower cost. We claim that the use of digital tools for control is an, for society and our well-fare, important utilization of (digital) technology.

Another important use of digital technologies in modern society is the use of digital technologies in combination with suitable sensors for taking measurements and making observations and displaying results from these. This use of digital technologies are of great importance in industry as weel as in research. In health care it is almost impossible to imagine a modern intensive care unit without this use of digital tools. As mentioned in section 1.3 digital measurement technologies has been used in physics teaching [11-16] since the mid1980:s and is, thus, not something very recent.

1.8 Consequences

The greatest value of using digital tools for our society is perhaps not primarily as tools for information and communication but, in our opinion, as powerful (and often affordable) tools for control and regulation, measurement, observations, calculations and more. If these aspects are missed, there is a risk that we give students a false picture of what digital tools have provided for contributions to our prosperity and welfare. Furthermore, if these aspects are missed, there is a risk that the potential of using digital tools in teaching will not be fully utilized! (cf. references [4, 20])

2 METHODOLOGY

The intent of the background in our paper has been to present a more comprehensive and multi-facetted picture of what we see as digital tools. Based on this background, on scholarly literature [1, 4, 20, 24], and our experience from theaching our hypothesis is that the dichotomy between digital and analogue tools is artificial and barren. We, rather support the view argued by Fawns [4] (and others) that we need to take a "*postdigital* perspective [in education], in which the digital makes up part of an *integrated totality*" (our emphasis).

We have, over a period of more than 15 years, collected a rather extensive set of video recordings [25] of (primarily) engineering students' interactions during engineering design projects and during physics and electronics labs. This video data have been recorded in regular teaching sessions at two universities in two different countries.

We have re-analysed the videos driven by our research question what kind of tools contributing to their fullfilment of tasks, and contributing to their learning, are students' using? As the material is, indeed, very extensive we will in this paper present evidence from two episodes:

Episode 1: Students in the fifth semester of the PBL-based master's program Architecture and Design at Aalborg University, Denmark, have been videotaped. The students work in groups of 5–6 students and have the task of constructing a real office building.

Episode 2: Students in the fifth semester of the master's degree program Electronics Design at Linköping University, Sweden, have been videotaped during a laboratory in high-frequency electronics. The task is to make a model of unknown (analog) circuit.

Because of the importance to illustrate the materiality of the settings and students' use of different tools and gestures, the results are not represented by traditional transcript. Instead we have put student dialogue (translated from Danish or Swedish into English) into speech bubbles. All names are pseudonyms and not students' real names. Informed consent was obtained from all, involved, students and the material have been handled according to the laws, ordinances and other regulations valid in Denmark and Sweden. The results and our analysis is presented in the next chapters.

3 RESULTS

3.1 Episode 1

The episode is taken from a videorecording of a preparation (lasting the whole day) the students are making for a presentation in a feedback seminar the next day. In the excerpt four of the students are sitting around a table working individually for a while. In the first group of two pictures Ina calls for Mette's attention to discuss a design decision. Mette rools over to Ina and in the exchange they use an iPad, a drawing, a styrofoame model, and their own fingers to highlight the issues involved. In the next group of pictures they use a 3D-styrofoam model to reason around and the make ample use of gestures. In the next step they move over to Mette's computer to look at a CAD-drawing and Ina is using her fingers to "walk" around the building in the drawing and finally Ina is pointing to a photo on the board where the group keep materials used for inspiration. She is pointing to a similar design already implemented in reality.

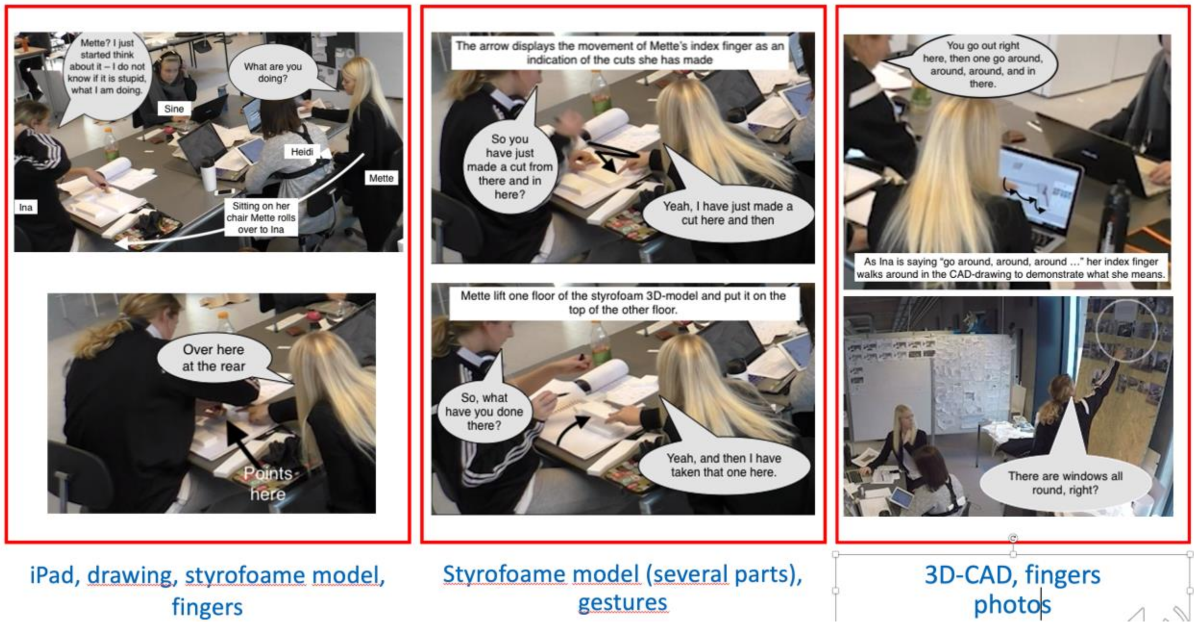

Fig. 3. Still pictures, with speech bubbles, taken from the videorecordings of a student group in a design project at Aalborg University. Below each pair of pictures are written the "tools" students are using.

We are here only showing a very short excerpt. A fuller presentation of this material can be found in references [24, 26-28].

3.2 Episode 2

In this episode students investigates an analogue high-frequency circuit with help of a digital oscilloscope and digital measurement technology. The task students are facing is to make measurements on several circuits consisting of unknown elements and to model the unknown circuit. For measurements a digital oscilloscope is used. The oscilloscope is connected to a computer enabling the results to also be displayed on the computer screen. A complication for the students in solving this task is that in high frequency electronics many of the idealization assumptions on which basic electric circuit theory and electronics are not valid.

In figure 4 a short excerpt from the lab is shown with the students Leif and Rune. In *a*) the oscilloscope can be seen in the upper left corner and the measurements are also displayed on the computer screen seen to the right. Moreover in *a)* Leif is responding to Rune by pointing at a graph feature displayed by the oscilloscope and in *b)* Leif continues by hand movements and gestures to indicate high and low frequency characteristics. He continues in *c)* by now indicating flank using a pen to point on the computer screen and moving the pen up and down. In *d)* Rune suggests that the circuit consists of a coil and a capacitance making a sweeping hand movement along the measured graph. For about a minute the students are continuing discussing the circuit, they go back to a previous measurement on another circuit to compare, and make some sketches. Finally they feel confident that the circuit consists of a coil and a capacitor and as a confirmation Leif points to the peak as displayed in *e*) and moves the pen as is indicated by the arrow.

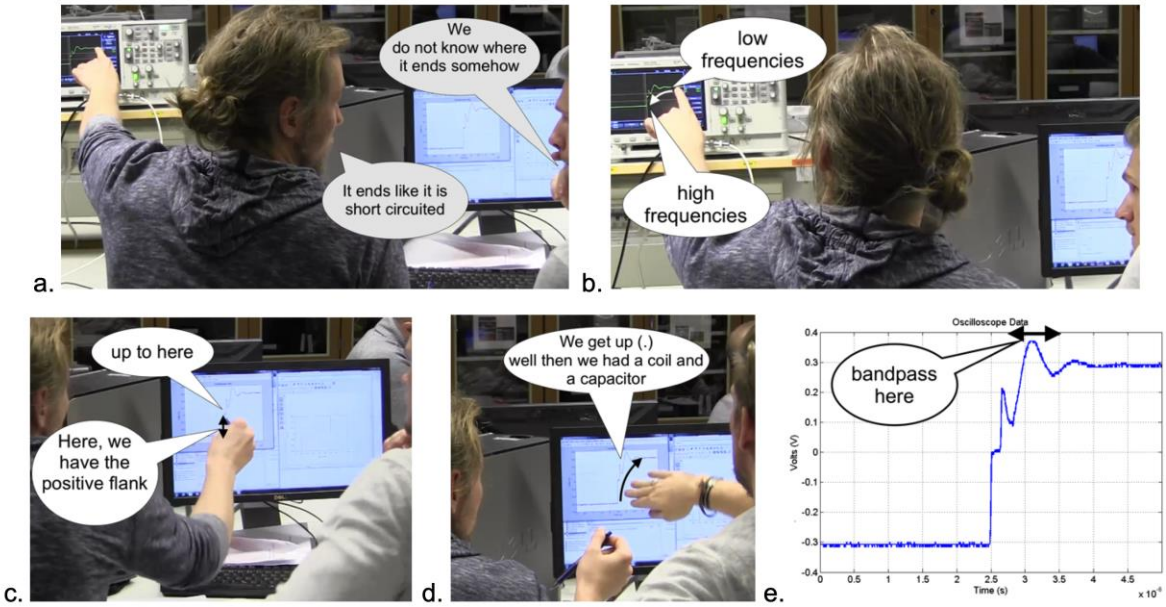

Fig. 4. Still pictures, with speech bubbles, taken from the videorecordings of a high frequency electronics lab at Linköping University.

We are also here only showing a very short excerpt. A fuller presentation of this material can be found in references [29, 30].

4 DISCUSSION

In both episodes, the students used in their interactions a rich repertoire of physical and material resources in an integrated and seamless way: Physical resources (eg. gestures, opinions, bodily orientation), concrete models (eg. 3D styrofoam models, paper models), low-tech inscriptions (eg. sketches, drawings on paper, post- IT notes) and equipment for "high-tech" inscriptions (eg. iPads, CAD drawings, digital measurement technology, simulations).

As mentioned in the introduction there is concurrently an urge that education (and society) should become more “digital”. As a consequence, if tools and resources are considered at all, it is common to see these as synonymous with “digital technologies”. For example, at the European engineering education conference 2018 in Copenhagen Flaata and Pitera [19] almost excused themselves for their students use of “old-fashioned” sketching and drawing by hand as they were supposed to become engineers in the “modern world”. However, our study shows that a focus only on “high-tech” resources would be problematic and that we in engineering education research should rather attempt to understand how students use many and varied bodily-material resources and in engineering education encourage their use [cf. 31, 32]. An apparent finding in this study is that students made ample, efficient and fluent use of gestures, sketches and hand drawings and that these procedures seems to be beneficial to the design process and/or the learning process as different tools and resources had different affordances [see also, for example, references 32, 33, 34]. It is important to note that the students did not use the “low-tech” resources because they lacked the necessary skills to use the “high-tech” resources. On the contrary we argue that the students displayed that they were highly skilled in using digital tools, but they, in each situation, used the tools and resources they deemed to be most beneficial for the task at hand.

Indeed, more than 20 years ago Henderson [33] in her study *On Line and On Paper: Visual Representations, Visual Culture, and Computer Graphics in Design Engineering* offered a critique of the dominant ideology that paper was soon to be a thing of the past to be replaced by the use of digital tools. In her work she showed the centrality of sketching and sketches in professional engineering work and argued that CAD lacked the flexibility needed to fully support collaborative design. In our study we can see that the students use sketches and sketching, physical models and gestures as these tools and procedures offered greater flexibility and that the students mainly turned to 3D CAD drawing when finalizing design and make more (final) formal drawings.

Moreover, our results challenge that the distinction between by hand and by computer, between analogue and digital tools, should be seen as a dichotomy. Rather, our results show a blurred distinction. We see that it is essential that engineering students are trained to work “by hand” *and* “by computer” and that it is *not* a question of “by hand” *or* “by computer”. Indeed, Fawns (and others) argue that we need to take a “*postdigital* perspective [in education], in which the digital makes up part of an *integrated totality*” [our emphasis, 4].

As we only, in this study, have studied two cases and only have looked on students’ interactions (not on teachers’) we can, of course, not draw a general conclusion (if this even can be made) of the optimal use of different tools. Neverheless, we suggest that engineering teaching should not be focused on “digitalisation” in a narrow sense, but should seriously consider a postdigital perspective where digital tools are part of an integrated whole together with other tools and resources. All the tools in the educational toolbox are needed and they are good for different things!

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SUSTAINABLE ENGINEERING EDUCATION IN RESEARCH AND PRACTICE

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ABSTRACT

Sustainability and responsible use of the resources at our disposal are among the most important goals of our time. Employees are looking for next-generation employees with ever more skills. To ideally foster these in engineering and prepare them for future challenges, the integration of education for sustainable development (ESD) with a linkage of technical and sustainability-oriented issues in the curriculum is essential. This paper takes up two points: Firstly, an analysis of the research landscape in Engineering Education Research (EER) on the topic of "sustainability" is undertaken. For this purpose, more than 3500 conference papers of EDUCON and FIE of the years 2014 to 2018 as well as 2021 (EDUCON only) are evaluated. The methodology of the analysis as well as the set of main and sub categories (among them "sustainability") will be presented at SEFI 2022. The results of the analysis of the research landscape show that the topic of sustainability has so far played a negligible role in the conference contributions. Secondly, the focus is on the implementation process and the linking of technical and sustainability-oriented issues. The study programme concept of the Leuphana University offers two options for sustainable technical education by combining major and minor study programmes. The interdisciplinary combinations are presented and explained using module examples. In total, this paper provides a research-based contribution to sustainable engineering education in research and practice.

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1 INTRODUCTION

Sustainability and responsible use of the resources at our disposal are among the most important goals of our time. Employees are looking for next-generation employees with ever more skills. In order to optimally promote these in engineering and prepare them for future challenges, the integration of education for sustainable development (ESD) with a linking of technical and sustainability-oriented topics in the curriculum is essential. Worldwide, studies show that the topic of sustainability is insufficiently addressed in engineering curricula [1-4]. For example, the study by [1] assesses the Nigerian engineering curriculum and shows that sustainability dimensions are poorly included, with environmental concepts mentioned most frequently and social issues least frequently. An analysis of the presence of sustainability issues in 16 Spanish higher education curricula in education and engineering show that they are more homogeneously represented in education curricula than in engineering curricula [2]. A survey of students in the Civil and Environmental Engineering (CEE) programme at the Georgia Institute of Technology investigated students' interest, knowledge and experience in sustainability. The results show that students are interested in sustainable development, but there is still potential to improve sustainability education [3]. An investigation of the integration of social sustainability into engineering education at the Royal Institute of Technology (KTH) in Sweden based on interviews and indicates that curriculum managers and teachers at KTH have difficulties understanding the concept of social sustainability [4]. Other studies show positive developments in relation to sustainability [5-6]. An analysis of the current state of Australian universities shows that a large proportion have successfully introduced sustainable engineering education, while the rest are currently focusing on integrating it into their curricula [5]. In addition, [6] describe the progress made over the last 25 years in incorporating sustainability and green engineering content into chemical engineering curricula.

The above analyses and studies show that there are some universities that have mastered the challenges and are well on their way to implementing education for sustainable development in engineering. However, a majority of the studies show that sustainability aspects are strongly neglected in engineering education, especially social sustainability aspects. Which is where this contribution intervenes. An analysis is made of the research landscape in engineering education research (EER) on the topic of "sustainability". For this purpose, 3570 conference papers of EDUCON and FIE from 2014 to 2018 and 2021 (EDUCON only) are analysed. The methodology of the analysis will be described in the following section. **Sec. 3** presents the evaluation with a focus on the issue of sustainability. Furthermore, the focus is on the implementation process and the linking of technical and sustainability-oriented questions. Therefore, the last **sec. 4** shows a successful implementation of sustainable engineering education. By the study programme concept of Leuphana University with the combination of major and minor study programmes, two options for a sustainable technical education are presented.

2 METHODOLOGY

The systematisation of the EER landscape is carried out as design-based research work, e.g. [7-8], which contributes to theory building by providing a categorisation of the international research field, but also leads to the structuring and bundling of research findings in practical application. For the purpose of gaining knowledge at the interface of engineering and sustainability, two leading IEEE conferences of the international EER research landscape, the FIE and EDUCON, were selected as the basis for the systematisation, whose publications appear annually in a two-stage blind review process. With the aim of an international and up-to-date analysis, contributions to EDUCON and FIE from the years 2014 to 2018 and 2021 (EDUCON only) were systematically analysed and categorised using a catalogue of categories developed in advance. In doing so, EDUCON, like SEFI Annual conferences, focuses more on the European research landscape, while FIE expands the research work to include a more international (especially American) view. This approach addresses the critiques of Williams and Wankat [9], Williams et al. [10] as well as Borrego and Bernhard [11], who point to existing disciplinary and geographical divisions in the research landscape. Although the research presented does not provide a complete overview, basic statements and research trends on sustainable engineering education can be derived. The number of articles from the respective years that were used to categorise the scientific articles is presented in **Table 1**.

Table 1. *Number of published and categorised papers of the international EER conferences Global Engineering Education Conference (EDUCON) and Frontiers in Education Conference (FIE) in the years 2014 - 2021, own data.*

Year	EDUCON	FIE	Total
2014	196	519	715
2015	154	403	557
2016	191	410	601
2017	289	306	595
2018	300	537	837
2021	265	-	265
Total number of categorised paper			**3570**

2.1 Methodological procedure, implementation and critical reflection

In the content-structured procedure according to [12], the categories for the systematisation of the EER research field were developed inductively from contributions of the EDUCON and the FIE of the years 2014 to 2018. The methodological design of the systematisation and selected partial findings were put up for discussion within the research community [13-14]. The result is a research-guided category system consisting of ten main categories and 78 subcategories, which encompasses the main aspects of the research field, their specification and the relations and delimitations of the individual categories to each other (exemplified with a focus on sustainability in **sec. 2.2**). To increase the quality of the research process and to minimise the subjectivity of the analysis, intersubjective validation was used consistently from the beginning of the research process. In order to check the uniform understanding, several papers were randomly selected from the total amount of contributions, individually categorised by at least two people and the categorisation subsequently discussed in the team. The discourse about the individual perspectives and the achievement of a consensus in the categorisation led to a secure handling of the category system and consequently to a reliability of the categorisation within the research team. Subsequently, 3570 contributions were systematically analysed and categorised using the category catalogue developed and are available as an Excel list. The topic of “Sustainability” is represented as a sub-category in the category system. For a more in-depth analysis, a keyword analysis within the Excel file was used in the submitted contribution. This in-depth analysis followed the procedures for systematic literature review regarding engineering education research, e.g. [11]. The titles, keywords and abstracts of the papers were searched for the keywords: "sustainability", "sustainable" and "climate change". The results of this extended analysis have been incorporated into the evaluation in **sec. 3**.

2.2 Theory-based positioning of sustainability in the EER landscape

The category system developed consists of ten main categories with up to 12 subcategories each, extracts of which are shown in **Table 2**. In addition to the categories, there are coding rules that describe the assignment criteria for the respective category and add concrete anchor examples or demarcation notes to other categories. For example, the publications sorted into the main category "Teaching and Learning" focus on the teaching-learning process and its design. The category "Topics related to Engineering" categorises publications that place the thematic focus on topics that are not subject-specific but are related to engineering content. One of the subcategories belonging to this main category is “Sustainability” (see **Table 2**). Each contribution was assigned to at least one and at most two main categories. The selection of two main categories ensures that interdisciplinary contributions and contributions that form a transfer between individual topics can also be considered in two different categories. One suitable sub-category can be selected for each main category.

Table 2. *Main categories and exemplary subcategories of the category system for systematising the EER landscape, own data.*

Main categories	
Assessment and Evaluation	**Student Motivation and Decision Making**
Curriculum Design	**Target Group Related Issues**
Discipline Specific Issues	**Teaching and Learning**
Diversity in STEM Fields	**Topics related to Engineering**
Research	**Digitalization**

Sub categories of the main category "Topics related to Engineering"	
• Language Issues • Philosophy in Engineering • Professional Ethics • Professional Skills • Entrepreneurship	• **Sustainability** • International • Academic Writing Skills • Interdisciplinarity & Education

The categorisation carried out according to the systematic and rule-guided procedure described above made it possible to examine the location of sustainability in the area of EER, and the results are presented below.

3 FINDINGS WITH A FOCUS ON SUSTAINABILITY

3.1 General statements of the overall evaluation

The total of 3570 FIE and EDUCON conference articles from 2014-18 and 2021 (EDUCON only) were each assigned a minimum of one and a maximum of two main and sub-categories. A total of 6627 categories were assigned. What is noticeable in the overview of the results of the category allocation is the lower number of allocations in the contributions to EDUCON, which can be attributed to the different absolute number of contributions to the respective conference (see **Table 1**). In both conferences, topics in the context of teaching and learning processes (main category "Teaching and Learning") were addressed most frequently by far. Articles dealing with project and problem-based learning were particularly prominent. Many of the contributions at both conferences also focus on issues and topics of a specific engineering discipline (main category "Discipline Specific Issues") or deal with the development, expansion or re-design of modules or entire curricula (main category "Curriculum Design") in the field of engineering. For limited reasons, a more comprehensive overall evaluation is not included in this paper, as the focus is on the evaluation of the topic area of sustainability.

3.2 Results with focus on the subcategory sustainability

As previously pointed out in the introduction, many educational institutions are lacking a reference to the topic of sustainability and thus to education for sustainable development. In the following, the number of contributions dealing with the topic of "sustainability" will be examined.

Fig. 1 gives an overview of the categorisations of the articles of the FIE and EDUCON to the sub-category sustainability over the years. Out of a total of 6627 categorisations, 48 (0.72%) were made in the sub-category "Sustainability". By way of explanation, it should be added that a category is only awarded if the *majority of the contribution* deals with the theme. Most articles mentioning sustainability issues were identified in 2017. In general, the proportion of articles that address the topic of sustainability is extremely low at 0.72%, which illustrates and supports the situation described in the introduction. Contrary to expectations, there is no trend to be noted in the results.

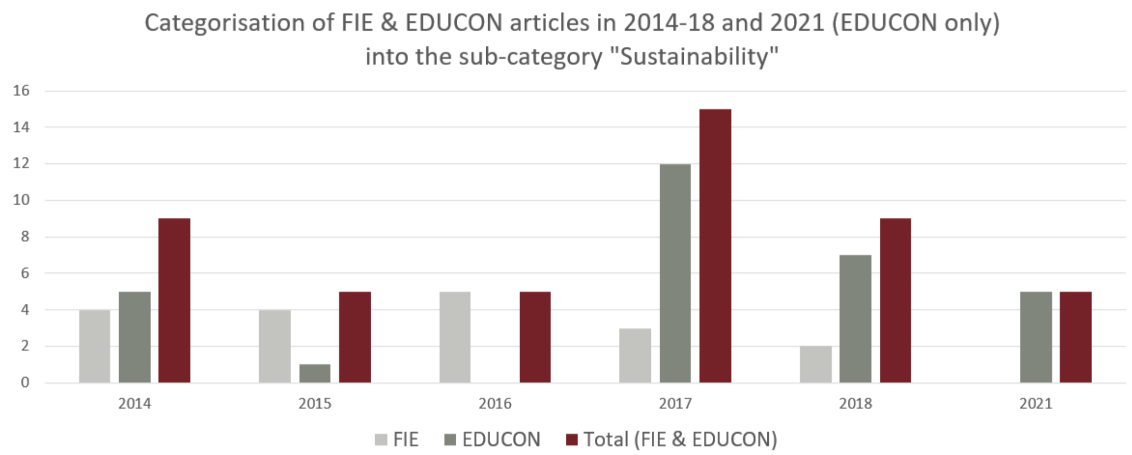

Fig. 1. *Categorisation of FIE & EDUCON conference articles in 2014-18 and 2021 (EDUCON only) into the sub-category "Sustainability", own data.*

In order to find out whether the topic of sustainability nevertheless plays a role in the categorised articles, a "COUNT IF" query was carried out in Excel. It was analysed how often the word "sustainability" was written in the title (9 times), in the keywords (20 times) and in the abstract (39 times). In addition, the words "sustainable" and "climate change" were filtered. The word "sustainable" appeared in a total of 18 out of 3570 titles, in 17 keywords and 55 abstracts. "Climate Change", on the other hand, was only mentioned once in the title and keywords and 3 times in the abstract. The occurrence of the word "sustainable" should be interpreted with caution, as it refers not only to sustainability aspects, but also, for example, to long-lasting projects that do not directly include sustainability issues. With a total of only 5 mentions, the occurrence of the word "climate change" can be neglected. **Fig. 2** shows the frequency of the word "sustainability" in the title, abstract and keywords depending on the year.

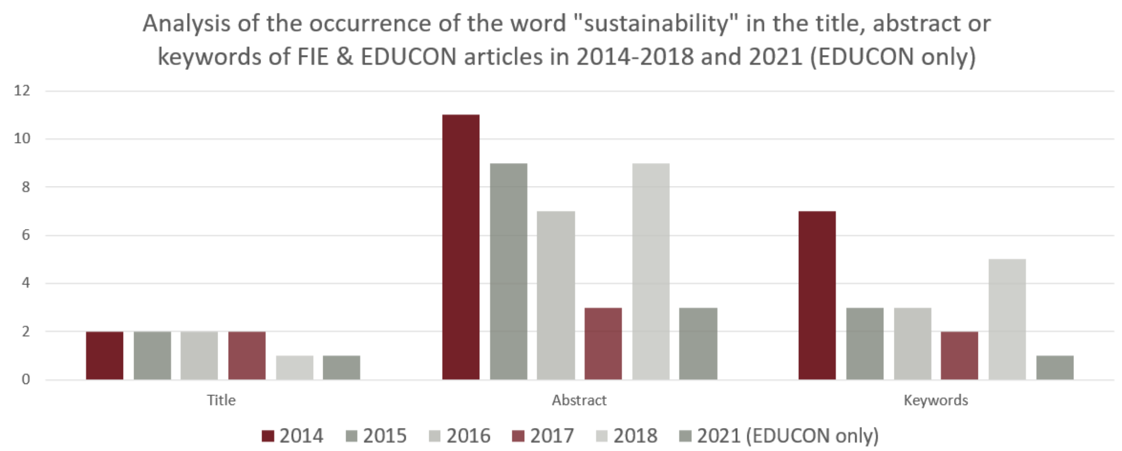

Fig. 2. *Analysis of the occurrence of the word "sustainability" in the title, abstract or keywords on FIE & EDUCON conference articles in 2014-18 and 2021 (EDUCON only), own data.*

The latter analysis confirms the results of the categorisation, as the frequency of the keywords is in similar dimensions to the allocation of the articles. Basically, however, it becomes apparent that very little relevance is attributed to the topic of sustainability in engineering education research and practice, which urgently needs to be changed. An approach for integrating sustainability aspects in engineering education is therefore presented in the following chapter.

4 INNOVATIVE TEACHING CONCEPT FOR SUSTAINABLE ENGINEERING EDUCATION PRACTICE

The interdisciplinary study model of Leuphana University provides a successful framework for the curricular connection between technology and sustainability. The individual study program is created from Leuphana first semester (30 CP), major (90 CP), minor (30 CP) and complementary studies (30 CP). Students even have the opportunity to customize their study focus and to freely combine their major and minor subjects. For the realisation of a sustainable engineering education, there are two possible combinations with different weighting of the technology and sustainability components, see **Fig. 3**.

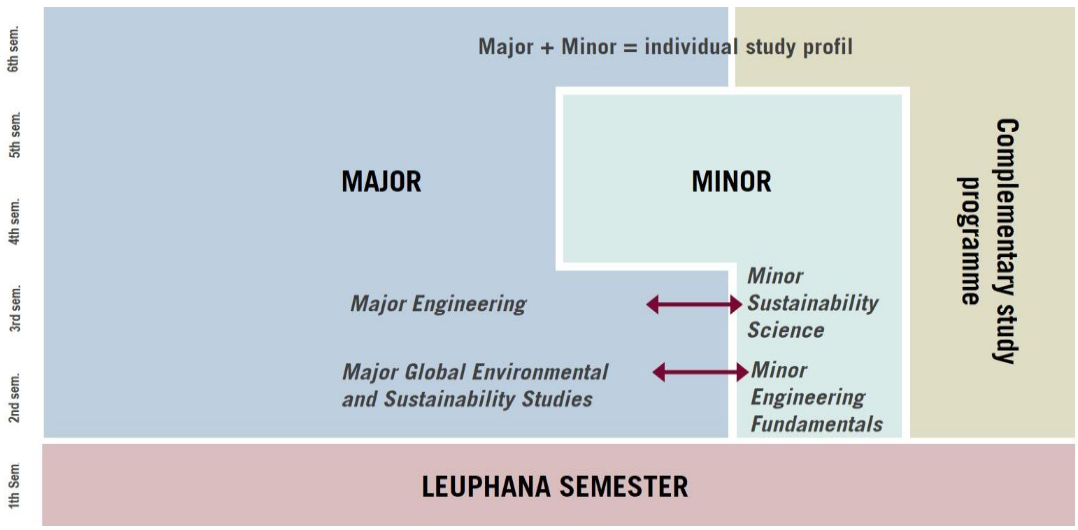

Fig. 3. *Leuphana Bachelor - Possibility of individualised profiling at the interface of technology and sustainability*

The M**ajor Engineering** provides a sound engineering and scientific knowledge as well as a deeper understanding of the controlling, optimising and controlling processes in digitised production and prepares students for the complex challenges of industry 4.0. Students of the **Major Global environmental and sustainability studies** acquire skills which will enable them to actively contribute sustainable development on a global level with an international perspective. The **Minor Sustainability Science** focuses on issues pertaining to the future of sustainable development. Students pursuing this minor will analyse the consequences of global change and develop sustainable solutions to real social problems that arise from unsustainable practices. The **Minor Engineering Fundamentals** provides an overview of the most im portant technologies and technology-oriented processes in the manufacturing industry. To illustrate the close interlinking of engineering and sustainability, the content of the course “Electrical and Automation Engineering” is presented as an example, see **Table 3**. The course is one of six courses of the Minor Engineering Fundamentals (among others Mechanical Engineering, Manufacturing and Information and Communication Technologies).

Table 3. Topics of the course “Electrical and Automation Engineering” with focus on sustainability, own data.

Course Topics and technical contents	Integration of technological innovations and industrial trends in the context of sustainability
Electrical engineering basics (DC and AC technology)	Renewable energies, solar cells
Measurement and sensor technology	Smart Sensors, VR/AR and vision application for sustainability-oriented issues and responsible use of the resources
Control and actuator technology	E-Mobility

The course takes up on innovative trends, on the interaction of technical components in complex and interlinked systems as well as on a strong focus on transfer between theory and practice. Students get basic knowledge of selected systems, models, and parameters in the range of automation technology (**Table 3**) in the context of digitalization and sustainability. Students and lecturers willingness and motivation to “bring to life” the interdisciplinary discourse, and their readiness to deal with interdisciplinary problems as well as new scientific fields independently, leads to an profound preparation of students for their future career in interdisciplinary and diverse teams in the interface between sustainability and technology.

5 SUMMARY

The paper proves in a research-based manner that the topic of sustainability has so far been underrepresented in the engineering sciences, which is why evidence-based interdisciplinary implementation procedures such as those presented in **Sec. 4** are highly relevant. At SEFI 2022 conference the authors will discuss the experience of the curriculum implementation and future perspectives within the discipline of engineering education and research.

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AN INTRODUCTION TO SLIDING MODE CONTROL FOR INTERDISCIPLINARY EDUCATION

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Keywords: *Interdisciplinary engineering education, practice-based learning concepts, theory-based engineering course, design for non-engineering students*

ABSTRACT

This paper proposes a new lecture structure for an introduction to Sliding Mode Control (SMC) for a wider audience of undergraduate students. In particular, the intuitive derivation of the sliding variable and choice of the sliding surface is emphasized in order to obtain an intuitive understanding in a gradual manner. The structure of the lecture is conceived in an inclusive way, considering only the common mathematical high school background and basic knowledge about simple differential equations and their solutions. In this sense, SMC can represent a possible application of the already acquired knowledge and in the meantime provide contact with one of the most important control techniques in theory and application. The paper intends to give a possible structure of an interdisciplinary lecture in SMC for teachers and students (in particular, non-technical students). By presenting the research-based approach and the results of the implementation, the paper contributes to the discourse on interdisciplinary education in engineering.

1 INTRODUCTION

Global transformation processes lead to challenges and changed framework conditions that the engineering and education sciences have to face. In view of digitalization and increased demands for the efficient use of resources, the challenges for control engineering solutions are constantly growing. These new issues are characterized by a high degree of complexity and responsibility as well as the need for broad knowledge at the interfaces of the disciplines. Graduates must be prepared to develop adequate solutions in diverse teams in order to contribute to change processes towards a smart and sustainable future [1–3]. On the one hand, this requires interdisciplinary approaches and an increasing awareness of the automatic control importance in our society. On the other hand, there is a massive shortage of qualified specialists in the technical field. Against this background, engineering sciences have to face the challenge of offering suitable engineering programmes for a broader target group (e.g. non-technical students) and an interdisciplinary education. The aim is to prepare the students for creative and responsible action in today's society in which the concept of complementarity, which means interdisciplinarity and transdisciplinarity, is essential for most leading positions in our complex society. This ambitious program calls for new lectures: inclusive, interdisciplinary and more based on the common background of the students. This paper contributes to this research discourse by presenting an innovative theory-based lecture

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structure for introducing the concept of Sliding Mode Control (SMC) to undergraduate students in non-technical fields and the related empirical findings on implementation.

1.1 Research-based didactic framework

Our objectives are standing for both theoretical understanding and educational practice. Therefore, we have chosen Design Based Research (DBR) as multi-faceted approach that provides valuable results for both, [4]. With a focus on engineering education for a sustainable and smart future, our contribution specifically addresses the theory-based approach for students who do not come from an engineering background. The very heterogeneous group of students requires an innovative teaching and learning concept to integrate different disciplinary cultures and to specifically support these *non-traditional* students in acquiring competences, as in [5]. The student-centered course design is based on Educational Reconstruction [6] as the research framework. In [7], this framework is further developed with a focus on engineering education. In order to take students seriously as an active starting point for the construction of knowledge, the Educational Reconstruction model can be of great help, see [6], especially for the special target group of non-technical students. In the Educational Reconstruction model, scientific concepts and the learners' perspective are related to each other, and from the comparison a conclusion is drawn for the design of student-centred learning environments. From this it can be concluded that teaching content must not simply be dictated scientifically, but must be created pedagogically meaningful through the conception of the learners themselves, as in [8]. With this framework, implementation results for heterogeneous student groups are available [9, 10], which have been incorporated into the new concept of the control lecture.

1.2 Institutional implementation and math. requirements

The newly developed lecture addresses the challenges for teaching in the engineering sciences described at the beginning. The lecture is offered at the Leuphana University Lüneburg in Lüneburg, Germany, which provides a conducive setting. Bachelor studies at Leuphana not only lays a solid foundation for the future professional career, but also aims at providing access to a university that values interdisciplinarity and emphasizes wide-ranging practical and theoretical competence. At Leuphana College, the individual study programme is created from major, minor and complementary studies, see Fig. 1. It forms a gateway to the academic world by exposing students to a wide range of scientific methods and offering a holistic education through individual choice of a major, minor, and complementary study electives. The College programme encourages students of all disciplines to look for solutions beyond the boundaries of academic discourse and to build a personalized and inclusive path of study. Therefore, such liberal education demands and encourages the intellectual and personal development of each and every specific student profile, in which new ideas to teach and to connect naturally or technically with human sciences represent a prerequisite. In addition, studies with a view to gender aspects underline the positive effects of an interdisciplinary design of study programmes on the selection of women [11,12]. Offering a control engineering lecture for an interdisciplinary target group can also contribute to securing and increasing young talent in the field. The presented lecture can be used in different contexts: in Bachelor courses for engineers as well as for courses dedicated to non-engineers (non-engineering minor programs, complementary study). In this way, the paper provides important insights into how to teach the first and only control course in non-control engineering programs. The lecture requires mathematical high school knowledge. Nevertheless, it is important that these courses start recalling basic knowledge of differential equations and, before starting with this lecture dedicated to SMC, the courses should introduce elements of nonlinear differential equations considering the fundamental direct method of Lyapunov related to the stability of a solution of a differential equation. Figure 1 shows the structure of the proposed course in which this lecture in included. In fact, as is visible there, the lecture closes by recalling Lyapunov's direct method in the context of sliding mode control. The goal of this contribution is to present a possible structure of a lecture concerning SMC which is held in the programs of study described above, and which realizes the possibility of an inclusive lecture in which just basic high school knowledge, such as computation of derivatives

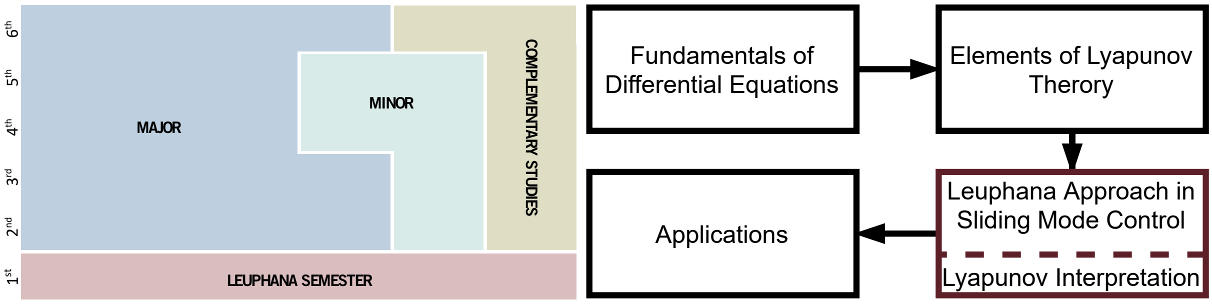

Fig. 1. Leuphana College model, see `https://www.leuphana.de/en/college` (left) and structure of the proposed course (right)

and integrals is necessary. The intuitive nature of the lecture and in the meantime the formal and rigorous explanation of some fundamental concepts of control realize an important contribution in the context of a new didactic treadoff between natural and human sciences. The course focuses on a broad-based education and at the same time developing individual essential skills, such as analytical and reactive thinking, clear and convincing argumentation, well-founded and perspective assessment. This takes place through intensive interactions with teachers and fellow students as well as in self-study, both during university events and extra-curricular activities. The protagonists of these lectures are the students. Therefore, this paper is written in collaborations with some of the students who attended these lectures and this emphasizes the inclusive nature of the course.

The paper is organized in the following way. Section 2 introduces the concept of Sliding Mode Control (SMC) in an intuitive way. Section 3 introduces the concept of an integral sliding surface for first-order systems. In Section 4, related empirical findings on implementation and future perspectives are presented for the engineering research and education community. Conclusions close the paper.

2 SLIDING MODE CONTROL

SMC is a robust control method which can handle both linear and nonlinear systems with uncertainties and unmeasurable disturbances.

2.1 Preliminary and Fundamental Aspects

Considering a plant with one state variable x and control input u, the goal is to steer the state to zero:

$$\frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} = u(t) \tag{1}$$

with $x(0) = \pm x_0$, where $x_0 > 0$ is the absolute value of the initial condition.

2.2 Obvious strategy

The intuitive solution is to select

$$x(t) > 0 \rightarrow \frac{\mathrm{d}\,x}{\mathrm{d}\,t} \overset{!}{<} 0, \qquad x(t) < 0 \rightarrow \frac{\mathrm{d}\,x}{\mathrm{d}\,t} \overset{!}{>} 0. \tag{2}$$

From this consideration, a control law $u(t)$ should arise.

2.3 First strategy

A surmisable first approach is to use a linear state-feedback control $u(t) = -kx(t)$ in which $k > 0$. Using this controller,

$$\lim_{t \to +\infty} x(t) = 0. \tag{3}$$

In fact, the simple closed-loop system

$$\frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} = -kx(t) \tag{4}$$

yields the well-known solution

$$x(t) = \pm x_0 \exp(-kt). \tag{5}$$

2.4 Second strategy

Since eq. (5) converges to zero only in infinite time, another strategy is to set $u(t) = -k\,\mathrm{sgn}(x(t))$, which renders the closed-loop system nonlinear

$$\frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} = u(t) = -k\,\mathrm{sgn}(x(t)). \tag{6}$$

The solution depends on the sign of the state,

$$x(t) = x_0 - kt \text{ for } x(t) > 0 \tag{7}$$

$$x(t) = x_0 - kt > 0 \to t < \frac{x_0}{k},$$

$$x(t) = -x_0 + kt \text{ for } x(t) < 0 \tag{8}$$

$$x(t) = -x_0 + kt < 0 \to t < \frac{x_0}{k}.$$

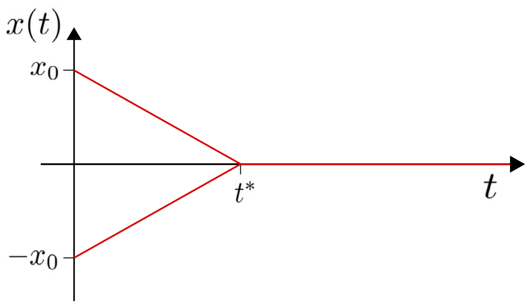

Fig. 2. Finite time dynamics

Considering $t > 0$, the solutions are valid as long as $0 < t \leq \frac{x_0}{k}$. Figure 2 shows the obtained finite time dynamics using the *static-friction-like* nonlinear component $\mathrm{sgn}(x(t))$. We obtain $x(t) = 0$ for $t = \frac{x_0}{k}$. For $t = \frac{x_0}{k} \to \mathrm{sgn}(0) = 0 \to \frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} = 0$. This means that we do not have variations, and thus we remain at zero $(x(t) = 0)$ – at least in a mathematical sense. This generates the following solution for $x(t) > 0$:

$$x(t) = \begin{cases} x_0 - kt & \text{if } t \leq \dfrac{x_0}{k} \\ 0 & \text{if } t > \dfrac{x_0}{k}. \end{cases} \tag{9}$$

For $x(t) < 0$, the solution is

$$x(t) = \begin{cases} -x_0 + kt & \text{if } t \leq \dfrac{x_0}{k} \\ 0 & \text{if } t > \dfrac{x_0}{k}. \end{cases} \tag{10}$$

Often, the discontinuous function sgn is approximated as $\mathrm{sgn}(x(t)) \approx \mathrm{sat}\left(\frac{x(t)}{\phi}\right)$, see Fig. 3, where $\phi > 0$ is the *thickness* of a boundary layer in which we may remain without switching:

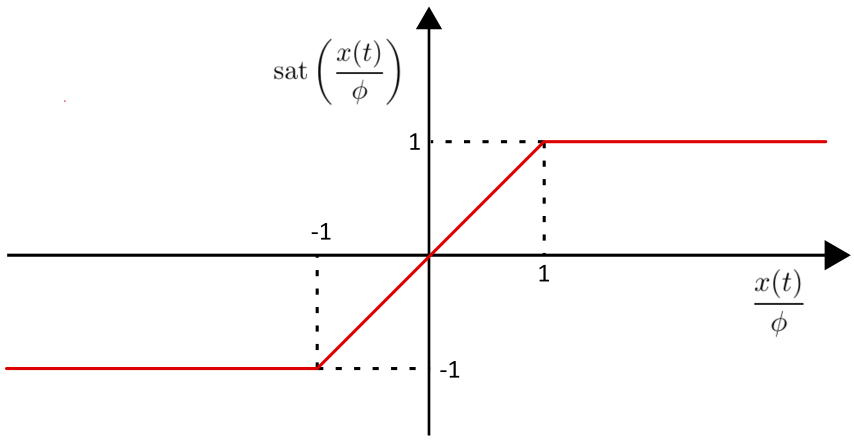

Fig. 3. Saturation function

$$\text{sat}\left(\frac{x(t)}{\phi}\right) = \begin{cases} \frac{x(t)}{\phi} & \text{if } \left|\frac{x(t)}{\phi}\right| \leq 1 \\ \text{sgn}\left(\frac{x(t)}{\phi}\right) & \text{otherwise.} \end{cases} \tag{11}$$

Considering an uncertainty Δ in the system model,

$$\frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} = u(t) + \Delta(x(t), t) \text{ with } |\Delta(x(t), t)| \leq \Delta_{\text{max}}. \tag{12}$$

If we apply the first strategy to this uncertain system,

$$\frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} = -kx(t) + \Delta(x(t), t). \tag{13}$$

In this case, we do not have the possibility to steer the state to zero. If we apply the second strategy, however,

$$\frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} = -k\,\text{sgn}(x(t)) + \Delta(x(t), t). \tag{14}$$

We simply need to choose $k > \Delta_{\text{max}}$ i.e. $k = \Delta_{\text{max}} + \eta$ with a positive η. If this expression is placed in (12):

$$\begin{cases} x(t) > 0 : \frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} = -\eta - \Delta_{\text{max}} + \Delta(x(t), t) \\ x(t) < 0 : \frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} = \eta + \Delta_{\text{max}} + \Delta(x(t), t), \end{cases} \tag{15}$$

which is now manipulated as

$$\begin{cases} x(t) > 0 : \frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} + \Delta_{\text{max}} - \Delta(x(t), t) = -\eta \\ x(t) < 0 : \frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} - \Delta_{\text{max}} - \Delta(x(t), t) = \eta. \end{cases} \tag{16}$$

If we consider that

$$\Delta_{\text{max}} - \Delta(x(t), t) \geq 0, \tag{17}$$

$$-\Delta_{\text{max}} - \Delta(x(t), t) \leq 0, \tag{18}$$

the following inequalities can be derived

$$\begin{cases} x(t) > 0 : \frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} \leq -\eta, \\ x(t) < 0 : \frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} \geq \eta. \end{cases} \tag{19}$$

Thus, η represents the minimal convergence rate. We can write this expression in a more compact form by multiplying both sides with $\text{sgn}(x)$:

$$\begin{cases} x(t) > 0 : \text{sgn}(x)\frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} \leq -\eta\,\text{sgn}(x) \\ x(t) < 0 : \text{sgn}(x)\frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} \geq \eta\,\text{sgn}(x) \end{cases} \Rightarrow \begin{cases} x(t) > 0 : \frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} \leq -\eta\,\text{sgn}(x) \\ x(t) < 0 : \frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} \leq -\eta\,\text{sgn}(x). \end{cases} \tag{20}$$

So, in general the closed-loop system results as

$$\frac{\mathrm{d}\,x(t)}{\mathrm{d}\,t} \leq -\eta\,\text{sgn}(x(t)), \tag{21}$$

where η represents the reachability condition.

2.5 SMC for higher-order systems

Now a system with two states is considered:

$$\frac{\mathrm{d}\, x_1(t)}{\mathrm{d}\, t} = x_2(t), \quad \frac{\mathrm{d}\, x_2(t)}{\mathrm{d}\, t} = u(t), \quad x_0 = \begin{bmatrix} x_{1,0} \\ x_{2,0} \end{bmatrix} = \begin{bmatrix} x_1(0) \\ x_2(0) \end{bmatrix}. \tag{22}$$

The goal is the same as before: steer the state to zero. Assuming that we can apply a state-feedback controller to achieve $x_2(t) = -c_1 x_1(t)$ with $c_1 > 0$, the dynamics result as

$$\frac{\mathrm{d}\, x_1(t)}{\mathrm{d}\, t} = -c_1 x_1(t). \tag{23}$$

If this is possible, $x_1(t) = x_{1,0} \exp(-c_1 t)$. This yields

$$\lim_{t \to +\infty} x_1(t) = 0, \quad \lim_{t \to +\infty} x_2(t) = 0. \tag{24}$$

However, it is problematic to assume the relationship $x_2(t) = -c_1 x_1(t)$. We are not able to set this condition through linear state-feedback control. In fact, if we consider a mechanical system, this means that the velocity must be proportional to the position. To remedy this, we introduce an abstract **sliding variable** $s(t)$ defined in the following way:

$$s(t) = x_2(t) + c_1 x_1(t) \quad \text{with } c_1 > 0. \tag{25}$$

Now, if we reach $s(t) = 0$, we have

$$0 = x_2(t) + c_1 x_1(t) \tag{26}$$

and thus $x_2(t) = -c_1 x_1(t)$, which is exactly what we wanted to obtain. Now the goal is to steer the system to $s(t) = 0$. Recalling system (22), if we differentiate s(t), we obtain

$$\frac{\mathrm{d}\, s(x_1(t), x_2(t))}{\mathrm{d}\, t} = \frac{\mathrm{d}\, x_2(t)}{\mathrm{d}\, t} + c_1 \frac{\mathrm{d}\, x_1(t)}{\mathrm{d}\, t} = u(t) + c_1 x_2(t). \tag{27}$$

Since we want to obtain

$$\frac{\mathrm{d}\, s(x_1(t), x_2(t))}{\mathrm{d}\, t} = -k \operatorname{sgn}(s(t)), \tag{28}$$

similar to (21), it is easy to see from (27) that we require

$$u(t) + c_1 x_2(t) \stackrel{!}{=} -k \operatorname{sgn}(s(t)) \tag{29}$$

which means that the controller *to stabilize* $s(t)$ is

$$u(x_1(t), x_2(t)) = -c_1 x_2(t) - k \operatorname{sgn}(s(t)) \tag{30}$$

The graphical interpretation of the dynamics is represented in Fig. 4. If we consider a saturation function with boundary layer instead of function sgn, we obtain the behaviour described in Fig. 5.

2.6 Recalling Lyapunov point of view

The proposed solution is now considered in a Lyapunov sense. The obtained sliding surface dynamics (28) can be multiplied by $s(t)$, yielding

$$s(t) \frac{\mathrm{d}\, s(x_1(t), x_2(t))}{\mathrm{d}\, t} = -k s(t) \operatorname{sgn}(s(t)) \tag{31}$$

and thus

$$\frac{1}{2} \frac{\mathrm{d}\, s^2(x_1(t), x_2(t))}{\mathrm{d}\, t} = -k|s(t)|. \tag{32}$$

Equation (32) is the Lyapunov stability condition, which the students are taught earlier in the course (see Fig. 1), and can be obtained starting from

$$V(s(t)) = \frac{1}{2} s^2(t) \tag{33}$$

and thus [13]

$$\frac{\mathrm{d}\, V(s(t))}{\mathrm{d}\, t} = s(t) \frac{\mathrm{d}\, s(t)}{\mathrm{d}\, t} = s(t)[-k \operatorname{sgn}(s(t))] = -k|s(t)| < 0. \tag{34}$$

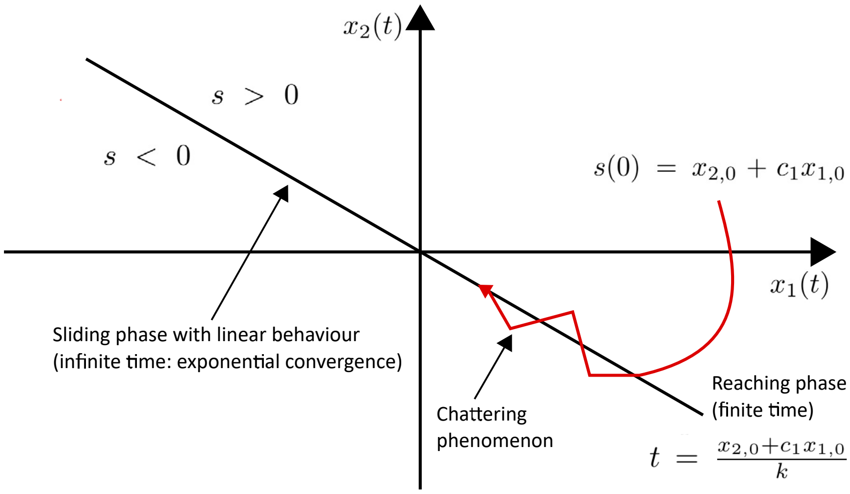

Fig. 4. Sliding phase

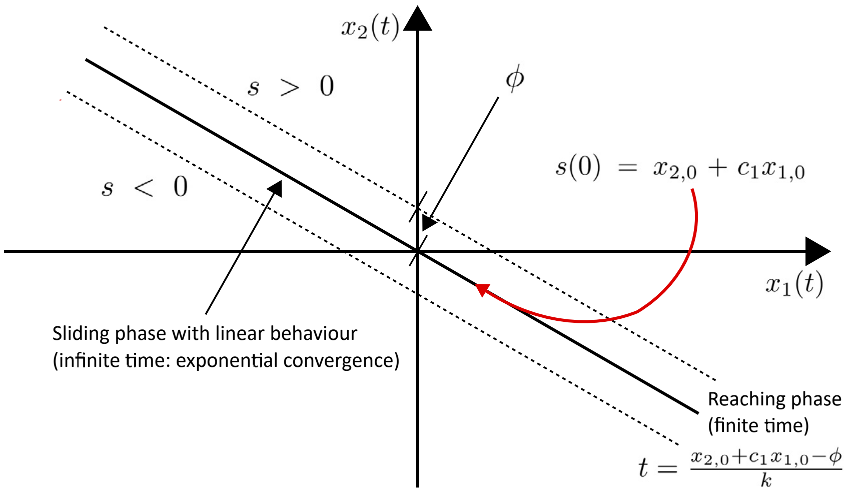

Fig. 5. Graphical representation of the dynamics in the presence of a boundary layer

3 INTEGRAL SLIDING SURFACES

Let us consider the following sliding surface structure as proposed in [13] and a system with just one state x (i.e. $n = 1$). The conventional sliding surface, based on an error $e(t) = x(t) - x_d(t)$, can be chosen as

$$s(t) = \left(\frac{\mathrm{d}}{\mathrm{d}\,t} + \lambda\right)^{n-1} e(t), \tag{35}$$

in which $n \in \mathbb{N}$ represents the number of states of the system. The exponent of this expression represents the derivative order as well as the *polynomial exponent*. If $n = 1$, then $s(t) = e(t)$. This is the simplest possible surface which is exactly the state error. This surface allows to reach error $e(t) = 0$ at a finite time ($s(t^*) = 0 \to e(t^*) = 0$). Let us now consider the following sliding surface, with the assumption of a non-impulsive control error $e(t)$

$$s(t) = e(t) + \lambda \int_0^t e(\tau) d\tau - e(0), \tag{36}$$

with $\lambda > 0$. Assuming that the trajectory reaches condition $s(t) = 0$ at $t = t^*$, then for $t > t^*$

$$0 = e(t) + \lambda \int_0^t e(\tau) d\tau - e(0), \tag{37}$$

and thus

$$e(t) = e(0) - \lambda \int_0^t e(\tau) d\tau. \tag{38}$$

Equation (38) is a linear one and admits just one unique solution, which is

$$e(t) = e(0)\exp(-\lambda t). \tag{39}$$

The trajectory remains on the surface, but the convergence is obtained in infinite time. This implies that, if the initial condition of the system state error is known and $e(0) = 0$, then $s(0) = 0$. In this case, the duration of the reaching phase is reduced to zero, but we introduce an infinite sliding time with respect to the sliding surface $s(t) = e(t)$.

Let us compare this result with those obtained using a slightly different surface:

$$s(t) = e(t) + \lambda \int_0^t e(\tau)d\tau. \tag{40}$$

Considering that (40) is obtained if $e(0) = 0$, the unique solution results as (39) with $e(t) = 0$. Using surface (40) instead of surface (36), the reaching phase cannot be reduced to zero because $s(0) = e(0)$, but once the surface is reached at t^* ($s(t^*) = 0$), then $e(t) = 0$.

Remark 1 *Another interesting consideration is that both surfaces (40) and (36) guarantee the invariant condition $\dot{s}(t) = 0$ (to remain at $s(t) = 0\ \forall t$) for each initial condition. In fact, both cases*

$$\dot{s}(t) = \dot{e}(t) + \lambda e(t) = 0 \tag{41}$$

admit the solution

$$e(t) = e(0)\exp(-\lambda t). \tag{42}$$

From a mathematical point of view, when $s(t) = 0$, then $\mathrm{sgn}(s(t)) = 0$ and considering (42), $s(t) = 0$ and $\dot{s}(t) = 0$, $\forall$ initial conditions $e(0)$.

4 FEEDBACK FROM STUDENTS AND FROM THE SCIENTIFIC COMMUNITY

Introducing the basic concept of sliding mode control, we received positive feedback from our scientific community which accepted our communications in different conferences and journals, see [14–18]. In an interview of a student from Arkansas University [19], who has published a paper in [14], it emerges that the students appreciated the intuitive idea to introduce this effective and robust (and in this sense, practical) method, despite the difficulty of the courses. Moreover, our community appreciated the contributions of our students which in some cases received best paper awards in the student papers competition [15]. In one case, a paper was selected as one of the best papers of the conference [16] and, in another one, a paper was selected for an extension within a reputable journal, see [17].

5 CONCLUSION

This paper deals with a new structure of an introductional lecture in the context of Sliding Mode Control for undergraduate students. SMC is one of the most used control techniques in industrial applications. This is due to its robustness and its straightforward structure to be implemented, at least in its basic form. Therefore it is worthwhile to introduce this techniques directly in the Bachelor's-level lectures together with the classical basic knowledge of control systems, such as control in Laplace domain and linear state space methods. In fact, concepts like differential calculus and integrals are already known when the students start lectures in control system.

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A Feasibility Study for inclusion of Ethics and Social issues in Engineering and Design Coursework in Australia

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ABSTRACT

This paper reports on a feasibility study on including ethics and social issues in the current curriculum of a school of engineering and information technology in an Australian university. The study has three goals: first, to understand the current status of inclusion of ethics and social issues in engineering courses. Second, to understand the willingness of staff within the school to include ethics and societal issues in their courses. Third, to understand the opportunities and challenges for inclusion of ethical and societal issues in the coursework. Our methods include interviews with school staff and subject matter experts as well as analyses of textual artifacts such as course outlines, course readings, student assignments, and accreditation reports. The analysis of textual artifacts runs partially via an automated text analyzer that search for words that have ethical connotation, such as safety, responsibility, privacy, harm, etcetera in the dataset of course materials. A manual (human) analysis of the coursework was done for those courses that give insufficient results in the automated text analyzer. We looked for opportunities to include ethics and societal issues in coursework. The conclusion is that there is general consensus amongst staff that ethics and societal issues deserve more attention in the school. At the same time, there is concern that including ethics and societal issues takes away valuable teaching time for technical material. There is preference for an integrated way of ethics teaching, rather than one seperate engineering ethics course.

1 INTRODUCTION

What constitutes a good engineer? What are the standards of excellence for a technical designer? Our research responds to the increasing demand from society for engineers that are socially and ethically responsible, especially in the face of current technological developments such as autonomous vehicles and AI [1]. The way engineers and designers are trained, not merely in their technical skills but also in their understanding of societal impact and ethical aspects of the things they design, may tacitly or explicitly influence design choices. Design choices that lead to concrete products or services may impact our societies for better or worse. Famous examples include Moses' low hanging bridges in New York that prevented the poor, travelling by bus, to visit the Long Island beaches, exacerbating socioeconomic inequality [2]. The recent collapse of the apartment building in Miami, Florida [1], is another example of the importance of nurturing and fostering ethically and socially responsible engineers. To better understand the role of ethics in engineering and design education, we conducted a feasibility study to probe the UNSW Canberra SEIT (School of Engineering and Information Technology) curriculum on where engineering and design students have space to critically reflect on and creatively play with societal and ethical aspects of their coursework. An explorative feasibility study in the context of curriculum improvement in higher education is a proven way to understand the potential for embedding a new element into a curriculum [3]. Numerous studies exist in the field of engineering ethics education, each stressing a different aspect of the challenge, such as cultural contexts [4], pointing to a decision focused method [5], addressing ethical and social aspects in AI education [6] or advocating a broader understanding of the task of the engineer [7]. For example, Taebi and Kastenberg [8] report on their experience on setting up engineering ethics education in UC Berkeley. They identified institutional and academic hurdles during their implementation phase. Our aim was to explore these and other hurdles and opportunities to systematically map the current approach in SEIT regarding social and ethical reflection in engineering and design courses. We were interested in understanding the opportunities for students to think through the effects of design choices on ethical issues in the short and long run (e.g. acquiring and recycling of used materials), on safety in use, on opportunities for transparency and honesty in functionalities, and social issues, such as: how do design choices constrain or enable patterns of social behavior, and how accessible and affordable does a technology become for certain groups in society? We agree with Grunwald (2000) [9] that the role of ethics in technology development is not equally important in all subjects of engineering and technology education, so one may question the degree and kind of ethical and social reflection that is required in certain areas of technology development or engineering subfields. Mapping the current situation in SEIT helps us better understand where there is space for ethical reflection and where not. Taebi and Kastenberg [8] furthermore note that faculty members from engineering departments are often the ones who can best relate to and identify the ethical aspects of their own specific field of engineering, hence our justification for interviewing staff in SEIT. Since the Australian context is rather specific [10][11][12], and as engineering education in Australia is accredited by professional bodies (Engineers Australia (EA)), we included Engineers Australia as participants in our interview round. This research is essential, as it fills a gap in knowledge around to what degree ethics can and should inform the engineering curriculum in UNSW Canberra's SEIT.

2 METHODOLOGY

This project used a qualitative research methodology, deploying the following data collection method/s:

1. Semi-structured interviews with SEIT staff and subject matter experts

2. Scoping, coding, analysing of existing textual artifacts (course materials such as syllabus, EA accreditation report, blank assignments, Moodle sites).

This two-fold methodology (data gathering through document analysis and interviews) satisfied our aim to understand the current situation of ethical and social reflection in engineering and design courses in SEIT and helped us understand the opportunities or hindrances to enhance this.

SEIT staff were selected for interviews through the UNSW Canberra Handbook for students, which lists teaching staff per course. Courses that were more inclined towards ethical aspects such as security, data handling and automation were chosen along with theoretically intensive courses such as engineering mechanics or radar technology. This was done keeping in mind the research aim: to capture insight from key insiders on where ethics can and cannot be implemented within the course structure. Subject matter experts on engineering ethics were selected from the professional networks of the researchers. All interviews were conducted online.

For the coursework materials analysis, we developed a simple regex based matching algorithm in Python, against ethics related keywords (e.g. honesty, trust, responsibility, danger, harm) and then manually checked those sentences, to find spaces where ethics is already incorporated or if there is room for the same. Regex stands for Regular Expressions, which are a sequence of characters that specify search patterns in a text. They have been developed in theoretical computer science for use in keyword find or find-and-replace algorithms.

3 RESULTS

In the following subsections, we present the results from interviews with SEIT Staff and subject matter experts as well as the coursework analysis. We interviewed a total of six SEIT staff members and three subject matter experts (SMEs). We coded the data collected in the interviews, and then clustered the codes into broader categories they fell into. From the clusters, seven themes came up. These themes are discussed in the following subsections. Our general observation was that five out of six staff members were in favour of incorporating ethics in the curriculum, while one staff member was not in favor, as they thought there was not enough space and necessity to incorporate ethics in the curriculum. We will now systematically address our interview findings based on the clusters that were made. The second part of the results section reports the automated and manual coursework analysis.

3.1 Interviews:

What is ethics according to SEIT Staff

Interviewed staff mentioned a range of aspects to be “ethics”, from values such as honesty, personal morals, to the professional aspects of taking responsibility, decision making and dealing with complexity. A relationship between ethics and systems engineering came up especially when staff related ethics to the professional aspects of taking responsibility and ensuring verifiability. For example, a staff member with a systems engineering background said, “engineering is often about design and when you design, the choices you make are related to stakeholder requirements, and those stakeholder requirements are strongly related to ethical aspects.”

The importance of ethics in engineering

SEIT staff mostly pointed out that ethics is important for engineers. They mentioned the impact of technology and the role engineers play in every aspect of the current society, hence the importance of teaching political, financial and intent related aspects in engineering. The staff also related the importance of ethics in engineering to safety, privacy and preserving lives. Furthermore, that technology can be used for both good and bad was often mentioned. All SMEs seemed to agree that a greater awareness of ethics in engineering is required. This was mostly attributed to the growing responsibility attributed to engineers who are today working in so many interdisciplinary sectors.

Possibilities to incorporate ethics in SEIT course content

When asked whether the staff think they can incorporate ethics in the curriculum, we were met with mostly positive responses either in terms of an intention to incorporate more of ethics in the curriculum, or ethics already being incorporated in the curriculum. Staff 3 for example, said that "[Ethics] is a very important aspect of the Master space postgraduate program. We have some world leading space ethicists, a very multidisciplinary team…Ethics is at the very core of what we are trying to build." Other staff members mentioned ethics is being implemented via role-modelling and inviting top-level executives and through teaching how to comply with professional codes in applied settings.

Barriers to incorporation of ethics in SEIT course content

Staff thought it less feasible to incorporate ethics into coursework in theoretically or mathematically intensive courses. Staff 3, for example, mentioned that "For me it's easy, but for someone who teaches fluid mechanics, would maybe not be as positive." Lack of expertise to teach ethics is also a common concern among staff. However, most staff were willing to put in the effort to improve upon their expertise in teaching ethics. Another concern is the lack of time, which results in staff being concerned about having to compromise the technical content of the course to be able to include ethics, such as Staff 6 said, "If specifically asked, we will have to take something out from the course, which means technical skills get taken out. Are we developing engineers with good technical skills or good soft skills?" As this quote indicates, some staff consider ethics a soft skill. Some think that it can be obtained later during the job, or they think of ethics in terms of personal or private values and that teaching ethics is pointless. Furthermore, some think that students might not be interested in ethics teachings. Other staff who have already successfully implemented or are trying to implement ethics in curriculum did not bring up this lack of interest from students. According to the SMEs, one of the barriers in incorporating ethics in an engineering curriculum, is the challenge in explaining ethics to engineering students who lack foundational knowledge. Some SMEs pointed out the importance of philosophical knowledge of ethics while others stressed the need for its application to engineering.

Incentives for incorporation of ethics in SEIT curriculum

Internal motivation and value based incentives, in terms of awareness amongst engineers about honesty and their general responsibility towards society was evident in most of our staff interviews. Another equally important incentive that came up in our interviews was accreditation. Both Engineers Australia and Australian Computer Society are responsible for accrediting engineering institutions in Australia. The staff raised concerns about the recent accreditation visits by EA and the resulting discussions at all organizational levels to incorporate ethics in the curriculum. SME 3 pointed towards an upcoming increased relevance of ethics in EA and International

Engineering Alliance (IEA) competency standards. They said, "International Engineering Alliance has updated their professional competency terms with an increased relevance of ethics. EA is aligned with IEA competency and therefore accreditation requirements will increase."

How to incorporate ethics and social issues in SEIT curriculum

Staff raised concerns about a lack of direction on how to implement ethics in the curriculum. Staff 4 mentioned that "we want to do it, but don't know how to do it" and, likewise, Staff 5 said, "There is definitely space for [incorporating ethics] but the challenge is how to fit it in naturally." Most SEIT staff interviewed think that a coherent integration would be the best way to incorporate ethics in the curriculum. Another relevant method that staff positively mentioned in interviews was a case-study based teaching of ethics, which is expected to be interesting for students. Staff 1 for example, said, "The thing is that it is a bit easy for me because I teach cyber, which is a hot topic, so new set of use cases all the time, and most of them have some or the other ethical aspect in them." An ethics course may be perceived as a box to tick, as Staff 5 mentioned, "A separate class would feel like a box to tick. It somehow needs to be authentically integrated into the project and I don't know how." Ironically, a forced implementation of ethics is also not preferred, as Staff 6 said, "If specifically asked, we will have to take something out from the course… If at the end of the day you NEED to teach it to engineers, then engineers should be doing it."

Who should include ethics and social issues in SEIT courses?

In general, SEIT staff showed a preference towards ethics being closely integrated within the curriculum and that it should be internal SEIT staff teaching it. Some staff expressed concern about potential lack of respect from engineering students for teachers from non-engineering faculty. However, some staff also had concerns about their lack of expertise in ethics, as mentioned in section 4.4. To mitigate this, some staff suggested the involvement of a multidisciplinary team. Staff 5, for example, said, "I am from a very technical background where things are clear but with ethics there is not necessarily wrong or right answers, although this is where humanities comes in to weigh." SMEs mentioned that commitment from the school leadership and support from course coordinators is vital for the success of enhancing ethics in engineering education.

3.2 Coursework Analysis

Most courses returned meanigful results through the text analyzer algorithm, which looked for ethically charged words in the text. The last two courses listed below and indicated with "*" did not return sufficient results via the analyzer, because of the document formats, so they were manually analysed by the researchers.

Course on Big Data and Decision Analytics for Security - This course takes a case-study based approach to ethics education. It incorporates readings such as "Losing Humanity: The Case Against Killer Robots", and "Discriminating algorithms: 5 times AI showed Prejudice", which cover ethical aspects such as human rights, moral and social responsibility, value of life and risk assessment. However, it is important that these aspects are not only introduced through readings but also explicitly discussed from an ethical perspective rather than merely a security breach perspective.

Course on Software Security Lifecycle - This course refers to the complete software development lifecycle, and therefore refers to notions of responsibility and verifiability. These notions however are not exactly emphasised from an ethical perspective. In other words, failures are interpreted from a pragmatic or economic point of view, without elaborating on how a software development lifecycle can fail in an ethical sense through its effects on society. There is room for discussion about stakeholder involvement, which is important for determining societal issues in design, as well as the ethical importance of the end-of-lifecycle: what are the risks if the software becomes outdated? Points for ethical elaboration exist in the security development lifecycle, where attention for threats, privacy, responsibility could be broadened.

Course on Computers and Security - Ethics is discussed in the first lecture of the course in a very explicit manner, under the heading of “Ethics and Cyber Ethics.” It discusses the importance of ethics to computer security professionals. The course often mentions security, rights and legal procedures and discusses the ethics of professional organisations such as the International Information System Security Certification Consortium and that of the Computer Ethics Institute. However, the course does not go into the details of ethics further down in the syllabus. There is room to mention ethics when discussing various aspects and case studies related to cyber security.

*Principles of Electrical Engineering** - This technical course has very limited opening to discuss ethical issues, but there are opportunities to discuss environmental effects or safety aspects of electrical design choices. For example, controllers used in the automotive industry where it is important to get controls and timings right due to potential harms in breaking, steering or airbags. An environmentally relevant issue relates to power consumptions in circuits, which can be optimized via smart switching methods and smart use of transformers.

*Cyber Offence: Threats and Opportunities** - This short course mainly focusses on cybersecurity. Given its topic, it includes methods of creating safe software and preventing cyber-attacks. It therefore emphasises on ethical keywords such as legal, illegal, safety and security. The course however approaches these aspects from a purely technical perspective and there is indeed more room for mentioning ethical and societal aspects using case examples.

4 SUMMARY AND ACKNOWLEDGMENTS

A majority of the interviewed SEIT Staff was in favour of including ethics into the SEIT curriculum in a more systematic manner. But this conclusion should be considered in light of two considerable limitations of our study. First, that our sample size of six staff members is small and not representative of the entire teaching staff in the school (approximately 90 staff members). Second, this majority inclination towards incorporating ethics and social issues in engineering and design coursework does not quantitatively imply a major support for it in the school at large, since staff that are not interested in ethics and social issues in engineering courses, are less likely to participate in research that explores these issues. Low interest and participation, pertaining to the undervalued perception of interdisciplinary research and the lack of incentive and organisational support on behalf of the institution, was also encountered by Taebi et. al.,[8] in running the first edition of a graduate engineering ethics course at UC Berkley.

Skinner et. al.[12], argued that engineering ethics is a special case of professional ethics and this is in line with what the majority of SEIT staff reported, together with often mentioned honesty and personal morals. Furthermore, we could see traces of the microethical model (cf. Martin et al) in SEIT staffs' understanding of ethics in engineering. A microethical model is "characterised by a strong emphasis on the individual responsibility of engineers" [13]. This was evident, for example, from the importance of an increased attention towards existing EA code of ethics that was pointed out in the interviews, by SEIT staff.

For most SMEs, on the other hand, the understanding of ethics in engineering was directed towards macroethics model, which, according to Martin et.al [13], looks at the engineering profession as a whole and the profession's responsibility towards development and society. This distinction between macro-and micro-ethics is further reflected in our interviews, as SEIT staff were a lot more inclined towards interweaving ethics in the curriculum compared to SMEs who thought having a separate course could play a role in laying the foundation and explaining ethics in much more detail from a more philosophical standpoint.

The way SEIT staff think about ethics in relation to engineering and design covers most, but not all content areas of engineering ethics education identified by Martin et al.[13]. There is awareness of responsibility, sustainability, professional ethics, societal context, value sensitive design, business studies and military applications, while less or no mention was made of health and safety, legislation, academic and research integrity or ethical theories.

One of the most popular methods of teaching engineering ethics[13][14] which was often mentioned in our interviews, is to use case studies. Cases are one of the three general models of teaching engineering as identified by Herkert [15]. Case studies can be incorporated in all coursework without much effort. A general approach is to decide upon the ethical goals related to a particular subject and then carefully choose cases. This also ensures that the incorporation of ethics is interesting for students as it is related to their own areas of study, as had been pointed out by many staff and SMEs.

Furthermore, an interesting observation from some of our staff interviews was how they related ethics to a systems engineering approach and to the ideas of responsibility, professional conduct and verifiability. A promising approach to incorporating ethics within an engineering curriculum is the VASE approach [16][17], which adds a values theory step to the pre-existing steps in a design thinking approach. This added step of values theory is targeted towards naming and teaching specific values and approaches to ethics and then relating them to values in design. Studies such as one by Lee et. al. [18], have shown how systems engineering approach can be moulded towards a human-centered/value sensitive design approach. We suggest that the VASE approach[16][17], in combination with systems engineering and value sensitive design [18] could lead to a well-rounded incorporation of ethics into something that engineers and software developers are already studying. Further research would indeed be required to come up with the exact steps of this implementation.

Although we may tentatively conclude that SEIT staff favours that ethics implementation is done by the SEIT staff, research suggests that implementation of ethics benefits from multidisciplinary attention, and it is important to have the say of philosophers and social scientists when designing it within the curriculum. Furthermore, as Skinner et. al. [12] point out, the inclusion of a formal course on ethics is not well received by all the school's staff. There is also "suspicion among the faculty of such interdisciplinary material 'diluting' the technical education of engineers" (ibid). It is therefore important to develop an understanding that teaching ethics will not take away the core theoretical engineering background but rather enhance it, if it is done in a coherent manner. It could be the university administration's responsibility to help incorporate ethics in the curriculum in a way which ensures the engineering topics are covered while including ethical and social issues. It is important for all levels of the institution to be actively involved for a successful implementation of ethics in engineering curriculum. Finally, it is important to pay attention to the cultural, educational, academic and life-experience based diversity within the student body and its effects on how a course on ethics is received by the students [12]. Engineering students may not be naturally interested in ethics, and, Skinner's[12] findings are promising, as they conclude that "students were initially suspicious, but they move beyond it over the weeks and find it liberating for their imaginations."

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CORRELATION STUDY BETWEEN THE ACCESS MARK AND THE PERFORMANCE IN PROJECT-BASED AND STANDARD COURSES

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ABSTRACT

The access mark to engineering studies is often used as an a priori success estimator. In our institution, we have observed that the correlation of the access mark with the grades obtained in project-based courses (R=0.52) is slightly lower than the one obtained with the average of the other non-project-based courses (R=0.58), and is especially low in capstone projects (R=0.31). Project-based and Challenge-based courses are one of the most acknowledged ways of promoting the learning of transversal skills, specifically innovation and entrepreneurship skills. In our institution, ICT engineering bachelor students perform a project-courses path, with three subjects of growing complexity in the 2nd, 3d and 4th year. While the first two are partially guided and with challenges proposed by the faculty members, the 3d one is a 12 ECTS capstone project with challenges proposed by industry or external institutions. In this study, we have analyzed the performance of the students along 10 academic years (2011-2012 to 2020-2021). Not only the correlation with the access mark in these courses is lower but the prediction interval is also different. While it is almost impossible that a student with a low access mark gets an outstanding average mark in the bachelor and vice-versa, there are students with a low access mark which have an outstanding performance in the capstone project and students with a very high access mark and with high results in analytical courses but with a poor performance in capstone projects. Therefore, a different kind of skills are promoted in these courses.

1 INTRODUCTION

1.1 Project-Based courses

Nowadays it is widely acknowledged that what is expected from future engineering graduates is far more than technical skills or disciplinary engineering knowledge. Initiatives and institutions like ABET, CDIO, NAE or ENAEE–EUR-ACE have stablished lists of personal, interpersonal and professional competences. This need of competences' development has been widely addressed from the academia in several ways. Project-Based Learning and, specifically, Capstone design courses where student teams develop "real" projects using their theoretical knowledge on a system level [1], [2] are considered among the more successful tools to promote that kind of skills.

The Bachelor in Telecommunication Technologies and Services Engineering at the School of Telecommunications Engineering of Technical University of Catalonia, in Barcelona, includes three project-based courses in order to provide a framework to facilitate the learning of personal, interpersonal and professional skills. The CDIO model [3] was used in the design of the program, which was completed 10 years ago. The three project-based courses are "Introduction to Engineering" (2nd year, 6 ECTS), "Basic Engineering Project" (3rd year, 6 ECTS) and "Advanced Engineering Project" (AEP, 4th year, 12 ECTS). In the first two subjects, students work in small teams (3-5 students) following a partially guided plan which also includes some disciplinary contents learning and in which the project topic is proposed by the supervisors. Although the goal of the three courses is to provide a context close to the practice of engineering, the first two are closer to PBL methodology [4], providing both context and contents through a known and guided sequence of activities. On the other hand, AEP, the third one, follows the Product Development Project (PDP) model, which can also be assimilated to the New Product Development model [5]. In this course, bigger working groups (8-12 students) carry out the design of a complete product or service, including its business model. The teams generate the requirements and specifications of the product or service from the initial interaction with the stakeholders, define the system block structure and the work packages and then distribute them among subgroups of 2-3 students. They must design, implement and test the subsystems, integrate them, define a business model based on the product or service and perform the sustainability and ethical analysis. In the first years (2011-2014) the challenges of the AEP projects were proposed by the teaching staff. Since then, external agents were gradually incorporated and currently, 7 out of 10 challenges are proposed by companies, hospitals, foundations or NGOs. This subject is compulsory and 1440 students have passed through it. They have worked in 138 different projects, being 81 of them proposed by external agents. Some examples of project challenges are: image processing software for rehabilitation of facial paralysis due to facial nerve injury, human-machine interface techniques for car cockpit, development of sensors for 3D printers, blockchain-based payment distribution system in the music industry or low-cost IoT sensor system for detection of irregular discharges in wastewater. A comparative study of the performance of the student teams according to the kind of stakeholders (internal/external) and other features of the projects has been reported in [6]. The AEP course is performed twice per academic year. There are around 10 different projects in the Fall term and around 7 in the Spring term. In the Fall term, 10-15 students perform AEP in a different way, following a Challenge-Based Learning (CBL) model [7] in multidisciplinary teams. A quantitative and a qualitative study on the differences in the learning of innovation skills among PDP and CBL modalities have been reported in [8] and [9] respectively. The learning outcomes of the course are mostly the ones of the involved personal, interpersonal and professional generic skills. Of course, there are learning outcomes associated to the disciplinary topics involved in the project development but they are considered as a reinforcement of the previous or parallel disciplinary subjects.

1.2 The effect of previous academic achievement

Previous academic achievement is usually considered a good a priori estimator of academic success in higher education. Most studies, for example, [10] are centered in the success in the first-year attainment and in the drop-out rate. Putwain et al [11] studied its effects in academic self-efficacy. The literature about its effect on the project-based courses is less abundant. Garry [12] concludes that student groups with high GPAs, on average, do well on their capstone projects after studying several success factors. Joo et al [13] state that PBL benefitted low performing students to a greater extent and decreased the achievement gap, but applied to secondary education.

The secondary education system in our country defines a University access exam when the students finalize their High School years. This exam includes several disciplines, some of them are common to all student and some others are specific for the kind of bachelor the students are going to enroll (scientific/humanities). The resulting mark is averaged with the mark of the last two years of the secondary education and provides a grade in a scale of 10 points. This grade can be improved by performing two additional exams on subjects specifically indicated for the kind of bachelor the students are going to enroll (usually Advanced Mathematics, Physics, Chemistry or Technology for Engineering studies), which can provide up to 4 additional points. Then, the University Access Mark is defined on a scale of 14 points. It is used as a ranking criterium to determine the access to each bachelor in each institution when there is more demand than available positions.

The initial hypothesis of this study is that the regular courses (the non-project-based courses) marks will be correlated with the access mark of the students and that the project-based courses mark, and specifically the AEP mark, will not be so correlated because a set of different skills, non-so analytical, are developed in these courses.

2 METHODOLOGY

Out of the 1440 students that have carried out the AEP capstone course between the academic years 2011-2012 and 2020-2021, we have included in the study the 1257 that had finished the bachelor when doing the analysis, so they had completed all the courses of the program. Their access marks are included in the range 5.00 – 13.78 (in a 14 points scale), with an average mark of 9.97 and a standard deviation of 1.93 (7.12 and 1.38 in an equivalent scale from 0 to 10). Half of the students are included in the range 8.70 – 11.50, while 25% joined our school with more than 11.50 points (8.21/10) and 25% with less than 8.70 (6.21/10). The students that enter our engineering degrees with an access mark lower than 8/14 have a high drop-out rate. Only the ones that reached the AEP course and finished the bachelor have been included in this study.

To check the validity of the hypothesis, we have performed a correlation study between the access mark and several performance indicators, most of them derived from the AEP subject individual mark. Assuming the limitations of the individual final grade as a valid metric to assess the performance in the course, we have chosen it as performance index for this study because of its integrative character. According to the learning outcomes of the course, the project supervisors assign a team mark, which reflects the assessment of the process (50%) (Preliminary and Critical Design Review, team dynamics) and the final result (50%) (Solution Technical Performance, Business Idea, Final Report, Final Presentation and Video). The individual marks are obtained from this team mark after applying a triple modulation (30% max): The Supervisors' Assessment of the individual performance, the Team Leader assessment (batch of points) and the Peer Assessment using a 10 criteria rubric. Therefore, the final individual marks are quite integrative of several aspects. The average of the individual marks along the 10 years of the study is 8.44 in a scale of 10, with a standard deviation of 1.17.

The parameters included in the correlation study are:

- The average of the grades of the regular courses (non-project courses), most of them with a high analytical content.

- The average of the grades of the two first project-based courses (PBL courses mark).
- The individual grade of the AEP course.
- The relative increment or decrement of the individual AEP mark respect of the team mark (individual boost).
- The individual grade of the AEP course separating the cases in which the project main stakeholder was internal or an external company or institution.

For each of them, the Pearson's R correlation coefficient was obtained and the linear regression between each indicator and the access mark was represented, including the +/- 95% prediction interval around the regression line. The analysis tool we used was SigmaPlot 14.5 (Systat Software, UK).

3 RESULTS AND DISCUSSION

3.1 Results

The results of the correlation analysis are displayed in the following graphs and tables. Table 1 displays the mean and standard deviation for each indicator and also the Pearson's R coefficient for the correlation between each indicator and the access mark.

Table 1. Mean and STD of each indicator and Pearson's R coefficient for the correlation between each indicator and the access mark.

Indicator	Mean	STD	R
Non-Project mark	6.75	0.69	0.58
PBL courses mark	7.25	0.88	0.52
AEP mark	8.44	1.17	0.31
AEP % individual boost	0.7%	13.0%	0.21

Figures 1 to 4 display the linear regression between each indicator and the access mark. The thick red lines display the linear regression line and the 95% confidence interval of the regression while the dashed red lines indicate the +/- 95% prediction interval of the indicator if the regression is used for this purpose. All graphs have the same axes scale in order of making easier their comparison.

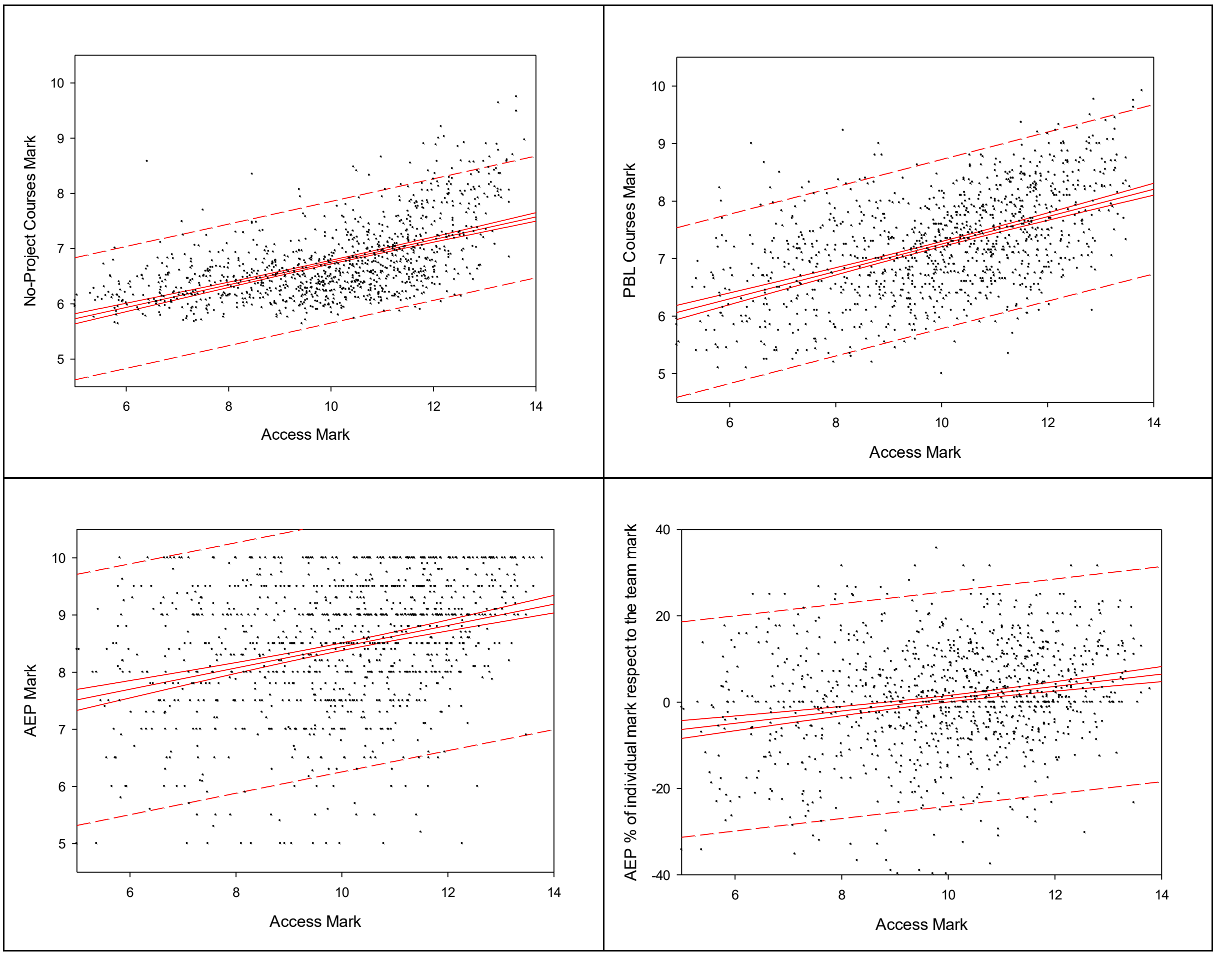

Fig. 1. Correlation Access Mark – Non-Project Courses Mark (top, left); Correlation Access Mark – PBL Courses Mark (top, right); Correlation Access Mark – AEP capstone course individual Mark (down, left) and Correlation Access Mark – relative increment or decrement of the individual AEP mark respect of the team mark (down, right).

In order to compare the likelihood of obtaining a good indicator having had a low access mark or a bad indicator having had a high access mark, the regression value (RV-6) and the upper 95% prediction value (UPV-6) for an access mark of 6 and the regression value (RV-13) and the lower 95% prediction value for an access mark of 13 (LPV-13) are provided in Table 2.

Table 2.Regression and prediction limit values for an access mark of 6 and 13

Indicator	RV-6	RV-13	% RV	UPV-6	%Improv	LPV-13	%Improv
Non-Project mark	5.94	7.37	21%	7.06	19%	6.25	-15%
PBL courses mark	6.30	7.97	23%	7.75	23%	6.52	-18%
AEP mark	7.70	9.00	15%	9.90	29%	6.80	-24%
AEP % individual boost	-4.9%	5.1%	10%	20.1%	25%	-19.9%	-25%

The individual grade of the AEP course separating the cases in which the project main stakeholder was internal or an external company or institution has not delivered significative differences among them, providing a Pearson's correlation coefficient of 0.30 for the first case and of 0.29 for the second one, very close to the global AEP one and a low correlation in any case.

3.2 Discussion

As we can see in Table 1, all the Pearson's R correlation coefficient are positive, displaying some better performance for the students with a higher access mark but is not high in any of the cases. The 0.58 value obtained with the correlation study between the Access Mark and the Non-Project Courses Mark can be considered as moderate [14], although we can observe in the corresponding linear regression graph in Figure 1 a clear dependency among both variables and a tight confidence interval for the regression. The correlation for the average of the two partially guided PBL courses is slightly small (R=0.52) but still moderate. The relevant difference can be observed with the AEP course, for which the correlation is weak (R=0.31). Looking at the corresponding graphs in Figure 1, we can see that, while it is almost impossible that a student with a low access mark gets an outstanding average grade in the bachelor and vice-versa, there are students with a low access mark which have an outstanding performance in the capstone project and students with a very high access mark and with high results in analytical courses but with a poor performance in capstone projects. This feature has been systematically observed by the project supervisors and commented in the coordination meetings, but we did not have a quantitative evidence. To avoid the possible bias eventually induced by the fact that the students with low access mark were assigned to projects that obtained higher marks (which is not reasonable), we also calculated the "Individual Boost" of each student, the relative increment or decrement (%) of the individual AEP mark respect of the team mark. A student with a high and positive Individual Boost has been acknowledged by his or her colleagues, by the Team Leader and by the supervisors as a valuable contributor to the success of the Team. The correlation between the Access Mark and the Individual Boost gives the very weak correlation of R=0.21, displaying that almost any student, independently of his or her access mark can receive a good or bad assessment by the peers. We have not done a study of a parallel assessment of the skills associated with the Team Work related skills such as commitment or leadership, which may be independent of the analytical skills, but they are probably playing a relevant role in this result.

In order to obtain quantitative indicators of the likelihood of obtaining a good indicator having had a low access mark or a bad indicator having had a high access mark, we have taken two extreme cases of access mark, 6 and 13 (in the scale of 14 points), which only have a 3% of the cases below and above respectively and have compared the estimated average indicator value through the regression line (RV-6) and the upper 95% prediction value (UPV-6) for the access mark of 6, to display the ability of obtaining a high indicator with a low access mark. Also the estimated average indicator value through the regression line (RV-13) and the lower 95% prediction value for an access mark of 13 (LPV-13) to display the ability of obtaining a low indicator value with a very high access mark. The results can be seen in Table

2. The 4th column, %RV, expresses the relative advantage of a student with an access mark of 13 respect to the one with an access mark of 6, calculated as the percentual change respect to the overall average of the indicator. We can see how, for the non-project courses, this advantage is 21% and similar for the PBL courses, but is reduced to 15% for the AEP capstone course and to 10% for the Individual Boost. In columns 5 (UPV-6) and 6 (% improvement) we can see how big is the maximum expectable value (95% confidence) for a student with a low access mark, respect to its average indicator value according to the regression. While a maximum of 19% can be expected for the non-project courses, up to a 29% can be expected for the AEP course and a 25% for the Individual Boost. On the opposite side, a student with a very high access mark can only expect a global result of -15% of decrement respect to his or her average mark in non-project courses according to the regression but up to a -25% in the AEP mark and the Individual Boost.

Further and specific research on direct measurement of the personal, interpersonal and professional skills involved in the performance in PDP projects would be needed to be able to determine up to which extent they are independent of the analytical skills, more relevant in the non-project based courses, but we consider that it is clear that a different kind of skills are promoted in these courses. We also consider that it is very positive that students that are not brilliant in most of the analytical courses could find a place to stand out. It enhances their self-confidence.

In any case, both the correlation coefficients, although weak, and the slopes of the regressions are positive and statistically significative ($p<0.001$ in all cases), which indicates a slightly better performance of the students with high access mark in the capstone AEP course, but what we consider relevant as result of this study is the evidence that students with low access mark are able of performing really well in that kind of courses, which are key for the complete education of graduate engineers. We recommend the institutions that perform or plan to perform that kind of courses to identify and highlight the good performance in capstone projects in students with average or even low marks in order to boost their self-confidence and self-efficacy.

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A SITUATIONAL JUDGEMENT TEST FOR ENGINEERS TO EVALUATE THEIR PROFESSIOANL STRENGTHS & WEAKNESSES

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Conference Key Areas: *Please select two Conference Key Topics*
Keywords: *Please select one to four keywords*

1 INTRODUCTION

This paper reports on the development and evaluation of a 23 item Situational Judgement Test (SJT) with scenarios tailored to the engineering profession. The SJT was developed around the PREFER model, with the support of professional engineers and academics in 11 panel discussions. In total 53 engineering professionals and academics were consulted during the development of both the item stems and the item responses of the SJT. Subsequently, the SJT was rolled out to 334 final year and masters students enrolled in engineering programmes at TU Dublin and KU Leuven respectively. After taking part in the test, students were sent automated reports on their performance and the test which highlighted how their response compared to a response gathered from a professional engineer with feedback on how they might improve their competence in a particular area, while also commending their performance in other areas. The results of this study highlight that 8 SJT items had significantly lower mean scores when compared with the test-mean. These items, which were related to *perseverance, client focus, vision, planning and organising, solution orientation, team player, work organisation, clear communication* and *networking* all represent potential competence deficits in the population of final year and master students that were tested. This work adds to engineering education scholarship by providing an engineering-specific SJT that enables educators to identify areas of relative strength and weakness in students' professional judgements in order to better prepare them for their future careers.

1.1 Rationale

Over the past three decades, there has been a strong emphasis on improving the employability of engineering students in order to address the mismatch between graduate skills and labour market expectations in the field of engineering (1). A recent meta-analysis by Passow & Passow (1) discovered fifty-two articles published over the past three decades regarding the professional skills that engineering programmes should emphasise. Looking at just the past decade, a strong emphasis on professional skills in engineering programmes has resulted in the development of a multitude of learning resources, courses, interventions and assessments (2) that attempt to address students' lack of competence in these professional areas, and as alluded to in a previous paper, the vast majority of which rely on student self-assessment of their competence via pre and/or post intervention (2).

Despite three decades of research and intervention into students' professional skills, the skills mismatch for engineering professions in Ireland and Belgium is not reducing (3). Action needs to be taken to provide a more direct means of assessment of students professional competence, assessment that can also be used to provide prompt and directive feedback to students about how their professional competence can be improved. The type of assessment that brings us back to Boud's reframing of the purpose of assessment, which shifts the focus from viewing assessment as confirmation of the achievement of a particular learning outcome, to the use of assessment as a tool for informing judgement (4).

1.2 Literature review

The practice of including Situational Judgement Tests (SJT's) in the candidate selection process, particularly in job interviews, has become increasingly popular in recent years (5).This section presents the taxonomy of a SJT item, how SJTs are scored and how success in SJTs relate to job performance. SJT's have been used in psychological assessment for almost a century, with the first documented SJT appearing in the George Washington University Social Intelligence Test (6). The first section of the test was entitled J*udgement in Social Situations* which contained a number of social situations that presented problems, each followed by four possible solutions to that problem (6).

The items of an SJT are composed of two principal components (7).The first component is called the *item stem*, this is usually set in a professional work environment and involves a conversation between two or more actors. The contexts present a dilemma which is outlined in dialogue by one of the actors. The second component of an SJT item area the potential *item responses* that the second actor can provide to the first actor who presented the problem statement to attempt to address the issue.

There is substantial variation in how SJTs instruct the participant to select responses. Asking the participant for only a single most preferred response can result in faking, particularly in high stakes scenarios, and guessing or failure to engage thoughtfully with the test. A number of strategies have been developed to address this, one of which is to ask the participant to identify a best and worst response, forcing the respondent to reflect on why a response is appropriate or inappropriate rather than simply selecting the optimal response (7). This of course introduces ipsativity (8) to the test, in that a ranking is introduced to the responses. This can lead to issues with reliability analysis as the data collected are far less *granular* i.e a four-response SJT item scored Ipsatively has a theoretical maximum score of four. A more favourable method of *rating* responses or normative rating, can be employed instead and allows a more granular score to be attached to each item rating and so a four-response SJT item scored normatively on a 5 point Likert scale produces far more variation in score than an ipsatively scored item. This is a general issue faced in all Multiple Choice Question (MCQ) testing, but the use of normative scoring has particular significance to the scoring of SJT's as it allows more nuanced data to be collected from subject matter experts, who's responses may shape the scoring key of particular test items.

Patterson (9) carried out a systematic review of the use of SJTs in the evaluation of a number of non-cognitive factors including empathy, integrity and resilience. The review found that SJTs compared favourably with IQ tests and personality tests in predicting job success and represented a cost-effective means of candidate selection when compared with direct observation through structured interview. In the assessment of candidates' interpersonal skills Lievens (10) found "significant added value" in using SJTs over cognitive tests alone in predicting interpersonal skills. Motowidlo, Dunnette & Carter (11) found poor correlation between test scores and the GPA of participants but significant correlation with interpersonal skills $r = .21$ and negotiation $r = .50$ respectively, which were evaluated in interviews with test participants. An SJT developed by O'Connell et al.(12) shared variance with cognitive ability $r = .33$, conscientiousness $r = .33$ and agreeableness $r = .31$ which are established predictors of job success and the results are in good agreement with previous findings (13–15). The above literature seems to suggest that while SJTs are not predictors of academic success they are reliable predictors of future job performance when aligned with the appropriate professional skill.

1.3 Research objectives & question

In order to answer the research question: *"can a SJT be an effective means of assessing engineering students professional competence?"*, four research objectives were identified:

1) Develop an novel SJT with items tailored specifically to engineering professional scenarios.

2) Evaluate the SJT with all stakeholders including students, academics and industry professionals.

3) Identify the areas of professional strength and areas for improvement in the sample of engineers tested.

4) Provide students with prompt feedback on these strengths and areas for improvement.

2 METHODOLOGY

This research utilised a fixed mixed methods design, in which the quantitative and qualitative methods employed were predefined, and did not emerge from research findings in a previous stage of the research (16). The development of the SJT required the application of qualitative methods to evaluate respondents accounts about the content of the SJT items. The roll out of the SJT required the application of statistical tests to make inferences about the data collected from students who took part in this phase of research.

2.1 Methods

The method used in this study builds on a previous study of Craps et al (2021) who developed a validated Professional Roles Model for early career engineers (PREFER model) (17). A list of skills was developed by Binder Dijker Otte (BDO) (a consultancy with a division in Human capital) using a seminal piece of research by Bartram in which 29 validation studies (n= 4861) of his skills framework "the eight great professional skills" were meta-analysed (18). This list was brought to 13 expert panels in Belgium, Ireland and the Netherlands, all of whom employed engineers. Fifty-five panellists took part in the research; 47 male and eight female panellists who were predominantly engineers (44 engineers, 8 HR managers and 3 engineering managers with HR expertise) comprised the thirteen expert panels. In these panels, the competencies listed were mapped to the three professional roles outlined by the PREFER model, which describes three roles that early career engineers can take on when entering to the labour market: product leadership roles (focusing on radical innovation and research and development), operational excellence roles (focusing on product or process optimisation and increasing efficiency) and customer intimacy roles (focusing on tailored solutions forspecific clients).As well as these three role profiles, the outcome of these panels was a set of twenty-three skills and their descriptions. Once these had been identified, these skills were used as the basis for the development of the SJT items. The advantage of this approach was that items could be framed in a

particular context by design, basing each item on one of the twenty-three skills that had been identified. Designing the items from scratch also allowed the situations to be kept to an appropriate length. More detailed questions result in higher validity but this must be tempered by keeping the cognitive loading of the items to a minimum (19).
In this study, once the items had been initially drafted, the test was reviewed by a further set of 11 panels, this time made up of academics and industry professionals alike. In total, 53 people took part in the panels; 33 males and 20 females. Three panels were academic, made up of lecturing staff from the schools of civil & structural engineering, school of mechanical engineering and school of electrical engineering at TU Dublin and KU Leuven respectively, who reviewed the item stems. The items stems were also reviewed by panels from industry, with ESBI, Siemens and ENGIE. Once the items stems had been reviewed and the feedback integrated, The item responses were scored by panels from ARUP, Siemens (2 panels), Bosch, and Materialize to generate a scoring key that would be used to compare with students responses to the items.

Once a revised draft of the SJT items had been created, the test was divided into 3, resulting in 3 tests with between 7-8 items each. It was decided to keep the items grouped by role, rather than randomly assigning items to each test. The tests were brought online using BDO's test platform and links were disseminated to 334 final year undergraduate engineering students and masters students at TU Dublin and KU Leuven The rationale for selecting final year and masters students was that they represented the students who were closest to joining the labour market. Through their potential exposure to work placements, internships, guest speakers and site visits it was posited that their responses should align well to the responses collected from the panels with industry, and where they did not align well, a mismatch could be identified in their competence. All students who took part in the rollout of the SJT received a feedback sheet that compared their responses on each item to the responses of industry professionals, to provide them with a means of reflecting on their competence. The feedback was sent automatically through the BDO online platform via pdf.

2.2 Qualitative data treatment

The first stage of the evaluation of the SJT began with a desktop review of the 23 test items by staff from TU Dublin and KU Leuven; their qualitative feedback was documented. In the second stage, the test was brought to three expert panels. These panels were comprised of junior engineers, senior engineers, engineering management and HR professionals from ESBI, Siemens and ENGIE. During these panels, the participants were asked to evaluate the item stems to check if the items were suitable representations of the professional skill which it had been related to while their qualitative remarks were recorded. In the third stage, the test was brought to three expert panels comprised of lecturing staff at TU Dublin with backgrounds in the engineering industry and psychology from the schools of Civil & Building Services engineering, Mechanical & Design Engineering and Electrical & Electronic Engineering. In these panels, the participants were asked to assign two or three skills to each SJT item to check for alignment between the item and the skill it was written to represent.The data from the third review stage were compiled and reviewed by the researcher. Following revision of the content of the test items a fourth review stage began where the four possible responses to the scenarios presented in each item were reviewed in a further four expert panels with practicing engineers, engineering management and HR professionals at ARUP, BOSCH, Materialise and two panels with Siemens. The participants were asked to indicate their level of experience and their role along with their scores of the level of appropriateness of *each* item response on a 1-5 Likert scale, their qualitative remarks were also recorded. The scores provided by the experts were compared to the theoretical scoring key established by the researchers to establish a hybrid scoring key.

2.3 Quantitative data treatment

At an item level, where scores on each of the four possible responses could be aggregated, providing a theoretical maximum score of 24, the data were found to be normally distributable, and parametric statistics were utilised (20). T-tests were carried out to look for differences in sample means between different items, in order to determine students relative strengths and weaknesses in their evaluation of the scenarios presented in the SJT items. Participantion in the research was voluntary and di not form part of the students final assessment for any module. This research was conducted with Ethical approval from the TU Dublin ethics committee (REC-17-112).

3 RESULTS

3.1 Box and Whisker plots

The distribution of the students' scores for each item are displayed in figures 1.1, 1.2 & 1.3 respectively, with the mean score represented by the black line on each box plot and the data which fall within the normal distribution represented by the shaded area. Data was tested for normality using the Shapiro-Wilks method and determined not to be significantly different from a normal distribution. Results of the t-tests are available in Appendix A.

As illustrated in Figure 1.1, *planning and organising, solution orientation, team player* and *work organisation* had lower mean scores than the other items. It was unsurprising that *planning and organising and work organisation* were of similarly low scores as the operationalisation of these items was very similar; in both instances a cognitively loaded item was avoided, for example an item where an optimised schedule had to be created – as this would not fit well within the taxonomy of an SJT item. Instead, responses outlining consistent and inconsistent plans were created and the respondent was asked to rate each of these in terms of their utility for completing a particular task.

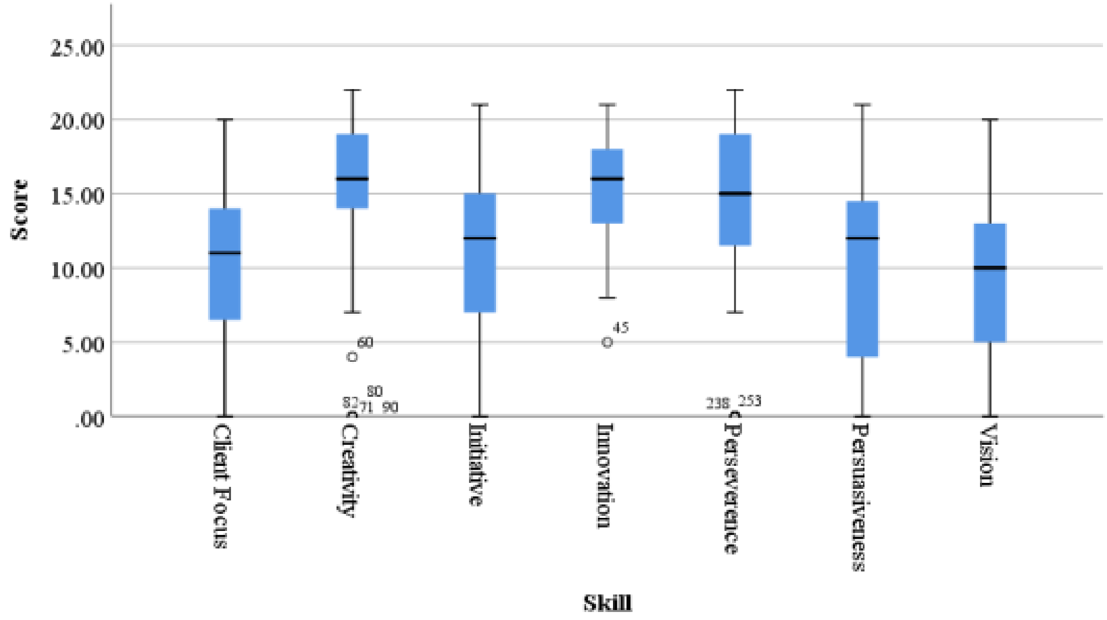

Figure 1.1 Box-Whisker plots for Product Leadership test

With reference to Figure 1.2, the *work organisation* item was of particular concern due to the low mean score, but also the variance in the score. The distribution of scores within the normal distribution presented as the shaded boxes in Figure 1.2 illustrate that the tail of the distribution of scores for *work organisation* was firmly placed between a score of 0-5. This was also the case for *planning and organising*, although to a slightly lesser extent These presented areas of weakness in the students' professional skills that should be addressed.

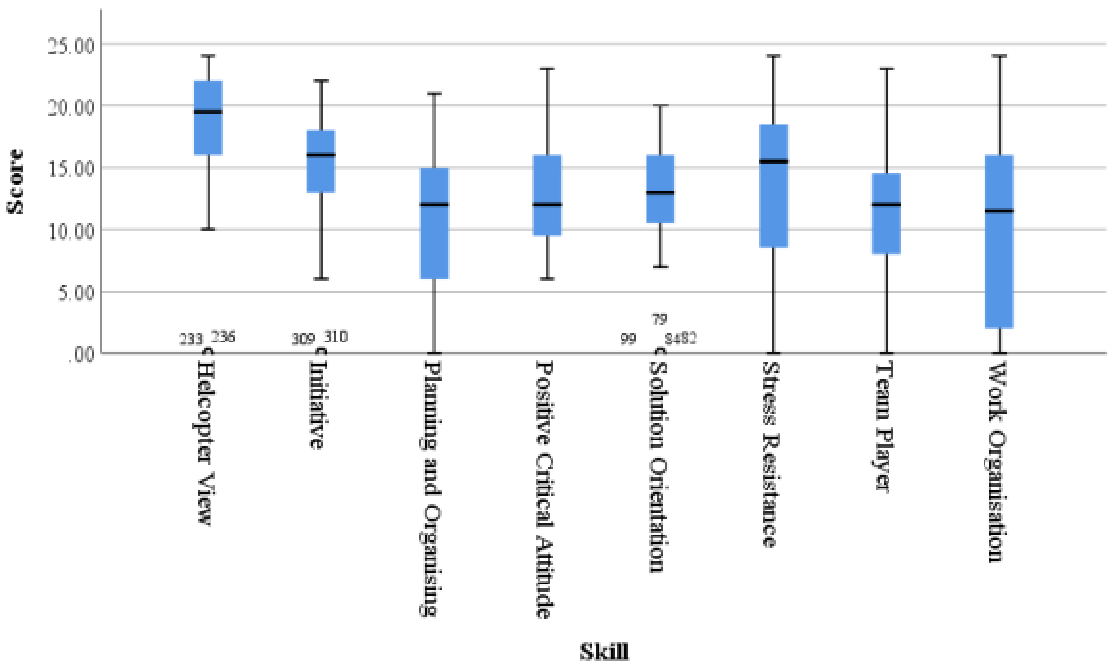

Figure 1.2 Box-Whisker plots for Operational Excellence test

With reference to Figure 1.3, *clear communication* and *networking* were found to have significantly lower mean scores than the test mean. The *networking* item was operationalised around a willingness to proactively network with an auditance of potential clients, or to stand back and take a more passive approach. This item may have been mediated by the introvert-extrovert personality trait, however it does suggest that on average, students are unwilling to engage proactively at a networking event.

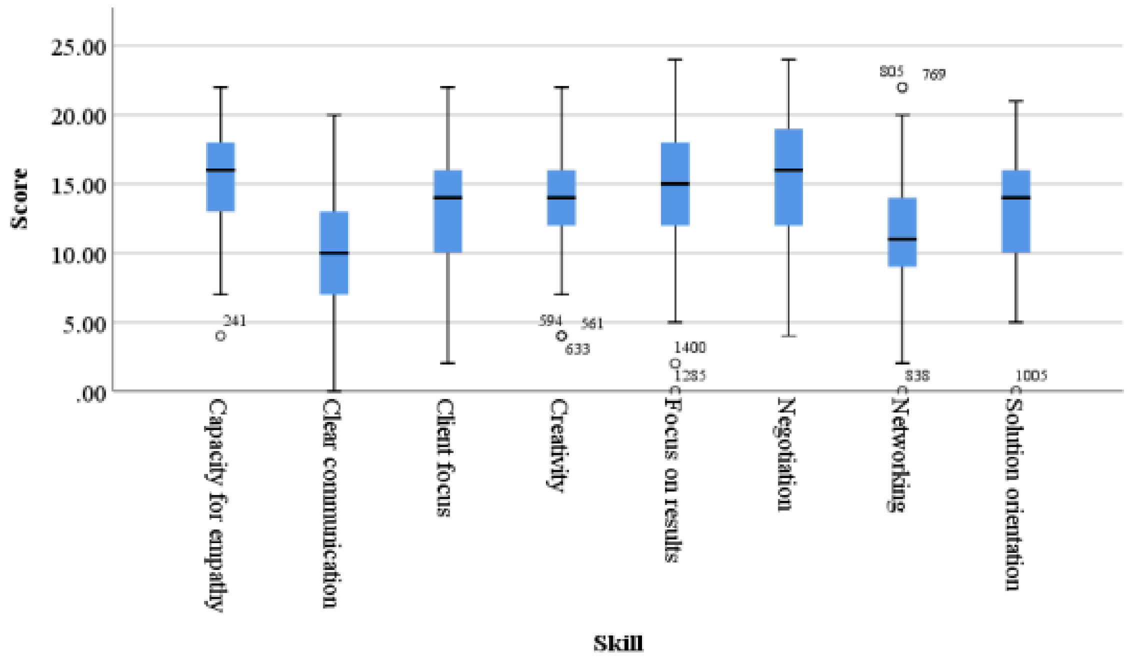

Figure 1.3 Box-Whisker plots for Customer Intimacy test

3.2 Paired sample t-tests

Items with the lowest mean score were identified and t-tested by comparing the item-mean to the test mean for each of the 3 tests, the results of these paired sample t-tests are presented in Appendix A. Eight of the twenty-three items of the SJT had significantly lower mean scores than the remaining thirteen items. These items, which were related to *perseverance*, *client focus*, *vision, planning and organising*, *solution orientation, team player, work organisation, clear communication* and *networking* all represent potential skill deficits in the population of final year and master students that were tested.

4 SUMMARY AND ACKNOWLEDGMENTS

As the students tested in this study are now in the labour market, it is useful to thinking about the ways in which these engineers may begin to bridge their skill gaps. As the sample of students tested are now in the labour market, implementation of the 70:20:10 model (21) of training may be useful, in which 70% of these gaps may be addressed through engagement with challenging projects, 20% engaging with a mentor to identify potential avenues, both formal and informal to bridge these gaps and 10% with further formal learning by engaging in courses offered by third level institutions and engineering professional bodies alike. Beyond the immediate needs of those students who were tested, further use of the SJT as a means of identifying skill gaps could be used proactively to inform engineering curriculua at third level, and also inform organisation's graduate development programmes regarding the types of training required of the incoming cohort of engineering talent.

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APPENDIX A

Item	Mean	Standard deviation	t	df	Sig
Product leadership					
Innovation	3.356	4.788	5.384	58	0
Creativity	3.153	4.266	5.676	58	0
Vision	-3.034	4.017	-5.801	58	0
Persuasiveness	-1.932	3.81	-3.896	58	0
Perseverance	1.661	3.646	3.499	58	0.001
Initiative	-1.034	3.429	-2.316	58	0.024
Client focus	-1.814	3.457	-4.03	58	0
Operational excellence					
Positive critical attitude	-0.1039	5.988	1.255	76	0.879
Solution orientation	-0.0649	4.072	0.859	76	0.889
Team player	-1.662	4.287	-0.689	76	0.001
Helicopter view	4.402	4.139	5.342	76	0
Initiative	1.324	3.529	2.125	76	0.002
Work organisation	-2.389	5.373	-1.17	76	0

Stress resistance	0.441	5.053	1.588	76	0.446
Planning and organising	-2.363	4.032	-1.448	76	0
Customer Intimacy					
Client focus	0.848	5.099	1.55	204	0.018
Capacity for empathy	1.921	3.907	2.46	204	0
Clear communication	-3.448	4.179	-2.873	204	0
Creativity	0.307	3.141	0.739	204	0.163
Networking	-2.224	3.453	-1.748	204	0
Solution orientation	-0.326	3.46	0.149	204	0.178
Negotiation	1.531	4.304	2.124	204	0
Focus on results	0.97	3.725	1.483	204	0

Table 1.1 Paired sample t-tests for each item, separated by test

Debates on tech-related moral dilemas usign ethical theories to teach engineering ethics

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Conference Key Areas: *Ethics in Engineering Education*
Keywords: *ethics, morals, technology ethics, ethical theories*

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ABSTRACT

A significant number of universities where engineering is taught acknowledge the influence on society and the environment of the scientific and technological practice, as well as the ethical problems it presents, and the need to provide their students with courses covering this as a subject. The accelerated pace of innovation in these fields amplifies the issue.

Computer Engineering schools are no exception. So, the IEEE/ACM Computer Science Curriculum 2013, identifies social issues and professional practice as key knowledge areas that computer undergraduate students must learn. Students should be knowledgeable about the interplay of ethical issues, technical problems, and aesthetic values that play an important part in the development of computing systems.

The authors have taught for many years an optional course about the social, and environmental aspects of ICT as well as ethics. In this paper, the authors propose an approach to study ethics in Computer engineering schools. The approach consists in providing students with general ethic frameworks to reason about moral dilemmas as well as providing the basics of deontology. The lessons are complemented with case studies where technology is a key factor. Students are assigned roles to work on the cases and in the end, a discussion is done in the classroom.
After the lessons, the authors have observed that students are able to understand and use the tools provided by the teachers to reason about moral dilemmas.

1 INTRODUCTION

1.1 Section 1

The existence of computers and computer networks has been identified as a source of a new class of ethical and social issues since the early days of digital computers [1]. Today it is obvious the pervasiveness and ubiquitousness of the moral, ethical, social, legal, and political issues related to information technologies (ICT).

For example, the technological not-so-distant promise of Self Driving Cars raises complex questions in a lot of dimensions: (1) moral "If technology is proven statistically better at preventing deaths and accidents than the humans, should we use it? should we make it mandatory?"), (2) ethical "Can we delegate ethical decisions to machines whose behavior we don't fully understand?", (3) social "Do we want a significant percentage of the labor force with automation? ", (4) political "How are we going to deal with the consequences and the loss of economic and political power of the ones laid off? ", (5) geo-strategic "What nations control the technology behinds the self-driving cars moving around in our country?", (6) legal "How do we structure a legal framework to regulate self-driving cars?", (7) security "How do we ensure the cyber-security of our cars and utilities?". But these questions and even more complex ones appear again for almost any new technology: smartphones, drones, 3D printers, the internet of things, social networks, the web, face recognition technologies, big data, and every single application of (shallow) AI (artificial Intelligence).

But all of the cited technologies, their sophistication, capabilities, and impact are connected with exponential-like tendencies like the ones expressed by Moore's Law (the number of transistors per square inch in a processor doubles every 18 months), Metcalfe's Law (the potential utility of a network is proportional to the square of the number of nodes), and similar observations that strongly suggest that the curve of technological change is exponential. According to Kurzweil, the technological development we are going to experience during the 21st century will be equivalent to 20,000 years of progress at today's pace [2]. So, we should at least pay attention to the technological singularity hypothesis: "The technological singularity—or simply the singularity—is a hypothetical point in time at which technological growth becomes uncontrollable and irreversible, resulting in unforeseeable changes to human civilization" [3]. Last but not least, biology now has become a technology subject to exponential-like patterns, which makes the term "singularity" even more intriguing.

Hence the introduction of engineering ethics into the curriculum makes a lot of sense. The IEEE/ACM Computer Science Curriculum 2013, includes social issues and professional practice in the key knowledge areas that computer undergraduate students must learn. Graduates should recognize the social, legal, ethical, and cultural issues inherent in the discipline of computing. They should be knowledgeable about the interplay of ethical issues, technical problems, and aesthetic values that play an important part in the development of computing systems [4].

The Barcelona School of Informatics (Facultat d'Informàtica de Barcelona - FIB) at Universitat Politècnica de Catalunya (UPC) on 1991 started including the subject of ethics in a specific course in the Informatics Engineering graduate program [5] For more than 30 years this course has been a space for experimentation on how to teach the subject of ethics to informatics engineering students. This paper describes one of the teaching strategies applied.

There are many approaches on how to introduce the study of ethics in ICT curricula. Some are focused on the importance of the process of ethical decision making, which places an emphasis on the process it takes to reach conclusions [6,7]. Other researchers focus on professional practice considering that ethics education should focus on practical applications, on the ability to solve ethical problems morally or technically [8]. In this line of work, Johnson proposes ethics education as a set of activities that provides students with basic knowledge about codes of ethics. The goal is to develop their skill at interpreting and applying these codes and standards because this will provide students with the necessary skills to handle ethical issues once they enter in their professional lives [9]. Samson [10] adds that codes of ethics provide valuable guidelines to achieve ethical behavior and to assess moral responsibility in a profession.

Nygard [11] thinks that apart from ethics it is necessary to teach the social implications of a given technology, because it helps students in ICT develop their ethical reasoning skills and an appreciation for the complex impact that technologies have on society. They work by exposing the students to as many of the cultural, social, legal, and ethical issues in the discipline of computing as possible in order to broaden their appreciation and understanding of complex issues. Barceló at UPC, and Gordon at the University of Hull [12] took a similar approach.

Bowden proposed an ethics course based on case problems, ethical theory, acting in the public interest (or whistle-blowing), the study of codes of ethics, and the role of the professional society. A similar approach is presented in [13,14].

Reviewing the related work authors propose an example of a case study in a mandatory course in a master degree in sustainability to reason about moral dilemmas using philosophical thinking. The case study includes the particularities of computer science that requires technical understanding of the domain.

The rest of the paper is organized as follows: Section two describes the methodology used for the lectures about ethics as well as an example of a case study and how we worked this case in the class. Section three presents the findings provided after working the case and section four presents the conclusions of this work.

2 METHODOLOGY

2.1 The course

The case study we proposed is applied in a mandatory course of the Master's degree in Sustainability offered by the Sustainability Institute also at UPC. The course is called "Fundamentals of business ethics and innovation" (FEEI from now on) and is taught in English language to an audience of local and international students. FEEI has three main topics: 1) Ethics applied in the field of engineering and legal frameworks for the development of professional activity in engineering, 2) Corporate social responsibility and Ethics in companies and organizations, and 3) Innovation. The course is taught in English language and the students are local, national and international, they are aged between 25 and 40 years old and they split evenly in genders.

Our approach to teach ethics is explained next. First, we cover the basics of ethics, morality, and culture, and how they are connected. Then we present ethical theories as tools to make moral decisions. We differentiate workable ethical theories from now workable ethical theories, and then we go through a selection of ethical theories and we analyze how they work by working on examples and short cases. The chosen theories (in the order they are taught) are Kantianism, Rule and Act Utilitarianism, Social Contract, and Virtue Ethics.

This part provides us with frameworks to identify and reason about moral dilemmas where the application of technology is involved. We can also make moral decisions about it and present and rebate arguments in favor or against it. With these two lectures we provide the basics of philosophical thinking.

Then to put these lectures into practice we present two cases to the students. The first one is about identifying important moral values when reasoning about morals. We use them to do a role play case where students have to argue in favor or against certain moral issues.

The second case is usually something of high profile in the news, where technology is involved - and the nuances of understanding right the technology are important - and where we can find a moral dilemma. Again, the case is a role play where students have to use ethical theories to argue in favor or against certain moral issues. This case is the focus of this paper.

Then, we have a final lecture about codes of ethics and acting in the public interest (whistle blowing) that are followed by a case study.

In this paper we are going to focus in the cases we use to work ethical theories. We think that technical knowledge cannot be separated from the reflection about its impact or how it affects society. No technology is neutral, usually the pros are presented as benefits for society as arguments in favor of its introduction, but often cons or negative side effects appear when the new technology is being used. So, engineers must have a critical spirit about new inventions and how they will affect society. To do so the philosophy, sociology and history are good tools as proposed in the framework of CTS (Science, Technology and Society).

2.2 The case example

Here is an example of a case study presented to the students in winter 2022. The case title is "*Crowdfunding the war in Ukraine with Cryptocurrencies*".

Since the start of the invasion of Ukraine by the Russian army, a lot of reactions have ensued: From the almost unanimous condemnation of the UN to logistical aid to the Ukrainian defense forces not in the form of humanitarian supplies but also war vehicles, weapons, and ammunition.

The MAD doctrine (Mutually Assured Destruction) advises that countries with nuclear weapons should not engage directly. Hence NATO and EU countries have started to apply unprecedented economic sanctions, like the exclusion of Russian banks from the SWIFT international banking communications, the ban of imports and exports from and to Russia (not including oil and gas by the time being), and the direct seizing of actives owned by Russian oligarchs in western countries, including Switzerland and Monaco. Media associated with the Russian government (like Russia Today) have been canceled on platforms like Youtube, Twitter, and Facebook in several countries. And this is just the tip of the iceberg of the cyber-war that arguably was already ongoing. For example, the cyber activist group Anonymous has declared war against Russia and has allegedly hacked media servers in Russia to expose news about the war in Ukraine to the Russian population. The Russian government has passed legislation that makes spreading "false information" about the war a crime punishable with up to 15 years of prison.

In this scenario, thousands of citizens worldwide have started donating cryptocurrencies (Bitcoin and Ether) to wallets owned by the Ukrainian government. This constitutes an unprecedented fact in history: the crowdfunding of a war effort in a country by foreign citizens. The Ukrainian government has decided to take advantage of this situation and promised the airdrop of tokens to the Ethereum wallets that had donated until a given deadline. This caused a significant increase in donations, including hundreds of thousands of micro-donations not motivated by solidarity but as speculation.

2.3 The assignment

The students were presented with the previous text introducing the study case and were given a week to prepare arguments in favor or against the actions described. They had to work in groups on the Moodle platform of the school. A special Moodle grouping (https://docs.moodle.org/400/en/Groupings) was created where the students were put in groups randomly. Each group was tasked to develop arguments in favor or against the case and using only arguments consistent with one or two specific ethical theories (Kantianism, Virtue ethics, Social Contract Theory and Utilitarism). The students had available a specific Moodle Forum to collaborate online to prepare the case.

After a week, a two-hour debate was conducted in the classroom, moderated by the professor. The more relevant arguments and rebaits were written on the blackboard. And at the end of the session, the class voted on the more compelling arguments.

3 RESULTS

In this section we are going to discuss the findings of the case study in the classroom.

The groups that work using the Kantianism ethical theory provided with arguments in favor and against the donations using cryptocurrencies. The most voted arguments in favor of the dotation were the next.

If roles were reversed one would welcome the help. This was the most voted argument. The second most voted argument was that the action springs from good intentions (not treating others as means to an end).

Students identified three arguments to rebate the previous ones. The arguments are:

1. Is it not self-interest? Isn't the action done out of fear and using the Ukrainian land as a shield for the West?

2. Good intentions should not lead to providing weapons.

3. This donation could backfire and make wars more gruesome (like Napoleonic wars after the French revolution, when all the people of the state got involved in the war effort) and it would certainly benefit and incentivize the weapons industry.

The groups using the utilitarian morals agreed that they had to minimize human and animal suffering. Those in favor of the donation argued that in the long term, stopping an authoritarian tyrant with a record of invading countries is necessary to prevent suffering. Ukrainians will suffer more under the Puttin's yolk than if they surrender.

Those against the crowdfunding argued that in the short term the best bet to stop suffering is to stop the war. Crowdfunding Ukrainian's defense only makes it worse, and what will come later is unknown. These two points are in heavy dispute with a slight majority on the side in favor.

The groups using the social contract theory in favor of the crowdfunding explained that the donation is an example of participatory democracy (vote with wallet). They also base their arguments using the United Nations Charter Preamble (first paragraph) that states: "We the people of the United Nations Determined to save succeeding generations from the scourge of war, which twice in our lifetime has brought untold sorrow to mankind, and to reaffirm faith in fundamental human rights, in the dignity and worth of the human person, in the equal rights of men and women and of nations large and small, and to establish conditions under which justice and respect for the obligations arising from treaties and other sources of international law can be maintained, and to promote social progress and better standards of life in larger freedom".

The groups that argued against the crowdfunding stated that a social contract for believers in the Christian religion states that you shall not kill.

4 SUMMARY AND ACKNOWLEDGMENTS

This paper presents an example of case study used to work the ethics topic in a mandatory course in the master degree of sustainability at UPC. The case study is an example of didactical resource that we use in our lectures to help students develop their philosophical thinking. This resource can be adapted to other courses where ethics is taught to engineers. The idea is to adapt the case to de specific domain of the engineers so that it presents an ethical dilemma.

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Acceptance of Pedagogical Agent (PA) enhanced eLearning communities by software engineering students in Southern Africa.

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ABSTRACT

Covid19 outbreak has seen eLearning becoming a viable alternative to the traditional face-to-face teaching globally. Software Engineering education has not been an exception to these changes. The use of multimedia enhanced eLearning communities is also on the increase in the teaching of software engineering. However, there is limited research on the acceptance of such technologies by African learners. Some of the multimedia being used to enhance these learning communities includes animated pedagogical agents (PAs) combining text, animation, audio, and video. Considering learner differences and aiming to achieve personalized learning, there is a need for institutions to understand how such technologies are being accepted by learners and the factors that influence the acceptance. This study focuses on the acceptance of pedagogical agent enhanced eLearning communities by Southern African learners in the teaching of Software Engineering. The aim of the study is to identify the factors that influence the acceptance of such communities. This will help eLearning designers to try and address the needs of learners in different contexts to achieve personalized learning. This study involved 137 software engineering students from South Africa and Zimbabwe who were being introduced to eLearning community enhanced with PAs. The unified theory of acceptance and use of technology2 (UTAUT2) was used in this study. The study revealed that only performance expectancy, and hedonic motivation constructs had an effect on behavioral intention to use these eLearning communities enhanced with PAs.

1 INTRODUCTION

Imagine an online software engineering course in which students learn the content being presented online using a combination of narrated slides, and pedagogical agents (PAs) on the screen, which is are human-like characters intended to facilitate instruction [1] and the learner's learning [2]. The PAs engage in a variety of activities, such as role-playing as characters in a case study or as a fellow learner, helping learners solve problems, asking and answering questions or even providing encouragement. The use of PAs has been on the increase in education. This is due to the increase in the need to animate and keep the learners engaged [3]. Pedagogical agents are frequently integrated in online learning environments because they may be capable of providing cognitive support to the learner and being able to enrich socially the learning experience [4]. Lane, [5] suggested that properly designed and deployed pedagogical agents have a small, but significant impact on learning while [6] said PAs do not improve learning]. With these kinds of conflicting findings on the effect of PA integration, it shows that this area of educational research still needs to be explored further. Other researchers suggested that future research should include the deployment of agents in naturalistic contexts and open-ended environments, and investigation of agent outcomes and implications in long-term interventions [3].

With the technological advancement having led to the development of many efficient methods for innovative pedagogies in the field of education [7], these technological advancements have seen the adoption of eLearning communities in institutions that used to be face-to-face, and lecturer centered dominated. That traditional teaching was found to have no ability to meet the needs of students' comprehensive practical ability [8]. There is a shift from the traditional approach to a student centric approach in which the learner plays an active role in the learning process. That shift has been taking place at a slower pace prior to 2020, but the emergence adoptions of eLearning due to COVID-19 changed everything. A survey by [7] on engineering education depicts that there is a change in the teaching and learning process from teacher-centric education to learner-centric education.

On learning technologies to support learner centric education, reaerch pointed out that the learning technology might be poorly adopted, discontinued or rejected by learners, due to a number of reasons [9]. This raises the need to investigate acceptance issues associated with the introduction of new technologies in different educational contexts.

There is limited research evidence on adoption of these learning technologies in Southern Africa. As the issue of learner motivation and engagement remain topics of interest for researchers [10], there is need for such research even so in the African context and in the study domain of software engineering.

With the shift towards technology driven education for the achievement of personalized learning, a lot of innovative ideas are being implemented in higher education to try and address educational challenges. Some of these initiatives include the use of eLearning communities that are integrated with multimedia in the form of pedagogical agents which may be capable of providing cognitive support to the learner and social enrichment to the learning experience [4]. The acceptance of these technologies needs to be investigated in the context and different study domains to achieve the intended objectives.

The use of these animated pedagogical agents APAs in the study of software engineering requires that acceptance and impact of such technologies be investigated in the context of African learners, hence the focus of this study. The concept of one size fits all approach does not apply when it comes to predicting academic success of technology usage in education [11]. Therefore, there is need to investigate different students' contexts without generalizing using the findings from a different environment.

In the context of student-centered learning in which students are made to realize that it is their responsibility to engage, absorb, and retain while the instructor's job is to prepare an environment in which that can happen [12]. In an attempt to achieve personalized learning in which learning environments are expected to enhance the learning experience by providing tailor-made services based on learner preferences [13], several questions can be asked when technologies are being introduced. Behavioral intention to use blended learning was found to have an effect on the actual usage [14]. The link between behavioral intention and acceptance requires that acceptance be investigated when introducing new technologies in education.

This study focuses on the acceptance of PA enhanced eLearning communities by Southern African learners in the study of software engineering. This study seeks to answer the following key questions:

- Are communities enhanced with PAs accepted by software engineering students?
- What are the factors that influence the software engineering students' behavioral intention to use eLearning communities enhanced with PAs as an elaboration of multimedia?

2 THEORETICAL FRAMEWORK

The theoretical model employed in this research is based on the widely used models of technology acceptance. In particular, this study was based on the UTAUT2 model of [15]. The use of the UTAUT2 model is still scarce when studying learning technology acceptance in higher education contexts [16].

In the interest of selecting an appropriate model covering all constructs in determining Southern African students' intention to use and adoption of eLearning communities enhanced with multimedia in the form of PAs, the UTAUT2 has been found to be the most appropriate theoretical framework for the conceptual model to be used in this study. Following [15], Figure 1 below shows the main constructs in the model, which were proposed as direct determinants of behavioral intention to use Technology.

Very few studies have used UTAUT2 model to investigate the factors that influence the intention to use new technologies in higher education. Some of the studies that used UTAUT2 include [16],[17], however most of these studies were carried out with students outside the African continent.

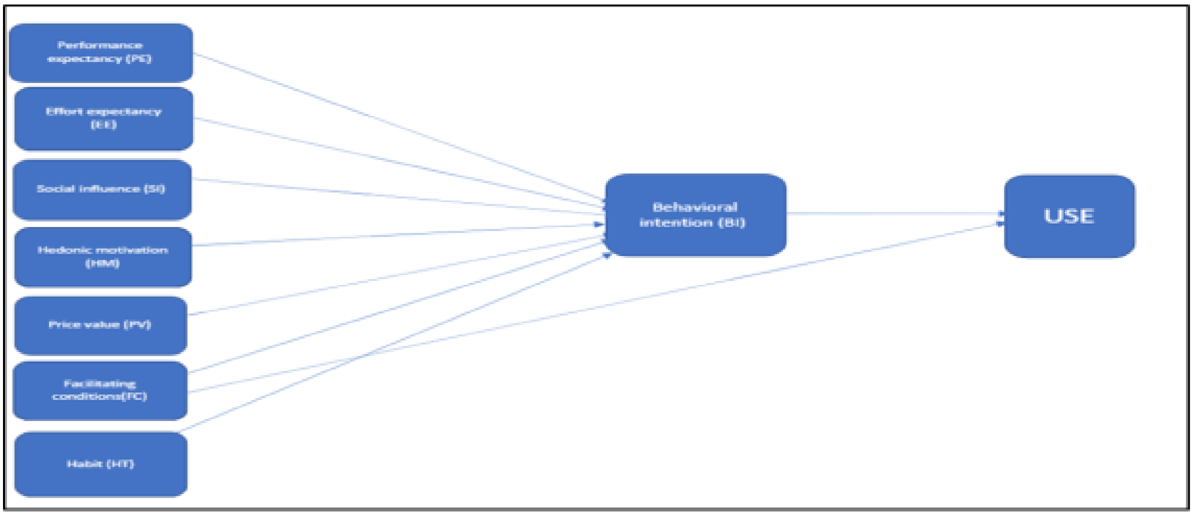

Fig. 1 The UTAUT2 model (Venkatesh et al. 2012)

From the UTAUT2 model two factors namely behavioral intention (BI) and facilitating conditions (FC) were seen as key predictors of adoption behavior [15]. The discussion of the model's constructs and how they contribute to the study is given below.

Performance expectancy (PE) is a key construct and the strongest predictor of BI to use a technology [15]. In this study, it has been defined as the degree to which students perceive that using eLearning communities enhanced with PAs will enable them to achieve improved performance in their studies.

Effort expectancy EE was found to be a determinant influencing people to BI, [18] and [19]. Wang and Wang [20] also found that constructs associated with EE will be stronger determinants of personal intention to use new technology. This study operationalised EE as the level of easiness related to using the eLearning environment enhanced with PAs.

Social influence (SI) has been operationalized in this study to refer to a student's belief in what significant others expect them to do.

Facilitating conditions (FC), in this study has been thought of as the degree to which students believe there is sufficient organizational and technical infrastructure, to support the use of PA enhanced learning environments in their studies.

Hedonic motivation (HM) is operationalized to mean perceived enjoyment. It refers to the fun, pleasure or enjoyment resulting from the students' use of the technology [21]. Previous research reported that perceived enjoyment significantly influences technology acceptance and use for learning [20].

Price value (PV), was found to be a predictor of Behavioral Intention to use a new technology. That was in other research where it could be operationalized like adoption of mobile phone [22]. PV could not be operationalized in this study because the students were expected to just use this environment for free without any direct costs linked to their use.

Habit (HT) considers results of previous experiences with community usage [15]. However, in this study the learners did not have any previous usage experience of such communities.

Behavioral intention (BI) was found to be a significant determinant behind the actual use of technology in different intention models [15]. In this study it refers to the extent to which students intend (and continue) to use environments enhanced with PAs.

USE behavior (USE), construct was not covered by the scope of this study because this study only focused on the acceptance of the environment. The study is being conducted during the initial stages of introduction to assess how the learners are receiving the new approach.

PV, HT, and Use having them operationalized as the stated above, these construct were excluded from some of previous studies [23],[24]. Although the constructs were also included during data collection. Due to students not being able to cognitively compare the enhanced environment with the financial cost that could be associated with using such an environment [15], and a lack of a lot of experience to talk of habitual behavior, meant that the construct HT could also be dropped. Although data was collected using all the constructs, it was left for the data analysis to confirm if those constructs were to be dropped or not.

The process of finding the appropriate model that fits the current study confirmed that the three constructs were supposed to be dropped. Model fit was only achieved after dropping the three constructs and a few items from the other PE and BI. This could be because of some challenges in operationalizing those constructs in this study as stated earlier and that could be due to the different circumstances of the learners.

Dropping those suggested constructs meant that the finally adopted model for the study reported in this paper was as shown in figure 2.

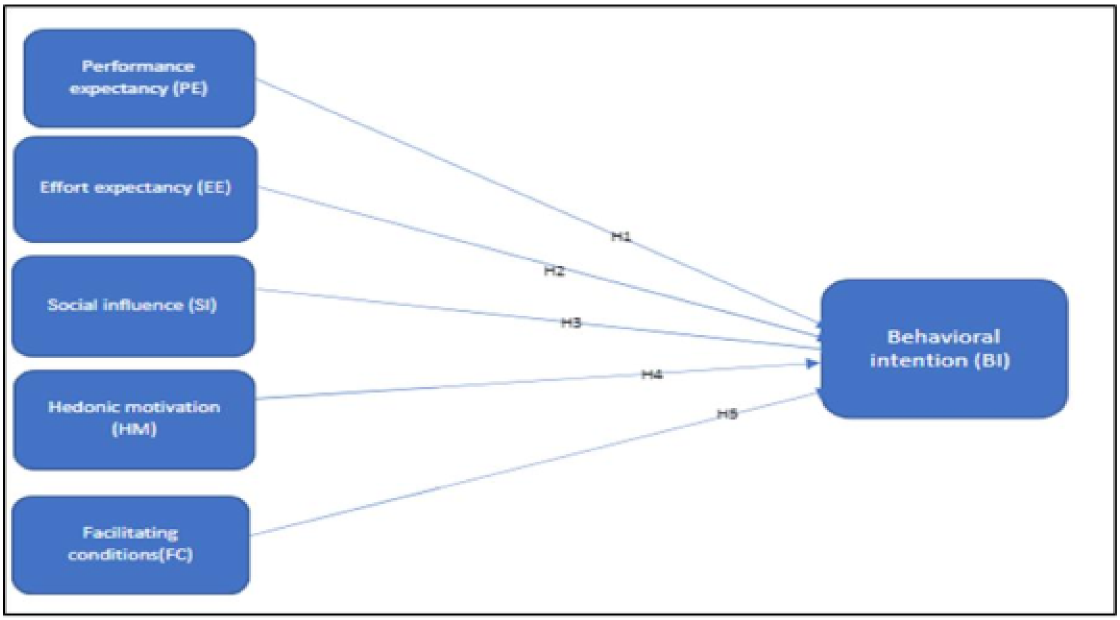

Fig2: Adopted model for the study.

3 HYPOTHESES

Using the given research evidence and according to Fig. 2, for the purpose of this study, the following hypotheses were formulated and tested:

H1: PE has an effect on software engineering students' BI to use PA enhanced eLearning communities.

H2: EE has an effect on software engineering students' BI to use PA enhanced eLearning communities.

H3: SI has an effect on software engineering students' BI to use PA enhanced eLearning communities.

H4. FC has an effect on software engineering students' BI to use PA enhanced eLearning communities.

H5: HM has an effect on software engineering students' BI to use PA enhanced eLearning communities.

4 METHODOLOGY

4.1 Participants and procedure

The sample consisted of 137 software engineering students from universities in South Africa and Zimbabwe as shown in Table 1. A questionnaire was completed by second year students studying at different universities. The participation in the survey was voluntary. The ethical standards of the institutional research committee were followed. The students were informed that the questionnaire is anonymous, and the data collected will be used solely for research purposes (confidentiality and privacy issues were followed). Students who accepted were placed in a WhatsApp group where the link for the questionnaire was posted. Anonymity was guaranteed because no personal information was added when students were submitting their responses.

4.2 The research instruments

The data were collected using the UTAUT2 questionnaire as described by [15]. The same items were operationalized to the context of this study. The questionnaire consisted of two parts. The first part consisted of 32 questions (items) to collect the data about the different constructs. Of the 32 items, 4 items measured PE, 4 items measured EE, 3 items measured SI, 4 items measured FC, 3 items measured HM, 3 items measured PV, 4 items measured HT, 3 items measured BI, and 4 items measured USE behavior. In responding to the items, the students were rating their views on a 5-point Likert-type scale (1 = strongly disagree to 5 = strongly agree). The second part of the survey question 33 and 34, were designed to collect demographic data namely gender and social category. The questionnaire was created and distributed using survey monkey link as well as hard copies. A total of 200 questionnaires we distributed and 148 were returned, 11 of them were not properly completed and were discarded.

The content validity of the questionnaire was evaluated by eleven experts and lecturers in the field of software engineering and information systems development, and blended learning. The questionnaire was found to be reliable; the questionnaire's Cronbach's alpha coefficient was calculated, and it was (0.936).

4.3 Data analysis

In terms of the demographics of the participants, of the 137 students participating in this study, 72.3% were female and 27.7% were male.

The validity of the model was assessed using Amos for both Convergent validity and discriminant validity. For convergent validity, the FL, CA, CR and AVE values were calculated. FL in all items were higher than 0.70. For all constructs, the CA reliability coefficients were higher than 0.70. In addition, the CR and AVE indexes were above 0.70 and above 0.50 respectively for all constructs. The results showed that convergent validity was at an optimal level. The index was evaluated using the square roots of the AVE. The square roots of AVE of factors were found to be greater than the correlational coefficient of the factors; because of that we could state that there was an excellent discriminant validity. The excellent model that emerged had the values CMIN/DF 1.794, CFI 0.936, SRMR 0.060, RMSEA 0.076, PClose 0.011

Structural Equation Modeling (SEM) was used to analyze the study hypotheses. The significant level was set at $P \leq 0.05$. The results of the structural model test are as presented in fig 3 below. The PE ($\beta = 0.144$, $P = 0.069$), EE ($\beta = 0.128$, $P = 0.273$), SI ($\beta = 0.080$, $P = 0.249$), FC ($\beta = 0.164$, $P = 0.216$) and HM ($\beta = 0.368$, $P \leq 0.01$).

In this model only HM constructs had a significantly positive effect on the students' behavioral intention to use eLearning community enhanced with pedagogical agents. PE was found to be at the borderline considering a P value of 0.05.

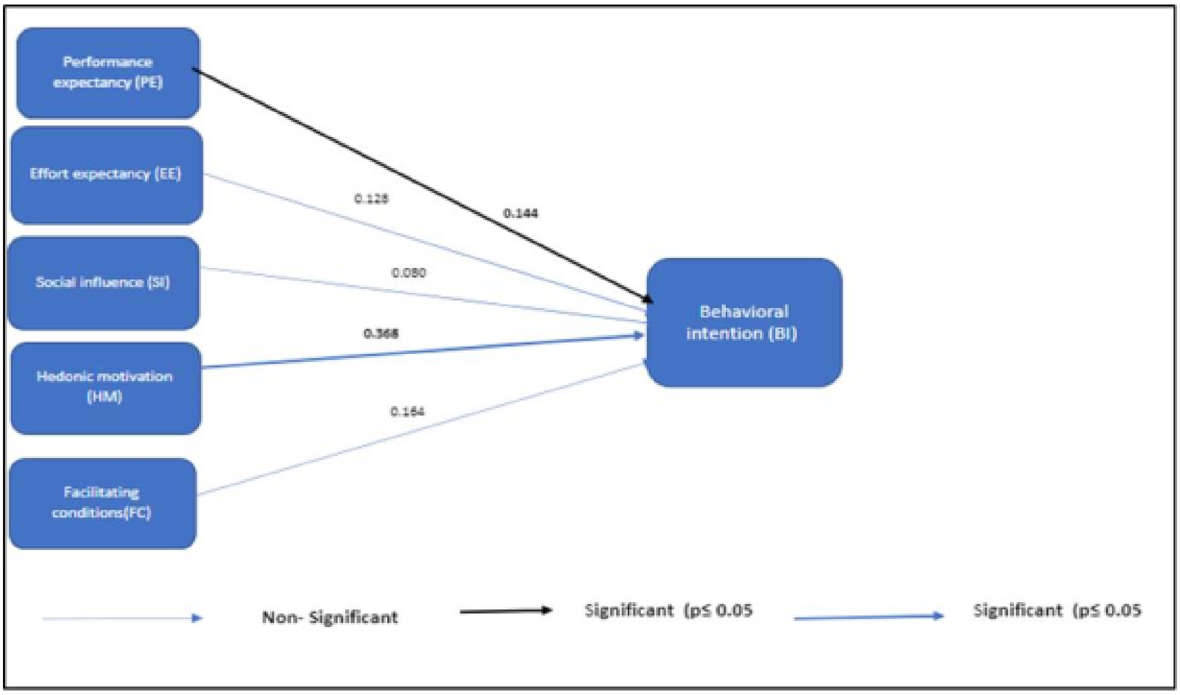

Fig 3: Structural model results

5 DISCUSSION

The results revealed that performance expectancy (PE) had a positive effect on the students' behavioral intention to use such PA enhanced communities. Although this was a border liner, this could be due to the sample size, since only 137 learners were used in this study, this finding was in line with [16] and [17].

The study revealed a significantly positive effect of HM on the students' behavioral intention to use eLearning communities enhanced with PAs. This finding was also in line with findings of [16].

However, EE had no effect on the students' behavioral intention to use communities enhanced with pedagogical agents. These results were in line with other studies that found no effect of EE on behavioral intention to use a new technology [17].

Also, social influence had no effect on the students' behavioral intention to use such communities. This was consistant with [16],[17] who also found the same results.

The findings of this study showed that software engineering students are willing to use eLearning communities that are enhanced with pedagogical agents as an elaboration of multimedia.

This study was not without limitations, some of which include the use of a self-reporting scale to assess the behavioral intention to use the community.

Having found the factors affecting intension to use PA enhanced communities, our suggestions for future work include investigation of the influence of other factors such as gender and social categories on the acceptance of such communities. We therefore recommend investigations to find if the usage of such communities will translate into some forms of educational benefit for the learners.

Caution must be taken when trying to generalize the findings to the whole of African learners and for all study domains, since only software engineering students from South Africa and Zimbabwe universities were involved.

6 CONCLUSION

This study revealed that the model emerged from the unified theory of acceptance and use of technology 2 (UTAUT2) is applicable for studies that seek to investigate the factors influencing the acceptance of eLearning communities designed using alternative elaborations of multimedia in different study domain.

Only PE, and HM, constructs had an effect on behavioral intention to use eLearning communities using pedagogical agents.EE, SI, FC, PV, and HT constructs have no effect on the software engineering students' intention to use such communities. Our findings were consistent with other studies.

This study can be used as a good reference for other studies researching on eLearning community design, multimedia integration, and eLearning acceptance in other study domains.

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PEER MENTORSHIP: EXPLORING THE UNMET NEEDS OF CURRENT MENTEES DURING COVID-19

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ABSTRACT

Peer mentorship is a mutually beneficial relationship that allows two individuals who are at approximately the same experience level to interact with one another with the goal of providing personal, professional, or both types of support. It has been found that peer mentorship within academic settings have generally positive retention, persistence, and student experience outcomes for both mentors and mentees. While peer mentoring research and initiatives are growing, very few instances exist of determining student perceived needs regarding peer mentorship. As such, at a western institution in the United States, students were surveyed to self-report their perceived peer mentorship needs. This survey occurred during Fall 2021, just after the onset of the COVID-19 pandemic.

Out of 223 participants, 79 students indicated that they currently had a peer mentor at the time the survey was administered. Students were given both a definition and examples of peer mentorship before indicating they had a peer mentor. Their mentors may have been formally assigned through an existing program at the college of engineering of interest or informally obtained through their own efforts. These 79 participants were asked what additional support they wish their peer mentor could provide. Through phenomenological analysis of open-ended responses, common avenues for additional support were determined. These findings allowed for development of recommendations for shaping the future implementation of more targeted and beneficial peer mentoring initiatives. The recommendations include providing flexibility in peer mentorship, training on resources and events, and a variety of peer mentoring opportunities early and consistently.

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1 INTRODUCTION

1.1 Defining Mentorship

The National Academies of Sciences, Engineering, and Medicine state, “There is a gap between what we know about effective mentoring and how it is practiced in higher education” [1, p. x]. The variety of definitions of mentorship and lack of needs assessments throughout research serve as evidence of that gap in knowledge. In general, mentorship is accepted as a mutually beneficial relationship in which two or more people work together to support eachother in their personal and/or professional growth [1]. Peer mentorship specifically is when the participants in mentorship are at the same or nearly the same stage of their journey [1], [2], namely in this study, their academic career. This is in contrast to traditional mentorships where the mentor may be more advanced, for example in age or experience, which may cause a power differential to exist when compared to the mentee [2].

Peer mentorships can be advantageous in the sense that participants in the mentorship may feel an increased level of interpersonal comfort when compared to traditional mentorships [1]. It has also been found that peer mentorship can positively increase self-efficacy, satisfaction, retention, success, and support, both for mentors and mentees [1], [3]–[6]. This is especially important in cases with underrepresented students who may traditionally receive less mentoring support [1], [7], [8]. Unfortunately, oftentimes peer mentorship is underutilized as a resource for supporting students, even though peer mentoring may be a more practical method of mentoring when compared to traditional mentoring in academic settings. Administrators, faculty, and staff may have overwhelming responsibilities to manage, which may not include, recognize, or prioritize mentoring with the same level of significance as other duties, such as teaching and research [1]. Peer mentoring allows for a lower cost method of providing support by drawing through a much larger pool of potential mentors who can effectively share similar perspectives, identities, and recent experiences while still providing role modelling in a way traditional hierarchical mentoring may not be able to [3].

1.2 Determining Needs

Throughout research in the realm of engineering peer mentorship, there is a lack of consensus on what student needs with regard to peer mentorship are; while the number of engineering peer mentorship initiatives are growing, there are few examples, especially in engineering, of student needs being examined when developing peer mentoring initiatives, as well as a lack of documentation on the continual improvement and success within these initiatives [1], [9]–[12]. As such, Christensen [9] developed a mixed methods assessment of needs for determining students’ perceived needs when it comes to peer mentoring activities. Within this study, responses from a single qualitative question, which was not explored in Christensen’s original study [9], were utilized to focus on students’ perceived gaps in support from their current peer mentors. The approach to this analysis will be discussed in the methodology section.

2 METHODOLOGY

2.1 Research Instrument & Rationale for Additional Analysis

As mentioned previously, Christensen [9] developed and validated (i.e., quantitative Cronbach's Alpha = .783; qualitative content and face validation in multiple rounds) an exploratory mixed-methods instrument to obtain students needs regarding peer mentorship. The instrument included a total of 33 quantitative Likert-scale questions, 8 qualitative questions, and 8 participant identifier questions [9]. Originally, only two of the eight qualitative questions were analyzed in Christensen's study [9], calling for a deeper dive into additional qualitative insight from other qualitative questions. The full content of the research instrument can be found in Christensen's study [9]

The first block of questions that participants were introduced to in the survey included a definition and question, as follows [9, p. 258]:

> Q2 **Peer mentorship** is a relationship between two or more people at a **similar stage** in their personal, educational, or professional development. They work together to support each other.
>
> In the case of **undergraduate engineering education,** an example of a peer mentor would be **another student** (undergraduate or graduate) that is in the **same semester or ahead of you** in their university education. This person could either be simply someone you **consider** to be a peer mentor or someone who has been **formally** assigned as your peer mentor.
>
> Do you currently have a **peer mentor**?

Participants could choose one of four options for "Yes, I have a peer mentor", which indicated whether their peer mentor was in engineering at this institution or not, or "No, I do not have a peer mentor" [9, p. 258]. Based on their response to this question, participants were given a block of questions, depending on whether they responded with one of the "yes" options or the "no" option. While multiple questions were asked in each of these blocks, the focus of this research paper is on the perspective of those who chose one of the four "yes" options. The qualitative question responses analyzed were in response to the question "What additional support do you wish the peer mentor could provide?" [9, p. 270].

2.2 Research Question

The qualitative question of interest stated previously provides an opportunity to explore gaps that exist in current peer mentoring relationships. These relationships may have been self-established through personal networks or they may have been formally assigned by the small, existing program at the institution of interest. As such, the research question for this analysis was, "What common additional support are students who currently have a peer mentor in need of?"

2.3 Researcher Positionality

The first author for this publication was a part of the engineering student population of interest studied while completing undergraduate and graduate studies. This allowed her to bring a unique, insider perspective [13] with a variety of personal experiences as a student, leader, and instructor, both in the classroom and in extracurricular activities. As such, she was intentional about keeping her positionality in mind throughout the study to allow for ethical analysis. The second author brought necessary experience in mentorship, teaching, and research to further verify and expound the findings in an impactful way. As a team, the authors acknowledge the gap in peer mentorship and recognize the critical nature of exploring and sharing well-researched recommendations for the future effective implementation of peer mentoring initiatives.

2.4 Recruitment

Recruitment and research study procedures were approved by the Utah State University Institutional Review Board (IRB) [9]. Because of the timing of the study, all recruitment and survey participation happened virtually because of the COVID-19 pandemic hybrid learning situation. All survey responses were completely anonomyous. Of the respondents, 199 participants shared their information in a separate form, not tied to their survey response, to enter a gift card randomized drawing. All the participants were undergraduate students in the College of Engineering at a western institution of the United States. Of the 325 survey submissions, 223 responses were kept for further analysis after cleaning the data. Of the 223 complete responses, 79 participants indicated “yes” to the question “Do you currently have a **peer mentor**?” These 79 participant responses are the focus of this study. Of the 79 participants, only 5 (6.3%) left their response blank to the question of interest. The demographic information for all 223 participant responses as well as the 79 participants of interest are shown in Table 1. This population was considered representative within the university of interest as well as United States averages where applicable [9].

2.5 Qualitative Analysis Approach & Coding Procedures

The purpose of the qualitative coding was to determine the common experiences among participants when they were asked about additional support needed from their peer mentoring relationships. Thus, similar to Christensen [9], a phenomenological approach was taken. Using phenomenology-like strategies allowed the researchers to summarize the essence of the peer mentoring experience of students at the institution of interest [14]. Recognizing the first author’s positionality as an insider to the college of engineering of interest, a hermeneutic approach was chosen to allow the researcher to interpret in conjunction with her experiences and background, yet always being aware of the influence those experiences may have on the analysis [15].

Of the 79 responses, 30 were randomly chosen, organized, and initial coded on a participant-by-participant basis to find significant ideas within the data, remaining open and preserving student perspectives by using in vivo coding [16]. The initial in vivo codes with conceptual similarity were then focused coded into thematic categories [16]. A codebook was developed to describe the categories. The focused coding results and codebook were provided to two undergraduate researchers external to the institution of interest to perform intercoder agreement to further check and correct for any potential biases [16]. This process resulted in an average agreement of 92% across the 30 responses, which is considered adequate [16]. The commentary for misalignment was considered in order to come to a consensus on the refinement and assignment of focused codes. The refined codes were then used to code the full 79 participant responses by the primary author. Additional codes were added and categories were rearagged as necessary, resulting in a final total of eight coding categories, which will be provided in the results.

Table 1. Demographic information for all 223 participants (abbreviated "part.") and the 79 participants who indicated that they currently have a peer mentor [9]. *While more options may have been included in the question statement, only responses that participants chose are shown in the table. All other options can be found in Christensen* [9].

Year in Undergraduate Engineering			**Declared Major**		
Category	**All Part.**	**"Yes" Part.**	**Category**	**All Part.**	**"Yes" Part.**
Freshman	19.7%	16.5%	Mechanical	55.6%	58.2%
Sophomore	13.0%	13.9%	Civil / Environmental	18%	11.4%
Junior	40.4%	39.2%	Biological	6.7%	10.1%
Senior	24.2%	25.3%	Electrical / Computer	15.7%	15.2%
Other	2.7%	5.1%	Intend to Pursue	0.9%	0.0%
			Other	3.1%	5.1%
Self-Identified Gender Identity			**Of Hispanic, Latinx, or Spanish Origin**		
Category	**All Part.**	**"Yes" Part.**	**Category**	**All Part.**	**"Yes" Part.**
Male	74.0%	72.2%	Yes	3.0%	5.0%
Female	23.8%	25.3%	No	90.0%	89.0%
Prefer not to	2.2%	2.5%	Prefer not to answer	7.0%	6.0%
First Generational Status			**Race**		
Category	**All Part.**	**"Yes" Part.**	**Category**	**All Part.**	**"Yes" Part.**
Yes	7.6%	6.3%	White	91.0%	92.4%
No	91.5%	92.4%	Person of Color	3.2%	2.5%
Prefer not to	0.9%	1.3%	Prefer not to answer	5.8%	5.1%

3 RESULTS & DISCUSSION

This section contains the results and discussion of the qualitative coding analysis. All participant quotations that are communicated in this paper are direct copies of survey responses; thus, any spelling or grammatical errors are included. As previously mentioned, eight final coding categories were established, which are shown in Table 2 with frequency counts and representative quotes. Overall, there were 81 total code occurrences amidst the 74 non-blank participant responses.

When examining the additional needs not met by the participants (Table 2), different types of needs are recognized, alluding to Maslow's Hierarchy of Needs [17], [18]. Students mentioned physiological needs, such as finances and food (Table 2, Participants1 & 59) and others mentioned esteem needs, such as being told they are doing a good job (Table 2, Participant 26).Others had belongingness and love needs that could come through friendship and informal socializing (Table 2, Participants 47 & 60) as well as professional connections (Table 2, Participants 43 & 74). Many students desired more guidance and help in self-actualization, such as determining future paths, classes to take, and how to take advantage of resources in building their future self (Table 2, Participants 53, 63, & 20). Finally, many of the students felt their needs were being met or were unsure how a peer mentor could help (Table 2, "No Suggestion" row). This emphasizes the overall complexity of developing peer mentoring initiatives to meet a variety of students' needs.

3.1 Recommendations & Implications

As structured in Garringer et al. [19], there are fundamental best practices in developing mentoring programs. The process of implementing these best practices allow adequate delivery of the perceived additional support reported by students in the aforementioned analysis. The six standards of practice are: (1) recruitment; (2) screening; (3) training; (4) matching and initiating; (5) monitoring and support; and (6) closure [19]. A proposal of how these six standards of practice are connected to each of the coding categories (Table 2) are shown in Fig. 1. While exploratory in nature, this figure gives an idea of the many spaces available within peer mentoring initiatives that students needs can be met through development, planning, monitoring or adjusting.

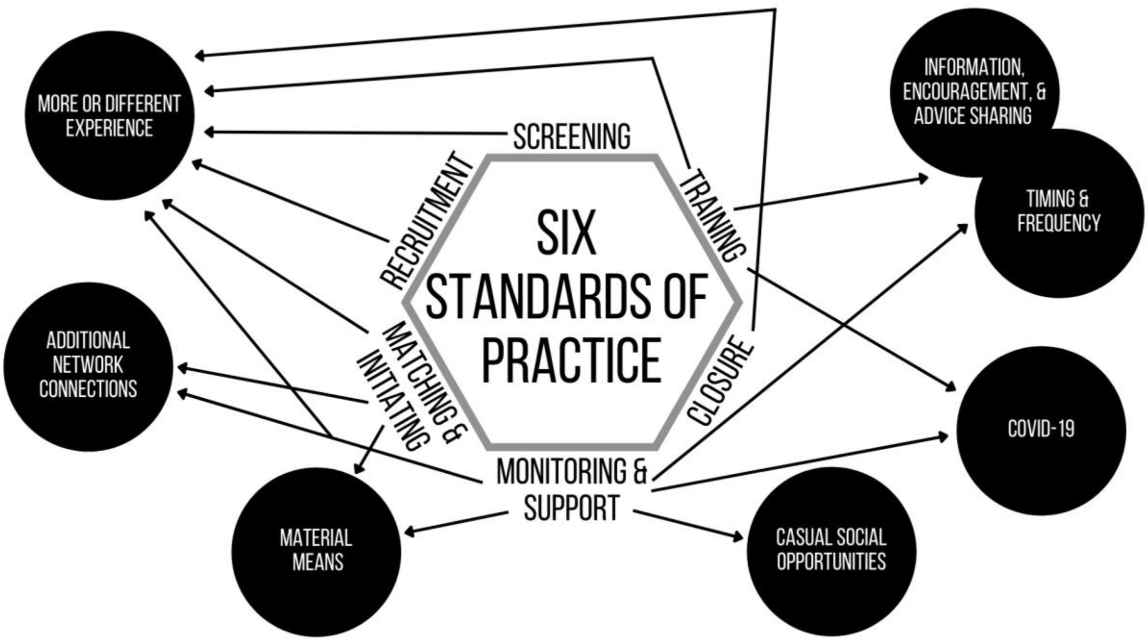

Fig. 1. Connections between the six standards of practice for developing and sustaining peer mentoring initiatives (sides of hexagon) and coding categories (circles). Coding categories that are touching have the same associated practices.

Table 2. Coding categories with frequencies, definitions, and representative quotes included

Code Category *(Frequency)*	**Definition**	**Representative Quote(s)**
No Suggestion *(37)*	Unsure of additional support that could be provided or they were satisfied with the support their current mentor(s) were providing	• "None. I feel like they cover all my needs" (Q16, Participant 2) • "I'm not sure." (Q16, Participant 41) • "I literally don't know how he could have been better. He help me accelerate my career for almost three years." (Q76, Participant 76)
Information, Encouragement, & Advice Sharing *(24)*	Desired sharing of general information about events and best practices, tutoring, providing advice on classes, guiding in future opportunities and decisions, and providing encouragement	• "I just need to be told I'm doing a good job and I am on the right track even if I mess up." (Q16, Participant 26) • "I wish they could help me secure internships and help me in the professional side of Engineering." (Q16, Participant 31) • "Networking or finding temporary jobs or long term jobs that prepare me for my future as an engineer." (Q16, Participant 43) • "Advice in figuring out what specialty/subfield to pursue" (Q16, Participant 63) • "Give me some advice about classes" (Q16, Participant 53) • "Remember all the information from the classes they took so they could help me more" (Q16, Participant 34) • "More clarity as to how to use clubs and the career service center." (Q16, Participant 20)
More or Different Experience *(6)*	Desired a mentor who had more experience, was farther ahead of them in school, or was in the same field as them.	• "It would be nice to have someone from my same major, so they can help me with things specific to biological engineering" (Q16, Participant 10) • "Ahead of me in the program by a semester or a year" (Q16, Participant 48) • "Be better at some subjects than me. So it won't be as one sided." (Q16, Participant 69)
Timing or Frequency *(5)*	Desired having a peer mentor earlier or having more frequent contact with the peer mentor.	• "Earlier in my engineering career. Since we have become peer mentors it has been great but I wish it could have happened earlier" (Q16, Participant 28) • "I wish she contacted me more often, she usually only reaches out to me about once month unless I contact her first." (Q16, Participant 40)
Casual Social Opportunities *(3)*	Desire time outside of formal opportunities to interact & socialize	• "More contact outside of school classes." (Q16, Participant 47) • "Time outside of work or homework to interact as people" (Q16, Participant 60)
Additional Network Connections *(3)*	Desired additional support in connecting to potential network members	• "Having more connections outside of education." (Q16, Participant 74) • "If I were getting more help from my peer mentor it would probably be networking" (Q16, Participant 43)
Material Means *(2)*	Desired additional material means were as support	• "Financial, but we both know that won't happen." (Q16, Participant 1) • "Food?" (Q16, Participant 59)
COVID-19 *(1)*	Desired implications of COVID-19 to change	• "The major thing I wish could change is COVID, as social distancing made it hard to make those peer mentor relationships." (Q16, Participant 14)

To summarize based upon the connections shown in Fig. 1, the following three recommendations are provided to support the future development, monitoring, and implementation of peer mentoring initiatives:

- **Provide Flexibility in Peer Mentorship:** Especially when formally assigning peer mentors, allow students adequate space and opportunity to match with different or additional peer mentors.
- **Provide Training on Resources and Events:** At the beginning but also continually as new resources or events arise, provide training to peer mentors on how to use take advantage of the resources or events as well as how to adequately share them with their peer mentee.
- **Provide a Variety of Peer Mentoring Opportunities Early and Consistently:** Students need peer mentorship consistently, regardless of what stage they are in, and desire both formal (e.g., professional support, tutoring, etc.) and informal support (e.g., socializing, student life events, etc.) through a variety of ways (e.g., texting, email, face-to-face, etc.)

As these recommendations are taken into consideration, a range of student needs from Maslow's Hierarchy [17], [18] can be met by allowing for consistent, flexible, and well supported peer mentorship.

3.2 Limitations & Future Work

The primary limitation of this study is that the survey was given under COVID-19 pandemic circumstances, which may have influenced student responses since students were in an emergency hybrid learning situation. This unique perspective may also have brought to light potential impactful practices that would have not otherwise been recognized. The short-answer, anonymous qualitative question format may have provided some limitation as well since students self-reported their answer and no follow-up for elaboration or clarification was possible. This leaves room in the future to pursue more in-depth methods, such as interviewing, in exploring student perceived needs.

This analysis did not take into consideration any participant demographic information or descriptions of who their peer mentors were. Future work will examine these aspects as well as participant explanations of what their peer mentor does effectively to complement the gaps identified in this study.

4 CONCLUSION

The three recommendations provided in this study, while not comprehensive, provide a foundation for designing, monitoring, and adjusting initiatives to address potential gaps in peer mentoring relationships. By providing flexibility, training on resources and events, and a variety of opportunities early and consistently, more students can receive the support they need. Whether that is by finding different or more mentors, receiving help in both formal and informal spaces, or simply finding support earlier, the benefits associated with peer mentorship (e.g., interpersonal comfort, retention, self-efficacy, satisfaction, etc.; [1], [3]–[6]) will be expanded.

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FOSTERING THE ENTREPRENEURIAL INTENTION OF UNIVERSITY STUDENTS: THE ROLE OF CHALLENGE-BASED LEARNING APPROACH

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ABSTRACT

Building on the Theory of Planned Behavior, the aim of this paper is to investigate the moderating effect of entrepreneurship education in the relationship between attributes like attitude, social norms and perceived behavioral control, and the entrepreneurial intention of university students. Specifically, the moderation effect of entrepreneurship

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programs that adopt a Challenge-Based Learning approach is analyzed. To do so, the Italian sample of university students who participated in the 2021 Global University Entrepreneurial Spirit Students' Survey (GUESSS) was used. Results confirm that participation in entrepreneurial programs that adopt a Challenge-Based Learning positively moderate the relationship between Theory of Planned Behavior attributes and entrepreneurial intention of the students. Specifically, the results show that participation in Challenge-Based programs increases the positive effect of attitude on entrepreneurial intention.

1 INTRODUCTION

Increasingly in recent years, particular attention has been paid to the phenomenon of venture creation by young people and especially university students (Loan et al. 2021; Meyer and Krüger 2021; Wach and Bilan 2021). This phenomenon, defined as student entrepreneurship, is of particular interest because of the positive impact it can have on the local economy, especially in terms of youth employment, but also because of the important role entrepreneurship plays as a source of innovation and technological change (Schumpeter 1934). Entrepreneurship, and in particular the identification of an entrepreneurial opportunity, is crucial for technological innovation to influence economic development (Shane 2000) and high-skilled young people can give a strong contribution in this direction.

In order to foster the growth of entrepreneurship among students, universities play a key role in terms of Entrepreneurship Education (EE) (Zahra and George 2002; Colombelli et al. 2021b). In this context, it is crucial to identify both behavioral and skills-related aspects that can influence students' decisions to pursue entrepreneurial careers. Many studies show that Entrepreneurship Education fosters students' propensity to pursue entrepreneurial careers and is effective in enabling students to acquire or improve their entrepreneurial skills and abilities (Martin et al. 2013; Bae et al. 2014). Kuratko (2005) through his study demonstrated how such competencies and skills can be shaped by education. Other works have tryed to develop models capable of predicting entrepreneurial behavior through entrepreneurial intention (Shapero and Sokol 1982; Krueger and Brazeal 1994). Intention is indeed considered the best predictor of behavior (Krueger et al. 2000). In particular, in the context of entrepreneurship, entrepreneurial intention is able to predict entrepreneurial action (Kautonen et al. 2015).

In the context of student entrepreneurship, the understanding of the elements that influence entrepreneurial intention is of particular importance, so as to design EE programs that are more effective in improving that intention. The most widespread model that allows us to investigate the drivers that guide the development of an intention and consequently a behavior is the Theory of Planned Behavior (TPB) (Ajzen 1991). This theory is based on three elements: attitude, social norms and perceived behavioral control. Schlaegel and Koenig (2014) suggest that these three elements underpin the development of entrepreneurial intention. The model of intention based on the Theory of Planned Behavior can be moderated by other elements and situations that influence the relationship between the three predictors and intention (Mathur 1998). One of these elements is Entrepreneurship Education. Previous works have revealed that TPB and EE can influence each other in order to improve students' entrepreneurial characteristics, including intention (Gorman et al. 1997; Kuratko 2005; Rauch and Hulsink 2015).

However, the literature investigating the effectiveness of EE on entrepreneurial intention and in relation to the Theory of Planned Behavior, has mainly neglected the impact of individual educational approaches. Consequently, the impact of entrepreneurial education programs could be investigated in relation to specific learning approaches, because different approaches may have different effectiveness in improving skills and intention of students (Rae and Carswell 2000). One of the approaches implemented in EE is Challenge-Based Learning, a learning methodology in which students learn in a real context, and deal with challenges and real problems proposed by them or by existing firms (Chanin et al. 2018; Colombelli et al. 2022a).

In line with these arguments, the aim of this article is to investigate the effectiveness of the Challenge-Based Learning approach on the development of entrepreneurial intention in the context of the Theory of Planned Behavior. Specifically, we sought to understand whether participation in a Challenge-Based Learning entrepreneurship program can intensify the effect of attitude, social norms and perceived behavioral control on students' entrepreneurial intention.

To investigate this, the database of the GUESSS (Global University Entrepreneurial Spirit Students' Survey) 2021 project was used, specifically the data collected in Italy on about 30 universities for a total of 346 valid observations. The data were analyzed through t-tests and multiple linear regressions. The results show that participation in a Challenge-Based Learning program increases the positive effect of entrepreneurial attitude on students' entrepreneurial intention.

The article is structured as follows. In section 2 the theoretical framework is described. Section 3 presents the methodology, describing in detail the sample used and the analyses carried out. Then, in section 4, the results of the study are analyzed. Finally, in section 5, the conclusions and limitations of the study are presented.

2 THEORETICAL FRAMEWROK

In the literature, there is an increasing interest in investigating the drivers that lead young people, and in particular students, to embark on an entrepreneurial career by starting their own business. This interest is also focused on identifying EE practices in order to exploit these drivers. In this context, scholars place great attention on intention models, because they are the most robust models to predict the intention to start a business (Krueger 2007; Koe and Majid 2014). Ajzen (1991) developed what is considered the theoretical reference model regarding intentions as main predictors of behavior, also in the entrepreneurial field (Entrialgo and Iglesias 2016). This model is based on the Theory of Planned Behavior and states that the greater the intention of an individual in undertaking a certain behavior, the greater the probability that this behavior will be performed. The TPB model adds a second concept to this first statement, namely that an individual's intention is in turn influenced by three elements: attitude, social norms and perceived behavioral control.

Attitude is the concept that represents perceptions of personal convenience with regard to performing a behavior. The more positive the perception of the outcome that can be obtained from a behavior, the greater should be the attitude towards that behavior and consequently the intention to perform it (Autio et al. 1997; Krueger et al. 2000; Luthje and Franke 2003; Segal et al. 2005; Pruett et al. 2009). The second concept is social norms, i.e. the social pressures from social reference groups (e.g. family and friends) that one perceives when performing a certain behavior (Ajzen 1991). With respect to attitude, social norms are not always agreed upon by researchers with regard to their impact on entrepreneurial intention. Ozaralli and Rivenburgh (2016) and Kautonen et al. (2015) in their studies point out that social norms are a relevant predictor of entrepreneurial intention. At the same time, in other studies a weak or even non-significant relationship between these two elements emerges (Krueger et al. 2000; Autio et al. 2001; Liñán and Chen 2009; Nishimura and Tristán 2011; Wach and Wojciechowski 2016). The third and final concept underlying the Theory of Planned Behavior is perceived behavioral control. This concept represents the ease or difficulty that the individual perceives in performing a certain behavior (Bandura 1986; Swan et al. 2007). The literature shows how perceived behavioral control has a positive and significant impact on entrepreneurial intention (Fayolle and Gailly 2004).

Several studies in the literature demonstrate the direct impact of the three constructs of the TPB on entrepreneurial intention (Kolvereid 1996; Krueger et al. 2000; Lüthje and Franke 2003; Souitaris et al. 2007; Kautonen et al. 2015). Yet, the impact of attitude and perceived behavioral control is more widespread and relevant than that of social norms. Consequently, this evidence allows the following hypothesis to be formulated:

H1: There is a positive relationship between attitude, social norms and perceived behavioral control, and entrepreneurial intention.

Within the context of TPB and entrepreneurial intention, entrepreneurship education plays a key role. Studies in the literature show that there is a positive and significant impact between Entrepreneurship Education and entrepreneurial intention (Turker and Selcuk 2009; Gubik 2014; Maresch et al. 2016; Kramarz et al. 2019; Karyaningsih et al. 2020). In particular, Bae et al. (2014) state that knowledge acquired through education is decisive in developing entrepreneurial intention. Furthermore, Entrepreneurship Education acts as a moderator by influencing the relationship between the elements of the Theory of Planned Behavior and entrepreneurial intention. This moderating effect is found to enhance the positive impact of attitude on entrepreneurial intention (Maresch et al. 2016; Shah et al. 2020), because in EE programs entrepreneurship is positively positioned relative to other career options, reinforcing positive attitudes for an entrepreneurial career. In addition, participation in EE programs allows students to improve their knowledge about entrepreneurship by becoming more aware of embarking on an entrepreneurial career and thus making them less dependent on the opinions of social groups (Kautonen et al. 2015). Consequently, the moderation effect in this case leads to a reduction in the positive effect of social norms on entrepreneurial intention (Shah et al. 2020). Regarding to perceived behavioral control, EE enables the acquisition of knowledge and skills, increasing confidence in own abilities and further improving entrepreneurial intention (Shah et al. 2020).

This evidence allows to understand the relevance of Entrepreneurship Education. However, when analyzing the impact of Entrepreneurship Education in these studies, it is done by considering education programs without distinguishing between different training approaches. Within this study we want to focus on the Challenge-Based Learning approach, an experiential learning methodology that allows students to apply knowledge and skills in a real context. Compared to other learning approaches, such as Project-Based Learning and Problem-Based Learning, it is characterized by the joint presence of a practice-based methodology and a real context due to the presence of a challenge proposed by existing companies.

Studies in the literature demonstrate the positive impact of Challenge-Based Learning on students' entrepreneurial intention (Johnson et al. 2009; Palma-Mendoza et al. 2019; Martinez and Crusat 2020; Colombelli et al. 2021a; Colombelli et al. 2022a). Moreover, these studies show that Challenge-Based Learning improves students' entrepreneurial skills and competences. A result that according to Bae et al. (2014) would favor the development of entrepreneurial intention.

Given the evidence from the literature on the moderating effect of EE in the relationship between TPB and entrepreneurial intention and the relevance of the Challenge-Based Learning in the context of EE. The study presented in this paper aims to investigate the influence of the Challenge-Based Learning approach within the relationship between Theory of Planned Behavior and entrepreneurial intention. Accordingly, the following hypothesis are proposed:

H2: Participation in a Challenge-Based Learning course increases the positive effect of attitude on entrepreneurial intention.

H3: Participation in a Challenge-Based Learning course decreases the positive effect of social norms on entrepreneurial intention.

H4: Participation in a Challenge-Based Learning course increases the positive effect of perceived behavioral control on entrepreneurial intention.

3 METHODOLOGY

3.1 Sample

This study was carried on using the data collected through the survey conducted by GUESSS in 2021 in Italy.

The GUESSS survey is part of an international research project on student entrepreneurship, conducted since 2003 by the "Swiss Institute for Small Business and Entrepreneurship" of St. Gallen University: it covers different research topics, from entrepreneurial intention to nascent entrepreneurship, highlighting factors of influence at the individual, family, contextual and university levels.

The sample includes 3294 students who answered the questionnaire and of these 32% declare to have at least a parent who is an entrepreneur; the average age of the participants is 24 years and in terms of gender, males represent 52% of the sample while females are 48% (Fig. 1). The survey has been proposed to all the students of the Italian participating universities, thus belonging to different fields of studies. The distribution of students by fields of study (Fig. 2) is skewed toward the engineering (incl. architecture) and economics areas (58,4%), compared to the other areas, which individually count less than 10%. Considering the level of studies, more than 63% of participants are pursuing a Bachelor's degree, 35% a Master's degree and less than 2% a PhD or an MBA (Fig. 3). Finally, analyzing the role of Entrepreneurial Education (EE), Figure 4 shows that 1829 students (~55% of the total) have never taken a general entrepreneurship course while 346 have at least once participated in a Challenge-Based Learning course.

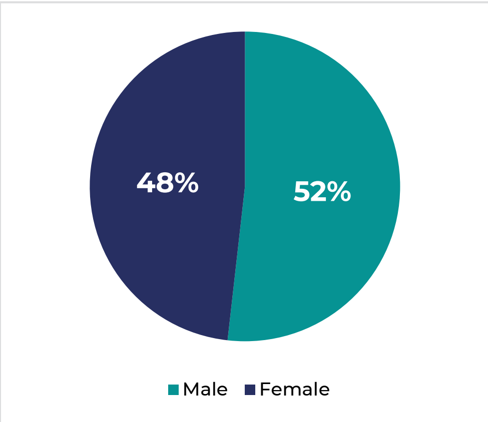

Fig. 1. % distribution of students by gender

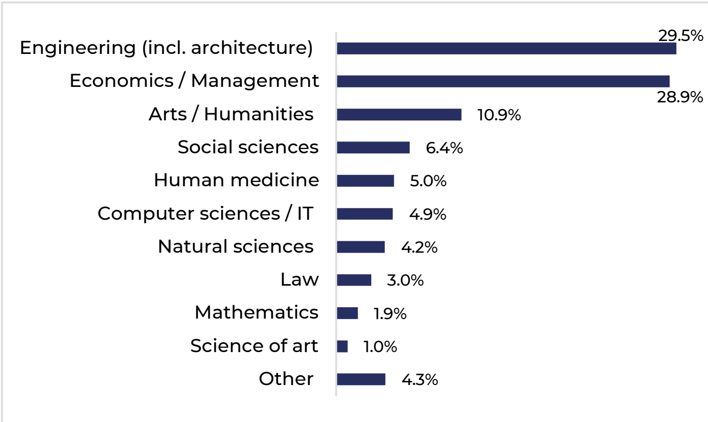

Fig. 2. % distribution of students by field of study

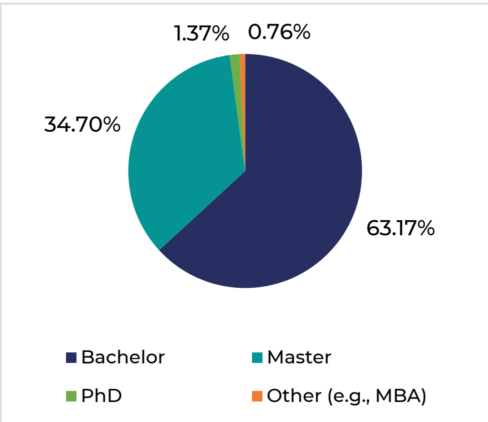

Fig. 3. % distribution of students by level of study

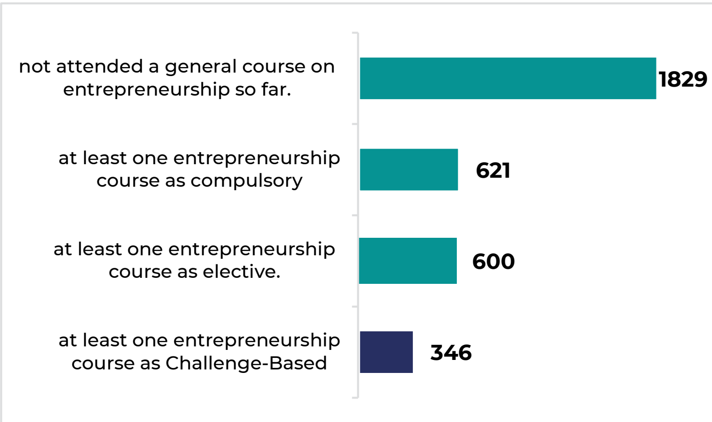

Fig. 4. % distribution of students by participation to EE courses

3.2 Description of variables and analysis

The variables of the econometric analysis of regression were built starting from the proposed research model in the theoretical framework section.

The dependent variable of the model is the Entrepreneurial Intention (EI) which is assumed to capture the motivational factors that influence a behavior: EI is an indication of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behavior.

The variables of the Theory of Planned Behaviour, in this research considered independent, are Attitude (ATT), Perceived Behavioral Control (PBC) and Social Norms (SN): they respectively refer to the perception of personal convenience, perceived ease or difficulty and perceived social pressure to perform or not to perform the entrepreneurial behavior.

The GUESSS questionnaire has a set of questions (or items) – prevalidated by literature - for each of these 4 variables cited above. Each question allows for the measurement of a single item of the considered variable and each question can be answered on a Likert scale from 1 to 7 (1=totally disagree, 7=totally agree). The arithmetic mean of the item values was calculated to obtain the value of these variables.

The Confirmatory Factor Analysis and the Cronbach's α - calculated for each of these 4 variables and higher than 0.7 for all of them - gave further confirmation of the reliability of the scales used.

Given the continuous nature of the dependent variable, the model's assumptions has been tested via a multiple linear regression.

Considering that the main focus of this work is to analyze the impact of Entrepreneurship Education courses, four dichotomous independent variable keys have been built, namely EE_general, EE_elective, EE_compulsory, EE_challenge: they respectively assume the value 1 if the subject has participated at least once in a general, elective, compulsory or Challenge-Based Learning course and 0 otherwise.

In addition, control variables such as age (continuous), gender (dummy), level_study (categorical), field_study (categorical), parent_entrepreneur (dummy) and home_university (dummy) were included to investigate aspects of individual character and socio-demographics and to improve the inference of the OLS estimator.

Finally, in order to meet the requirements of multiple regression, the correlation matrix and the calculation of Variance Inflation Factors – all less than 5 – excluded the existence of imperfect collinearity or multicollinearity.

4 RESULTS

T-test

As anticipated in the methodology section, statistics were initially developed to compare the average values of students' entrepreneurial variables distinguishing between those who participated and those who did not participate in Challenge-Based Learning courses.

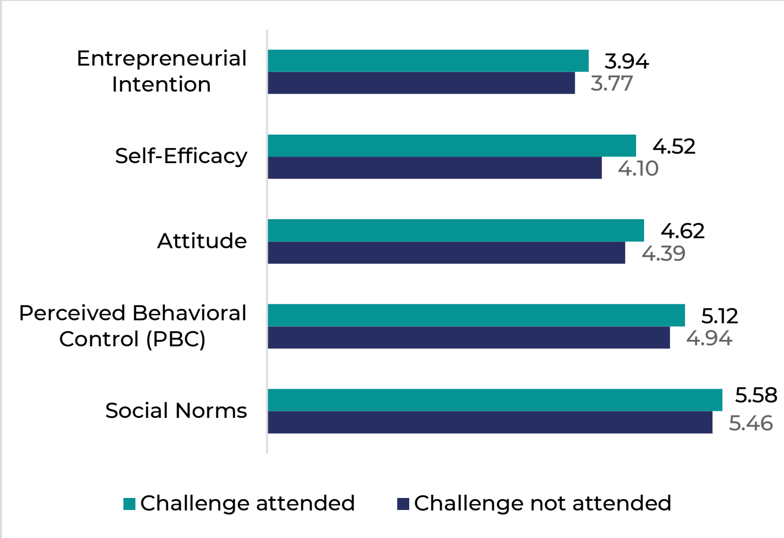

Fig. 5. Entrepreneurial characteristics by participation in challenge-based courses

Figure 5 reveals the existence of an always positive difference between the averages of entrepreneurial attributes distinguished for participation in a Challenge-Based Learning course. Similarly, the same trend emerged distinguishing by participation in general, elective or compulsory courses.

To test whether such differences between entrepreneurial attributes, in addition to being positive, were also statistically significant, a t-test was performed.

With regard to the Challenge-Based Learning courses, between participants and non-participants, there was a positive and statistically significant difference, at the minimum level of 5%, between the averages of all entrepreneurial attributes; an exception is the difference between the averages on entrepreneurial intention, which was only significant at the 10% level. The most marked increase concerned entrepreneurial self-efficacy: this preliminary evidence shows how the practical approach of Challenge-Based Learning courses instils a greater awareness of one's entrepreneurial skills.

Table 1. Output t-test by (EE_challenge)

Variables	**Average Challenge attended**	**Average Challenge NOT attended**	**diff = Avg Challenge Attended - Avg Challenge NOT Attended (H0: diff=0)**	**p-value Ha: diff>0**
Entrepreneurial Intention	3,94	3,77	0,17	0,06
Self-Efficacy	4,52	4,10	0,42	0,000
Attitude (ATT)	4,62	4,39	0,23	0,009

Perceived Behavioral Control (PBC)	5,12	4,94	0,19	0,007
Social Norms (SN)	5,58	5,46	0,12	0,037

The results obtained are in line with the reference literature (Colombelli et al. 2021a, 2022a, 2022b). Further distinguishing by field of study, Challenge-Based Learning courses even have negative effects on social or natural sciences students; on the other hand, the only category on which the effects are all positive is the sample of engineering (incl. architecture) and business students. On these categories, the most statistically significant effects of CBL courses concern the PBC, social norms and self-efficacy variables. These preliminary results confirm that the range of action of the Challenge-Based Learning courses is still limited to the sphere of entrepreneurial skills and less oriented to that of intentions-actions.

Finally, distinguishing by participation in general, optional and compulsory entrepreneurship courses, with the exception of social norms, the differences between the averages of the two groups were all positive and statistically significant at the level of 1%.

Regression Analysis

Results of the regression analysis are shown in Table 5. Models I and II are calculated in the absence of moderation effects while III and IV are the full models.

The results show that the Theory of Planned Behaviour is confirmed: having a positive entrepreneurial attitude (ATT) and a high perceived behavioral control (PBC) - that is, believing in the feasibility of one's idea - increases entrepreneurial intention (EI). A social opinion that encourages entrepreneurship more, on the other hand, would lower the level of entrepreneurial intention but the effect is not statistically significant except in model IV: however, in this model, the joint hypothesis test ($F = 1.19$; p-value = 0.3133) - conducted by imposing social norms = 0 & its interactions (*EE_elective X SN, EE_compulsory X SN, EE_challenge X SN*) = 0 - confirms the null hypothesis: the overall effect of social norms on entrepreneurial intention is therefore not significant.

Let us now consider the effect of entrepreneurship courses. As shown in model I, participation in general entrepreneurship courses has a positive and significant effect ($p<5\%$) on entrepreneurial intention. Although in model III the coefficient of EE_general is not statistically significant, the joint hypothesis test ($F = 2.37$; p-value = 0.0507) - conducted by imposing EE_general = 0 & its interactions (*EE_general X Attitude, EE_general X PBC, EE_general X SN*) = 0 - confirms the significance of the overall positive effect of EE_General on EI.

Unlike elective or Challenge-Based Learning courses, in general entrepreneurship courses there is less self-selection: participants in general courses usually arrive with a low level of entrepreneurial intention that is increased by participation in the course.

Also, for this reason, participation in specific entrepreneurship courses (elective, compulsory, challenge-based) has not statistically significant effect on entrepreneurial intention. However, considering the time gap between intention and its translation into entrepreneurial action, it is good to conduct longitudinal studies to assess the direct impact of these specific entrepreneurship courses. Considering instead the moderating role played by Entrepreneurship Education, it emerges that only participation in a Challenge-Based Learning course modestly increases the positive effect of attitude ($\beta = 0.0677$, $p<0.10$) on entrepreneurial intention; the remaining interactions are not statistically significant. Finally, the analysis of the control variables shows that graduates compared to postgraduates, males compared to females, those who have a parent who is an entrepreneur compared to those who do not, the former all have a higher level of entrepreneurial intention than the latter.

Dependent Variable	**Entrepreneurial Intention (EI)**			
Variable	**Model I**	**Model II**	**Model III**	**Model IV**
Attitude (ATT)	*0,9099**** *(0,1265)*	*0,9124**** *(0,0126)*	*0,9185**** *(0,0154)*	*0,9144**** *(0,0148)*
Perceived Behavioral Control (PBC)	*0,0669**** *(0,0184)*	*0,0700**** *(0,0184)*	*0,0474*** *(0,0231)*	*0,0677**** *(0,0222)*
Social norms (SN)	*-0,0242* *(0,0166)*	*-0,0247* *(0,0167)*	*-0,0231* *(0,0216)*	*−0,0376** *(0,0200)*
EE_general (Base: Not Attended)	*0,1020*** *(0,0399)*		*0,0667* *(0,2178)*	
EE_general X Attitude			*-0,0253* *(0,0258)*	
EE_general X PBC			*0,0559* *(0,0375)*	
EE_general X Social_norms			*0,0002* *(0,0334)*	
EE_challenge (Base: Not Attended)		*-0,0537* *(0,0594)*		*-0,3392* *(0,3343)*
EE_challenge X Attitude				*0,0677** *(0,0411)*
EE_challenge X PBC				*0,0217* *(0,0531)*
EE_challenge X Social_norms				*-0,0234* *(0,0533)*
EE_elective, EE_compulsory		*YES*		*YES*
EE_elective ## (ATT, PBC, SN)				*YES*
EE_compulsory ## (ATT, PBC, SN)				*YES*
Control Variables	*YES*	*YES*	*YES*	*YES*
_cons	*-0,9908*	*-0,6519*	*-0,9691*	*-1,8044*

	(9,9359)	*(10,1271)*	*(9,8542)*	*(10,1619)*
Observations	*2473*	*2473*	*2473*	*2473*
R-squared	*72,15%*	*72,09%*	*72,18%*	*72,18%*

*Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1*

5 CONCLUSIONS

This paper investigates the effectiveness of Entrepreneurship Education methodologies. In particular, the effectiveness of the Challenge-Based Learning approach was investigated within the relationship between the Theory of Planned Behavior and students' entrepreneurial intention. The study was based on data collected through the GUESSS (Global University Entrepreneurial Spirit Students' Survey) 2021 project, specifically on data collected in Italy on about 30 universities. The results show that students who attended a Challenge-Based Learning program show a greater positive effect of entrepreneurial attitude on their entrepreneurial intention, compared to students who attended a program with a different approach. In general, the results confirm the findings of studies in the literature, i.e., the Theory of Planned Behavior positively influences entrepreneurial intention.

The contributions to the literature from this study are several. The first concerns the impact of the Challenge-Based Learning approach in the context of Entrepreneurship Education. This impact is still under-explored in the literature and it is essential for universities to understand it in order to foster the creation of enterprises by students (Zahra and George 2002; Colombelli et al. 2021b) and consequently foster an improvement in the economic context. A second contribution concerns the Theory of Planned Behavior, where we provide further evidence of how this theory can be a predictor of entrepreneurial intention (Schlaegel and Koenig 2014). A further contribution concerns the interaction between the Theory of Planned Behavior and Entrepreneurship Education. There are still few studies in the literature that investigate this interaction, and a closer look in this direction helps to understand the conditions for achieving a high level of effectiveness in Entrepreneurship Education.

After summarizing the results of the study and highlighting the contributions to the literature it is useful to describe the limitations of the study in the hope that they will become insights for future studies. In the literature, intention is referred to as a predictor of behavior and in this study the predictors of intention were investigated. However, there is a time lag between intention and its translation into entrepreneurial action. Consequently, it may be useful to conduct longitudinal studies in order to assess the actual impact of the Challenge-Based Learning approach on the phenomenon of venture creation by students.

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ENHANCING (FUTURE) STUDENTS' SENSE OF BELONGING TO INCREASE DIVERSITY AND INCLUSION IN ENGINEERING

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ABSTRACT

The shortage of engineering talent leads to a loss in economic output. This shortage-combat has to be fought on several fronts, one of them is attracting and retaining more currently underrepresented students. This paper discusses the need to improve a sense of belonging and to increase professional awareness, or the understanding of the different roles an engineer can take on, in order to increase diversity in engineering. Based on an extensive literature review an overview is given of previous research on this topic from an interdisciplinary perspective.

Research has shown that professional identity development has high impact on persistence and study success. Although identity development is a hot topic in engineering education research, several studies indicate that engineering students still have difficulties in grasping what it is to be an engineer and often fall back upon the rather stereotypical, harsh technological, male image. However, research also shows that it is important for students to know what to expect and value in order to develop feelings of belonging or fit. The former European project PREFER has developed promising tools in this regard. However, these tools have not been tested regarding inclusiveness.

The paper also outlines the next steps that will be taken by the authors as part of an interdisciplinary project URGENT to increase attractiveness and retention of underrepresented groups in engineering education. This URGENT project proceeds on the outcomes of the PREFER project and will focus on the attraction and retention of female students and students with a migration background.

1 INTRODUCTION

In this rapidly changing world, facing many global challenges, engineers play a crucial role. However, the demand for engineers has never been greater [1], [2]. To decrease the engineering shortage, education and industry should focus on a relatively large but unexploited talent pool that lack the opportunities necessary to prepare for engineering careers [3].

The project URGENT (UnderRepresented Groups in Engineering Technology) that was launched at KU Leuven (Belgium) aims to improve motivation and persistence for female students and students with a migration background in engineering education. Research conducted in an earlier European project PREFER (Professional Roles and Employability for Future EngineeRs) indicated that different groups might have different role preferences [4], [5] and that professional awareness (the knowledge and understanding of different engineering roles) is important in making career choices [6].

The objectives of the URGENT project are threefold. First, the project aims to increase insight into the constraints to recruitment and retention in terms of cultural or gender expectations and stereotypes. Are the initial beliefs and predispositions on engineering the same for male and female students and for students without and with a migration background? Second, possible differences in interest and motivation between the different student groups will be investigated using the recently developed PREFER tests [7], [8]. These tests were designed to initiate and stimulate reflection among engineering students about their professional identity. In order to be able to implement them in an inclusive learning environment, the tests will be evaluated on gender and cultural inclusivity and validity. Final, the third objective builds on the insights from the first two objectives and aims to develop and pilot a number of interventions in secondary schools and in university to break through the stereotypical perspectives on engineering.

In order to realise the URGENT objectives, a well-balanced interdisciplinary consortium was built involving partners from university, secondary education and industry in Belgium. Research expertise in engineering education, sociology and social psychology are brought into the project. The project is actively supported by university's central offices of Communication and Recruitment, Diversity, and Career Guidance. Also, different secondary schools, companies and STEM organisations engaged in the project, as well as ie-net, the Belgian engineering federation.

This paper reports on a literature review that laid important foundations for the project. First, the context of this study is described, emphasizing the need to increase the representation of different groups in engineering (education) (Section 2). Section 3 presents theoretical insights from sociology and social psychology regarding the importance of a sense of belonging to the engineering field. Section 4 brings the perspectives from engineering education research, in particular on professional identity development. Final, the paper concludes with a summary presenting the next steps of the URGENT project.

2 BACKGROUND

2.1 Different hurdles for different groups

The characteristics of a target group determines what actions a university should take to attract and retain different groups. For example, in 2021-2022, female students made up half of the first-year students at KU Leuven[2] but only 18,9% of the students who enrolled in a Bachelor's programme in Engineering Sciences is female and even less in the Bachelor's programme in Engineering Technology (10,2%) [9]. However, their retention is better compared to male first-year bachelor's students [10].

Engineering students with a migration background also face a recruitment problem. If we look again to KU Leuven, they make only 8,4% of the first year students in Engineering Technology (and 13,1% in Engineering Sciences) [9]. However, by a large extent, this can be explained by their underrepresentation in the higher tracks in secondary education that prepare for the engineering programmes. Since students with a migration background, on average, show lower retention at university than the students without [11], engineering faculties should try to improve the retention of this group of engineering students.

[2] KU Leuven is a comprehensive university, offering a broad range of programmes in Humanities and Social Sciences, in Biomedical Sciences, and in Sciences, Engineering and Technology.

This shows that universities should remove different barriers to increase the representation of different groups in engineering, such as barriers during recruitment for female students and hurdles during their studies for students with a migration background leading to lower retention. Removing these barriers will increase the representation of diverse groups in engineering, which will be beneficial for industry and the society at large [12].

2.2 Different groups for a smarter industry and a prosperous society

Increasing diversity in engineering, like the representation of female engineering students and students with a migration background, has never been more important. When businesses truly embrace diversity and inclusion, they create a powerful team that is unbeatable together [13] and outperform homogenous groups on complex tasks. These "diversity bonuses" include improved problem solving, increased innovation, and more accurate predictions, all leading to better results [12].Today, more effort is needed in this regard as stated by Hilary Leevers, Engineering UK chief executive [14]: "Workforce diversity improves innovation, creativity, productivity, resilience and market insight and the engineering workforce could and should be much more diverse." Also, SEFI and ASEE, the European and American Societies for Engineering Education, recognize that higher education should find better ways to retain and support individuals who are commonly underrepresented [15]. Historically, the demographic of practicing engineers has not reflected societal heterogeneity.

The recruitment of more female students and the retention of students with a migration background will improve the diversity of these groups in the community of professional engineers. This will make the industry smarter and society more prosperous. The next question is: how? Making a choice for a (future) career is a complex process, in particular when one does not feel that they belong to or fit in a (professional) group. In the next section, we look for theories and insights, in particular from the perspective from social psychology and sociology.

3 FEELING A SENSE OF BELONGING

3.1 What do I expect?

Young people's educational decision-making is a complex process, and many approaches have been taken to understand it in the STEM field (for an overview, see e.g., [16]). One key approach is the expectancy-value model of achievement-related choices [17]. The underlying premise of this theory is that choice, persistence and performance can be explained by individuals' beliefs about how well they will perform in a particular activity ('Will I do well and succeed?') and the subjective values they attach to the activity (e.g., 'Do I like this?', 'Is it useful?', 'Does it fit with what is important to me or others around me?'). Both expectation of success and subjective value predict career choices [18]. These beliefs are a result of gender and cultural socialization.

3.2 What do I value?

Although young women and people with migration backgrounds may have equal formal access to higher education, informal constraints in terms of cultural or gender expectations and stereotypes still restrict access for certain groups. For example, stereotypes about women's mathematics capacities and about ethnic minorities' intellectual capacities can reduce their expectation for success [19]. Importantly, expecting to succeed is not enough to choose a field, the subjective value is key too. Due to gender and cultural socialization, women and ethnic minorities often attach less value to engineering. For example, in STEM fields, characteristics such as brilliance and independence, being self-focused and agentic traits are strongly valued [20]. Additionally, the STEM fields are much less associated with communal characteristics (working with and helping others [21]). Although these characteristics in itself seem neutral, they are stereotypically associated more with the majority groups, and subtly exclude minority groups, such as, in the male dominated STEM fields, women and ethnic minorities [19] (also called 'majority group defaults' [22]). Brilliance and agentic traits are much less associated with women and ethnic minorities [23], [24], and communal characteristics are typically valued more by women and ethnic minorities [21], [25]. As a consequence, these minority groups tend to feel less sense of belonging in these fields and they tend to be less interested in fields such as engineering [26]. Within engineering, women also tend to be less likely than men to value technological leadership but more likely to value social consciousness [27]. The intersection of the two target groups is studied by Phalet et al. [28]. They discovered that women with a migration background in Belgium show the same relative educational advantage as the women without a migration background: they are more inclined than men to start university and to stay on.

3.3 What do I want to become?

The role of subjective value in career choices has also become stronger with increases in economic prosperity in many Western countries and having more alternatives to choose from [26]. As put by Yalcinkaya and Adams ([29], p. 363): "Our review of cultural-ecological variation in STEM gender gaps suggests that freedom from financial or relation-maintenance concerns and freedom to pursue personal dreams may [actually] insidiously constrain women, who seem otherwise liberated, to conform to particular stereotypes about gender and academic pursuit." In our rich western societies, we value the idea of free choice. The question 'Who do I want to be?' becomes more and more important during the process of choosing [26]. As a consequence, the concept of professional identity development has become increasingly relevant, and this concept needs more empirical attention. Identity development is a particularly important part of young people's lives. For students it is not only a question about what they want to study, but also of who they wish to become, i.e. of constructing an attractive identity, or an ideal possible self [30], [31]. Moreover, study choice is not an isolated event but a continuing process, also after entering higher education.

4 REFLECTING ON THE ENGINEERING IDENTITY

Research about professional identity and value creation within the field of engineering is hot [32]. The incentives to focus on this specific topic within the engineering community are numerous. The professional possibilities of engineers are diverse but that makes it also vague for students. Students are not aware that they should reflect about the ideal match, resulting in a possible mismatch [33], [34].

4.1 Knowing what to expect or value: the importance of professional awareness

Engineering students who choose a discipline through a deep exploration of the field and who believe the choice matches their interests, skills and prior experiences, are more likely to have positive beliefs about their competencies in engineering and the value of an engineering discipline [35]. The importance of professional awareness (knowing and understanding different engineering roles) and career exploration was confirmed in a recent study: engineering students who showed more career exploration and a better understanding of the possible future engineering roles were more confident that they would fit their future role [6], young graduates perceived also a higher job satisfaction [36].

4.2 Knowing what to become: the PREFER instruments

To aid students in getting a grip on the variety of engineering jobs, Craps et al. [37] developed a competency based professional role model describing three roles that early career engineers can take on when entering the labour market. These roles, independent of discipline, are product leadership (focusing on radical innovation and research and development), operational excellence (focusing on product or process optimisation and increasing efficiency) and customer intimacy (focusing on tailored solutions for particular customers). This PREFER model is a unique reflective instrument that offers a compact view of engineering practice in the early stage of the career in a flexible manner. The model was validated with both education and industry stakeholders, and 13 expert panels including engineers and HR representatives identified the professional competencies that industry requires to be successful in these roles [37]. Based upon the PREFER model, two innovative tests were developed: PREFER Explore is a personal preference test, aiming to inform students about the three professional roles and their personal preference for one (or two, three) of them [7], [38]. PREFER Match is a situational judgment test, aiming to trigger a process of reflection on students' drives by measuring to what extent engineering students are able to judge professional situations [8], [39].

4.3 Breaking through stereotypes: the interventions

Recent findings from a large-scale review of interventions focusing on identity development consistently point to an increased representation of minority students in STEM in the US [40]. This encourages us that it will also work in Belgium and, by large, in Europe. However, it is important that the instruments that are used in these interventions are validated by the different target groups, and not only by the majority ‘white, male’ students. Quoting from Morelock’s systematic literature review [32, p. 1255]: “The interventions – with their focus on more engineering experiences or more professional ones – may help change individuals’ perceptions of the field, but none ask students to connect their beliefs, values, or other aspects of identity to engineering.”

The PREFER tools seem promising instruments to fill this gap. The extent to which these PREFER tests counteract a sense of belonging in and fit with the field, experienced by females and students with a migration background, was not yet examined. However, a small exploratory study with a limited group of students (N=67) suggested that the customer-related role in which competencies such as empathy and creativity are essential, was more attractive to female students than to male students [5], although the university traditionally focuses on the product leadership and operational excellence roles in engineering programmes. Similar indications were observed in a comparative study on role preferences in Belgium and Ireland [4]. In her study on gender-troubled engineering identities, Faulkner [41, p. 351] concludes that “engineering as a profession must find ways to foreground and celebrate heterogeneous understandings of engineering and heterogeneous engineering identities”. Such a broader view of what engineering is, and what one can do with engineering, benefits all [future] students trying to find a good fit.

5 SUMMARY

Increasing diversity in engineering has never been more important. In order to choose and to stay within a field it is key to feel like you belong and like the field fits with your sense of self [40], [42]. However, in engineering these are lower for women and people with a migration background because of the stereotypes of the field and majority group defaults (characteristics that seem neutral but are associated more with majority groups) that fit less with these groups’ sense of self. An important objective of the URGENT project is to collect empirical evidence within the field of engineering for the majority group defaults (aim 1).

The PREFER tools seem valuable instruments to break through the stereotypical thinking of engineering and increase a sense of belonging in and fit with the engineering field. However, the extent to what these tests counteract this sense of belonging or fit by female students and students with a migration background has not yet been examined. This will also be an objective of the URGENT project (aim 2). If the tests are validated with different groups of engineering students, they can serve as instruments to set up different interventions. These interventions are set up to examine the effects of broadening the view on the field of engineering and of helping (potential) students see the different professional roles they could take in engineering (aim 3).

It is expected that this will help a broader group of students (including women and ethnic minorities) to feel a sense of belonging in and fit with the field, aiding their professional identity development and increasing both their recruitment and retention.

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LACK OF GENDER DIFFERENCES IN ENGINEERING STUDENTS' ASSESSMENT OF GROUP-BASED PROJECT EXAMS

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ABSTRACT

At Aalborg University in Denmark, engineering, science, and mathematics students usually spend half the time each semester working in groups on projects within a problem-based learning (PBL) curriculum. These projects are assessed through group-based exams where students receive individual grades. A previous survey of all engineering, science, and mathematics students showed significant differences in how they, respectively, view various aspects of the group exam. However, students also differ when comparing engineering programmes. This paper focuses on potential gender differences in perception of the group exam. Studies of other exam types showed, e.g., that female students report higher levels of text anxiety, have different reactions to exam pressure, and are less overconfident than male students. The present survey was answered by 915 students (617 males, 298 females) from all semesters and study programmes in engineering, science, and mathematics. The analysis showed that on the majority of questions, there were no significant differences between males and females. However, female students are significantly more in favour of an individual exam, and significantly more often experience they need to speak before having finished thinking. Significantly more male students find that participating with their peers during the group-quizzing phase of the exam gives a sense of security, and they are significantly more tactical about when to speak. The paper discusses the areas of significant differences among males and females and the areas without such differences, and concludes that a group exam might be a more gender neutral type of exam for engineering students.

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1 INTRODUCTION

1.1 Problem-based learning (PBL) and how they are assessed

At Aalborg University (AAU) in Denmark, problem-based learning (PBL) is the comprehensive curriculum model and PBL-projects usually take up half the study time each semester. Students here work in groups of up to seven participants. In PBL, projects evolve through a process starting with an ill-structured initiating problem, through an analysis of this problem leading to a specific problem formulation, and finally the problem solving [1].

At AAU, PBL projects are currently assessed through oral group-based exams. At the two engineering faculties, the rule is 45 minutes per students, but the exam should never take longer than five hours in total, including giving students the grades. The group-based project exam consists of three phases in which both an internal examiner (the project supervisor) and an external examiner (usually from another university) take part: (1) Group presentation of the project where students take turn. (2) Group-quizzing in which the examiners asks the group questions, students voluneteer to answer, and the students may comment on each other's answers. (3) Each individual students is asked questions aimed specifically at them, either by polling a random question or by being given a question within an area in which the examiners have noticed that the student has not yet talked about. Each student then receives an individual grade, and the grades may not be similar. During 2006-2012, the Danish government banned group exams. AAU PBL-projects continued as before, but the projects became assessed by an individual oral exam of around 30 minutes per student. When the group exam was again allowed in 2013, the third phase mentioned above became a new addition [2].

The present paper focuses on potential gender differences in this type of exam. A previous study [3] argues that PBL, including engineering programmes with more contextualised content, could result in increased recruitment of women. However, as exams play a central role in any curriculum, a part of an assessment of PBL from a gender perspective, must also include the type of exam.

2 THEORETICAL FRAMEWORK

2.1 Assessment of the PBL group-based project exam

The banning of the group-based project exam was researched by, e.g., [4] who concluded that the students, the academic staff, and the external examiners preferred the group-based project exams. It was also concluded that the individual exam could not assess core PBL process competencies such as collaboration and teamwork, which created misalignment between PBL and its assessment method.

Studies done after the reintroduction of the group-based project exam again found that the majority of students were in favour of the group-exam, but with significant differences in how engineering, science, and mathematics students, respectively, viewed various aspects of the group exam; and students also differ when comparing engineering programmes [2]. These studies, however, did not have a focus on how male versus female students experience the group-exam.

2.2 Studies of other types of exams and the issue of gender differences

Some studies focus on achievement, where, e.g., [5] argues that exams define achievement as the type of work which is valued higher may be areas in which either boys or girls are more able. UK upper secondary education in English is used as an example where boys are better at keeping to the point, take more risks, and show more confidence, which is valued higher, while girls, take less chances, write more lengthly, and are less courageous to discard irrelevant material.

Not only achievement is studied, but also emotional aspects such as anxiety and confidence. As also indicated above, female students appear more cautios than males, which is also the case for university students where females usually report higher levels of test anxiety than males even though they do not have lower academic achievement than males [6]. Emotial aspects are also seen with female students having a lower level of overconfidence in terms of grade expectations than males [7]. Emotions may also impact achievement as studies on secondary students found that females perform relatively better on low stake tests, but this difference is reduced or disappear when stakes increase. Males perform slightly better than females on high stake test such as national exams [8]. Other studies did not find gender differences, e.g., [9], who compared performance when switching from a traditional paper-and-pencil exam to a computer-based exam.

2.3 Research questions

Given that gender differences exists in many other types of exams, which gender differences, if any, exist in the students' assessment of the group-based project exam in PBL? This paper therefore re-analyses the questionnaire from 2013 as this was not part of any of the previous analyses of the questionnaire.

This paper focuses on the differences among male and female students taking all the engineering and science students as a whole. One might also have chosen to focus on differences and alikeness between male and female students in each study programme, or engineering versus science versus mathematics. This would be interesting, also given that previous research shows some differences between these student groups. However, given that the students answering the questionnaire came from 38 different programmes, and given that the female student population is often a lot smaller than the male, some programmes were only represented with very (female) students making statistical analysis irrelevant. For instance: Computer Science (34 males – 5 females), Physics (7 males – 4 females), Mathematics (6 males – 8 females), Software engineering (47 males – 4 females), Energy (39 males – 10 females), Electronic (47 males – 1 female), Building (49 males – 14 females).

3 METHODOLOGY

The quantitative survey from summer 2013 reused some tems from a previous study from 2006 [4] in order to (1) compare results now and then, and (2) enhance the validity of the present study by building upon items that previously worked well. In addition, new items were formed, some of which were based on comments from a survey to all first-year engineering, science and mathematics students after the January 2013 exams. The January survey functioned as a pilot study prior to a larger study in June 2013. An email provided the link to the questionnaire in SurveyXact to all 4,588 engineering, science, and mathematics students at all semesters after the June 2013 exams. 1,136 answered the questionnaire of which 928 completed the whole of it. 915 of these indicated gender (not a mandatory item). This gives a 25% response rate, which is low. This is usual for online surveys, but still relatively efficient compared with paper-based surveys, particularly for cohorts above 300 [10].

The questionnaire consisted of 20 items, of which most had several sub-items where respondents should indicate their level of agreement on Likert scales. In total 97 items. Five of these asked background questions about study programme, semester, gender, physical campus, and if they had experienced the previous individual project exam. Hence 92 items were directed at their experience with the group-based project exam. The analysis uses chi-squared tests of independence to assess the relationships between the male and females variables.

4 RESULTS

Of the 92 items, there were significant differences among male and female students on 32 of them. Below items with and without significant differences are analysed.

4.1 Items with no gender differences

On the three items where students were asked about their overall experience of each of the three phases of the group-based project exam, there was not any significant differences between the male and females students (e.g. Figure 1).

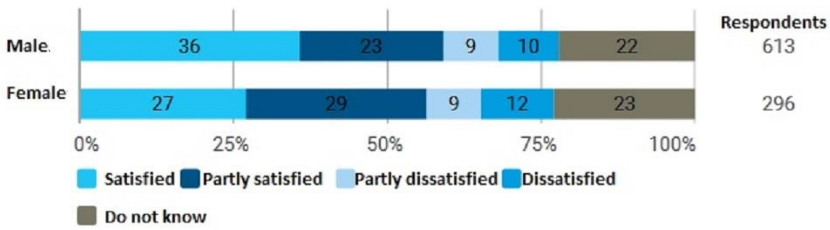

Fig. 1. Item: Are you satisfied with how the individual questioning took place? X^2*(1, N = 705) = .576, p = .448*

Each of these three phases had several subitems, and in terms of the first presentation phase, most items showed no significant differences among the male and female students. For instance: the items asking if they had enough time to talk about central phases in the project, if the distribution of topic was made more difficult by the fact that the presentation counts towards the grades, if the presentation became better knowing that this part counts towards the grades, that one can show one’s competencies, it gives a sense of security to present together with others in the group, and that the presentation made one relax more.

Concerning the second phase, the group-quizzing, around half the items showed no significant differences. For instance: the items about if you can hide, some students dominate through their personality, the examiners asked questions about my deeper understanding, experiencing that others said something they themselves were about to say, and that the group-quiz more shows the individual student's initiative in answering question than showing group-work.

In terms of the third individual phase, on most items, the male and female students agreed: the presence of the other group members gives sense of security, I do not need to understand all the content, I can show my knowledge, there was too much difference in the level of questions asked to each group member.

Concerning the students' view of their assessment and grades, there was not a significant difference on items asking if all students got the assessment they had expected, if the assessment shows who is good at selling themselves at the exam, and that there is a correct spread of grades in the group.

In particular, on issues relating to anxiety, students agreed on many items, which is different from the results of the studies referred to above. When looking into some of the details of the phases, and the grading, some differences appear between the male and female students, which are discussed below.

4.2 Items with gender difference

In terms of the first presentation phase, only two items showed gender differences: Group members mainly present things they wrote themselves (males agree more), and they learn something new through doing the presentation (Figure 2). Although the majority of all students agree, the female students agree significantly more.

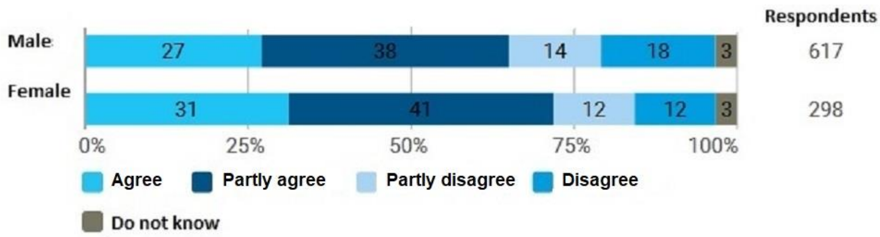

Fig. 2. Item: I learn something new through doing the presentation? X^2*(1, N = 884) = 4.525, p = .033. The legend is similar below, unless otherwise stated*

In terms of the second group-quizzing phase, there was significant differences between the male and female students on items asking: sitting together with ones group gives a sense of security, you do not need to know all the content, you can follow up on what others have said, there is time for me to tell my knowledge (males agree the more on these items), I feel I should say something before I have finished thinking (females agree more; Figure 3, top) and I am tactical about when I offer a comment (males agree more; Figure 3, bottom). These two items are somewhat connected with males perhaps better at being tactical while females somewhat being stressed during this phase.

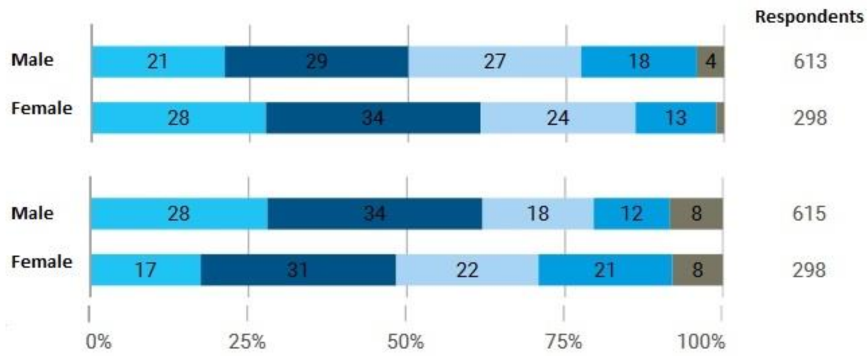

Fig. 3. Item (3, top): I feel I should say something before I have finished thinking. X^2*(1, N = 880) = 7,706, p = .006. Item (3, bottom): I am tactical about when I offer a comment.* X^2*(1, N = 837) = 18.017, p < .001*

In terms of the third individual questioning phase, males and females answered significantly different on items such as: I would prefer that the other group members are not present during this phase (females agree more; Figure 4), and there was time enough for me to tell my knowledge about the project (males agree more).

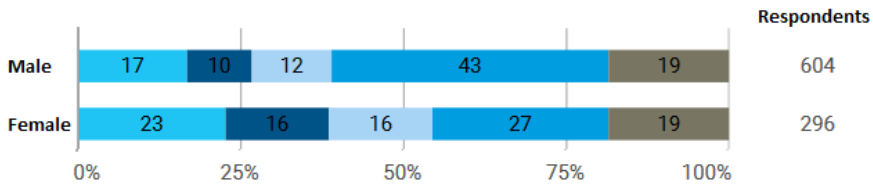

Fig. 4. Item: I would prefer that the other group members are not present during this phase. X^2*(1, N = 733) = 14.668, p < .001*

Concerning the item illustrated in Figure 4, only a minority of students do not want the other students present during the individual phase, however among these, the female students significantly more often prefer this.

In relation to the students' view of their grade assessment, there was a significant difference on the item asking if all group members had received a fair assessment (males agree more) and the item that some had received a better assessment than they had deserved (females agree more; Figure 5).

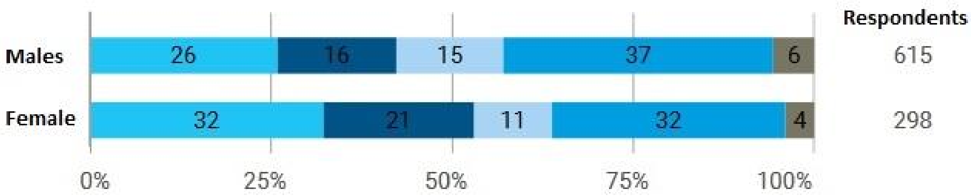

Fig. 5. Item: Some received a better assessment than they had deserved. X^2*(1, N = 866) = 8.324, p = .004*

4.3 Overall – individual versus group-based project exam

In terms of an overall assessment of individual versus group exam, although only a minority of the students preferred an individual project exam, female students were significantly more in favour of an individual exam (Figure 6).

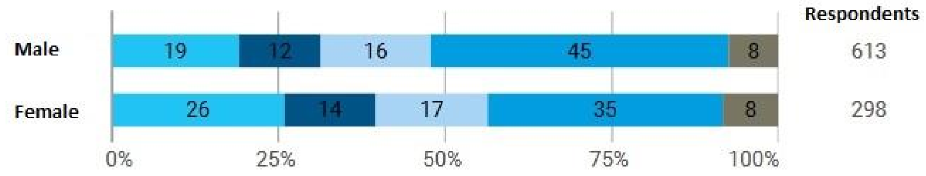

Fig. 6. Item: I would prefer an individual project exam. X^2*(1, N = 840) = 6.935, p = .008*

In exams, the opportunity to get a fair assessment is essential. Above showed mixed views about grades. On the items asking students who had experienced both the individual and the group exam about the grades, there was no difference among males and females about the opportunity to get a fair grade (Figure 7):

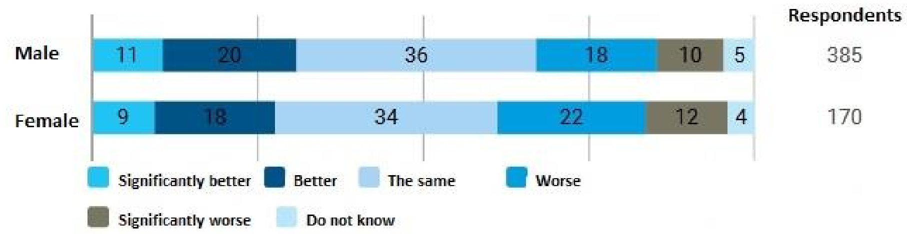

Fig. 7. Item: If you compare the new group-based project exam with the previous individual project exam, how did you experience the opportunity to receive a fair grade? X^2*(2, N = 530) = 2.225, p = .329*

The students were also asked if they experienced a bigger differentiation of grades in the new group exam compared to the previous individual project exam, and again there was not significant difference between males and females (Figure 8).

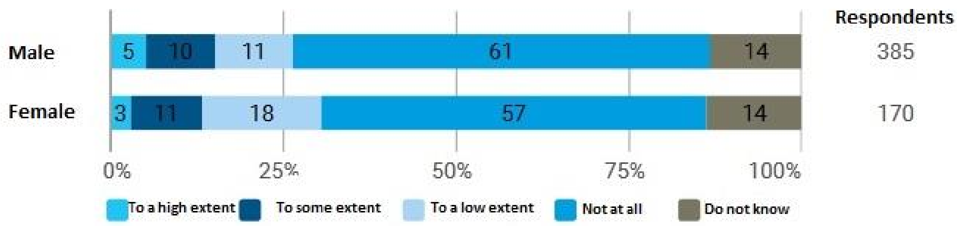

Fig. 8. Item: Have you experienced a greater differentiating of grades at the group-based project exam compared to the individual project exam? X^2*(1, N = 489) = 0.319, p = .572*

Combining the results shown in Figures 5, 7, and 8 suggests that females are more sceptical about the fairness of the group exam compared to the individual exam, including that the differentiation of grades may be less in group exams. The latter was also seen in some of the comments provided in the questionnaire. Some also mentioned that larger groups may make grading more difficult than smaller groups.

4.4 The sense of security

Sections 4.2 and 4.3 showed that in terms of the first phase of the group-based project exam, the students overall agreed (73%) that sitting together with their group members, gave a sense of security, with no gender difference. However, concerning the second phase, the group-quizzing, there was a significant difference in the male and female answers (Figure 9). Overall the students agree (75%), but with the males students agreeing significantly more than the females.

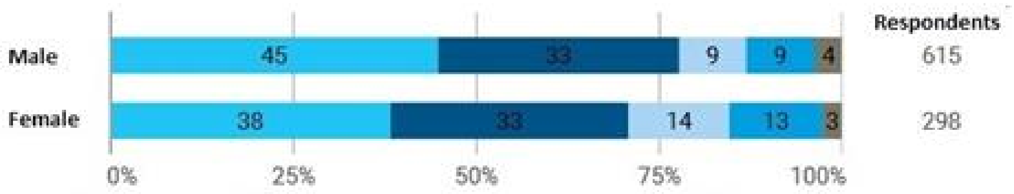

Fig. 9. Item: Sitting with the group members give a sense of security [about the group-phase]? $X^2(1, N = 882) = 7.26, p = .007$

In terms of the individual phase, again there is no difference between male and female students, with overall 46% agreeing and 35% disagreeing that it gives a sense of security having the other group members present.

5 CONCLUSION

Does this study show that the group-based project exam is a more gender neutral type of exam? The analysis showed that on most of the items (approximately 2/3), there are no gender differences. Also, the items asking for an overall assessment of each of three phases showed not gender differences. This indicates a type of exam that is at least relatively gender neutral.

Some items, however, showed gender differences such as being tactical (males agree more) or feeling rushed (females agree more) to say something during the second group-quizzing phase. The second group quizzing phase is the one with most differences between males and females. The majority of females favoured the group exam, however significantly more females than males prefeered the individual exam. Hence, the picture is not unambiguous. Significantly more males find that participating with their peers during the group-quizzing phase of the exam gives a sense of security, which may be surprising giving that the studies refeered to in Section 2.2 pointed to that males are less cautious than females and more willing to take risks. Compared to the studies in Section 2.2, this study found that females did not appear to have more anxiety than the males.

These results provide insights for examiners on design of a group exam, e.g. should all group members be present during the individual third phase, optimum size of groups for fair assessment, etc. The study points to areas in which examiners may need training to be able to administer a group exam, e.g. how to make sure all have time to tell their knowledge, that students do indeed need to know the content, etc.

A limitation of the study is that females are very likely to have been the minority in the groups, which may or may not have affected their answers more than the fact that they are female. I.e. “minority” students might feel more comfortable in individual exams than “majority” students. A further study might reveal this.

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Self-Directed versus Guided Learning – Searching for the Sweet Spot with Lesson Activities in Moodle

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Conference Key Areas: *Navigating Open Learning Environments (Moodle and others)*
Keywords: *self-directed learning, guided learning, interactive learning, lesson activities, Moodle*

ABSTRACT

In times of a pandemic many university courses have to be taught in an online learning format to respect the requirements of social distancing. Online learning takes place between the poles of self-direction by the student and guidance by the lecturer. In this paper a first-semester course in industrial economics for engineers, which was taught in the self-directed learning format of flipped classroom, was enhanced with lesson activities in the Learning Management System (LMS) Moodle as a means of guided learning with student-content interaction. The paper describes the design and the evaluation of the lesson activities. For the evaluation a student survey to gather the opinions and self-assessments of the students was conducted, and statistical data from Moodle on the performance of the students were collected. The results of the student survey show an overall positive evaluation of the lesson activities by the students who participated in the lesson activities. Furthermore, the results of the statistical data about the students' performance show a relation between participation in the lesson activities and exam success. As a caveat, however, the results also show that the majority of the students chose not to participate in the lesson activities.

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1 INTRODUCTION

1.1 Research motivation

Due to the Corona pandemic many university lecturers were forced to switch their teaching approaches to accommodate the new reality of social distancing. For the authors this meant that their first-semester introductory course of industrial economics in engineering with more than a hundred participants had to be taught as an online course. In the course of this change the teaching approach of flipped classroom with learning materials on the Learning Management System (LMS) Moodle and an online consultation-hour with the instructor via MS Teams was introduced. Learning materials included lecture videos, lecture slides, multiple choice tests and calculation exercises with master solutions which required a high degree of self-directed learning.

The student feedback from the course evaluation showed that although students valued the independence of time and space the teaching material offered, many students struggled with the freedom of self-directed learning. Furthermore from an analysis of the exam results it could be seen that students who failed had mostly difficulties with the calculation questions of the exam. Hence, it was concluded that students in this introductory course seem to need more structure and guidance in their learning activities. It was decided to support the students in this regard by introducing the interactive format of lesson activities in Moodle and to measure the impact of this format.

1.2 Theoretical foundation

This paper deals with the format of online learning. Although there is no common understanding of the term online learning and related terms (such as e-learning), many authors agree that online learning offers learning experiences via web-based technologies [8]. Ally [1] for example defines online learning as “the use of the Internet to access learning materials; to interact with the content, instructor, and other learners; and to obtain support during the learning process […]”.

Empirical research in didactics shows that personal control as well as structure and clarity are – amongst others – proven characteristics of successful lessons [11]. This leads to a certain paradox that effective learning needs to on the one hand respect the freedom and individuality of the learner. On the other hand learning also requires a certain structure or guidance from the teacher, at least in an institutional context with predefined learning goals and outcomes. In learning theory this is connected to the concepts of self-directed learning and guided learning as well as interactive learning.

Self-directed learning typically requires that a large part of the initiative and responsibility for the learning process is with the learner. This implies that learners have at least some personal control over learning needs, goals, resources, strategies and outcomes [7]. Also for online learning one key implication is that learners have a certain extent of control over the learning process [1].

One concept of self-directed learning is the concept of flipped classroom by Bergmann & Sams [4]. In a flipped classroom, students work through pre-defined content on their own (e.g. watch pre-recorded lectures via an online platform), before they attend the lecture. This way, the lecture time can be used to solve problems by applying the content and clarify issues in understanding the content.

Guided learning can be defined as “a process in which learners initiate and advance their learning guided by more experienced partners and socially derived sources, such as tools, text, and/or other artifacts” [5]. Hence, the guidance can either take the form of interaction with other persons or with some form of learning material or tool. In online learning the content is typically provided by a Learning Management System (LMS) such as Moodle. The structure in Moodle is typically linear or hierarchical, and the display of information takes the form of folders and subfolders, as in the folder structure of MS Explorer. Apart from that there are some tools in Moodle that offer personal interaction such as forums, chats and messaging as well as tools offering interaction with content such as tests and lessons [6]. Thus, LMS such as Moodle offer the opportunity for interactive learning which can be defined as “[…] a process involving some form of digitally enabled reciprocal action between a teacher or designer and a learner. Interactive learning requires access to content, tasks, and problems by at least one human being (a learner) using digital technology (e.g., a computer with Internet access)” [9].

This paper deals with interactive learning in the form of student-content interaction in an asynchronous form according to Anderson [2, 3]. In online learning, the learning material should be sequenced in ascending complexity (“from simple to complex”) and novelty for the learner (“from known to unknown”) [1]. Apart from sequencing, interactive learning material should also include a chance for self-monitoring [7] which in online learning can be achieved via feedback loops and repeated trials [1, 3]. This implies that there is not only the question of sequencing, but also questions of branching and looping to generate learning feedback and enable self-monitoring of the learner. The goal of this paper is to show how the authors combined the concept of flipped classroom as a means for self-directed learning with the concept of lesson activities in Moodle as a means of guided learning with student-content interaction and how the authors measured the success of the approach.

2 METHODOLOGY

2.1 Designing lesson activities

The goal of the lesson activities was to provide freshmen with a more efficient learning process through interactivity in learning. A total of seven lessons were offered on the various topics of the course. These are lessons on the topics of business, management, accounting, cost accounting, marketing, financing and investment. The lessons were structured in such a way that existing learning materials such as exercises, lecture videos, multiple-choice tests, etc. were put into a logical order suitable for online teaching (see fig. 1).

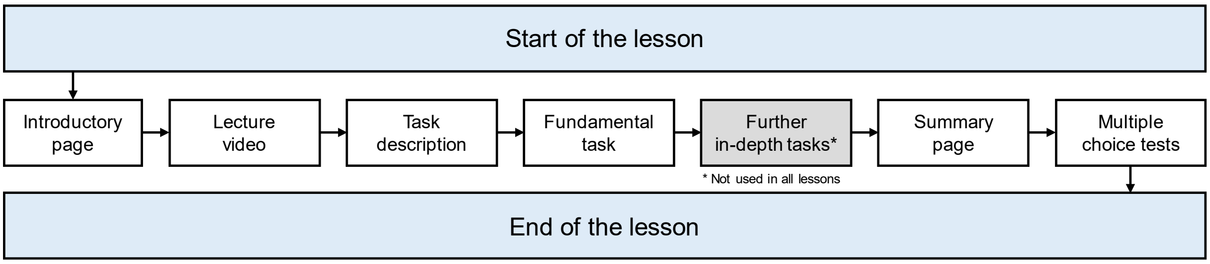

Fig. 1. Structure of the lesson activities

Each lesson starts with an introductory page that presents the educational objectives of the lesson. Moving on to the next page, the student is taken to a lecture video where the main content of the particular topic is presented. The next step is the task page, where the task is introduced and hints on how to complete the task, such as important formulas, are given. This is followed by the actual exercise task, which must be solved by the students. To ensure interactivity, students are given the opportunity to self-monitor by being guided into a feedback loop after each solution they submit. If the answer is correct, the students receive the message that their answer is correct and they can move to the next page. If the answer is wrong, the students receive the information that their answer is wrong and they get the opportunity to repeat their answer several times. After a specified number of attempts, the learner is automatically directed to the next page.

In order to customize the lessons as much as possible and thus increase the learning effect, common answering errors were identified and entered into the system when the lessons were designed. The authors' many years of teaching experience were used to identify typical answer errors on specific tasks. For each error, a suitable hint was entered into the system so that each student receives an individual answer depending on the error he or she made and hence is guided to the correct solution in as specific a way as possible. Furthermore, video snippets from the lecture video have been included as an answer aid so that the student can explore certain topic points in more depth.

In some lessons, the basic task is followed by a more in-depth and complex task to reinforce what was previously learned. Here, the methodology of sequencing the learning material in ascending complexity (“from simple to complex”) was applied [1]. Before the theoretical knowledge is tested by multiple-choice tests at the end of the lesson, there is an overview page including the sample solutions to all questions, corresponding formulas and a memory box with the most important theoretical content.

2.2 Evaluating lesson activities

In order to evaluate the effectiveness of the lessons, student surveys were conducted and statistical data were analysed. The student surveys took place in two ways. First, intensive feedback communication was performed with students via MS Teams prior to each consultation-hour during the semester. Second, a questionnaire was developed for students to submit their assessment at the end of the semester, which was then evaluated. The statistical data was analysed from Moodle.

The feedback discussions with the students represent a kind of group discussion and hence are part of the qualitative research. The qualitative research approach is particularly suitable when individual opinions and impressions are in demand, suggestions for improvement are to be collected, and certain causes are to be explored (e.g. reasons for satisfaction or dissatisfaction of the participants) [10]. The feedback sessions were intended to fulfill the mentioned purposes and were held after each completed lesson so that the following lessons could be improved or adjusted according to the students' requests.

To measure participation in the lesson activities for the survey, the authors divided the students into two groups: In the group “lessons accomplished” students completed at least three out of the seven lessons. Students with fewer than three lessons completed were counted as “lessons not accomplished”. For the first group, a nine-item online questionnaire was designed in which students rated aspects of the lesson activities such as structure and interactivity and performed a self-assessment on several items such as understanding and enjoyment. The items were rated on a Likert scale with five response levels. For the second group, a questionnaire including the reasons for not participating was designed.

The statistical data from Moodle were analysed after the exam to determine, if working on the lessons had an impact on passing the exam. For this purpose, participation in the lessons was related to exam grades and exam success. In a final step, it was analysed whether the time period in which the lessons were worked on had an impact on the score achieved in the exam. For this purpose, two time periods were defined: during the lecture period and after the lecture period. For the analysis of the statistical data, the same two groups of students were used as before to measure participation.

3 RESULTS

3.1 Student survey

A total of 27 students participated in the student survey. Five of them indicated that they had worked on fewer than three lessons. Thus, according to the criteria we specified, those five students did not work intensively enough on the lessons to be able to give a meaningful review. When asked why they did not work intensively on the lessons, they all indicated that they wanted to work on the lessons just before the actual exam. This leaves a total of 22 students who worked intensively enough on the lessons to be able to give a meaningful assessment.

The results of the assessment of the 22 students are displayed in the chart in fig. 2. Overall, the students give a positive evaluation of the lesson activities. Most of them agree or strongly agree that the lessons had a clear structure (90%) and enhanced their understanding (86%) and that they enjoyed working on the lessons (68%). This is in line with the finding that most students would recommend the lesson activities to fellow students (86%) and would like to have more lessons in this course (77%) as well as in other courses (82%). The most critical part of the lesson activities is the feedback system, i.e. getting the branching right. Only 41% of the students agree or fully agree that the feedback helped them to identify the correct answer, while 14% diagree (45% remain neutral), as some of the feedback had to be adapted during the lecture time. The lesson activities are seen as an add-on rather than a substitute for other learning materials. Almost 86% see the lessons as a good addition or variation to the learning materials they already have, while only half of the respondents feel that working through the lessons has prepared them well for the upcoming exam (10% disagree on this point).

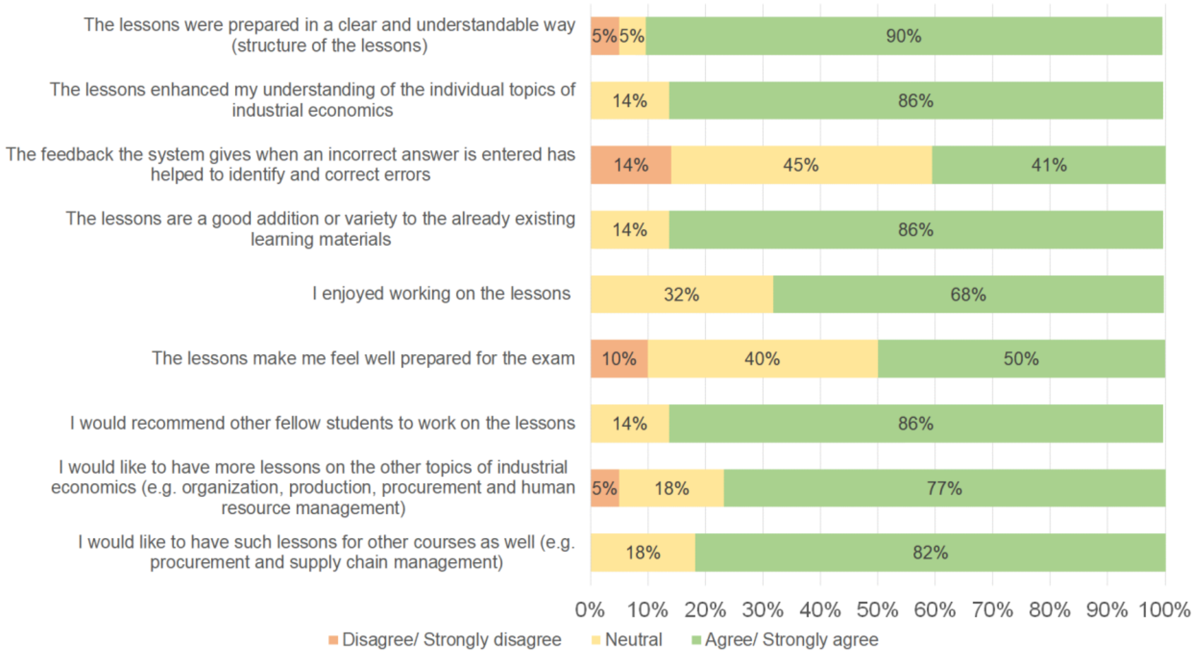

Fig. 2. Assessment of the students who accomplished the lessons (n = 22)

The evaluation of the questionnaire reflects the impression the authors gained from the feedback interviews during the semester. In each interview, the students gave a mainly positive feedback on the lessons. They said they were well guided through the lessons and especially found the video snippets helpful. Because of the feedback sessions it was possible to identify and correct small errors that were overlooked or not taken into account when the lessons were created, such as incorrect links or the setting of larger rounding tolerances. Also, suggestions for improving the branching of lessons, such as reducing the number of failed attempts, could be obtained from the interviews with the students.

3.2 Statistical analysis

Analysis of the data in Moodle showed that 103 students participated in the exam. Of these 103, a total of 36 students accomplished the lessons and 67 students did not accomplish the lessons, i.e. worked on fewer than three lessons or did not work on them at all. 92% of those who accomplished the lessons passed the exam, and 8% failed. Of the group of those who did not accomplish the lessons, 61% passed the exam and 39% failed.

Looking at the number of points achieved in the exam by both groups, it can be seen that the average score of those who accomplished the lessons is around 70 of the maximum 100 points achievable in the exam (arithmetic mean and median). In comparison, the score of those who did not accomplish the lessons is about 53 points. Furthermore, the group of students who accomplished the lessons has a higher maximum score (96 points in comparison to 87 points), a higher minimum score (42 points in comparison to 21 points excluding two outliers) and a higher and narrower interquartile range (see fig. 3).

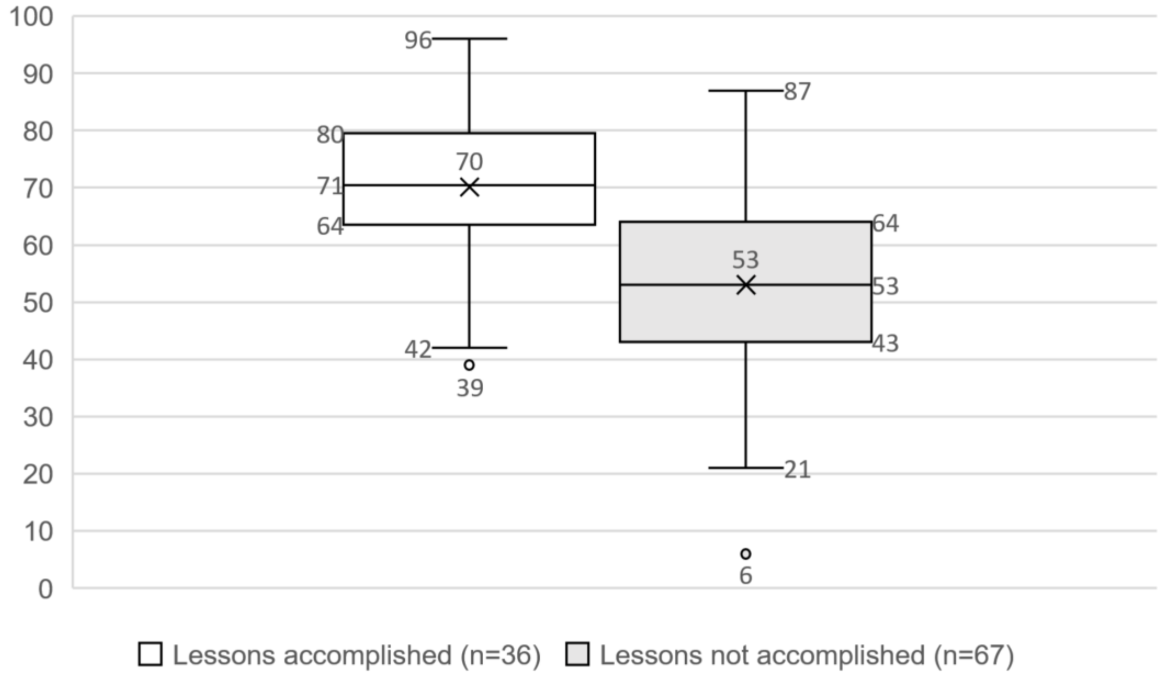

Fig. 3. Participation and exam grade

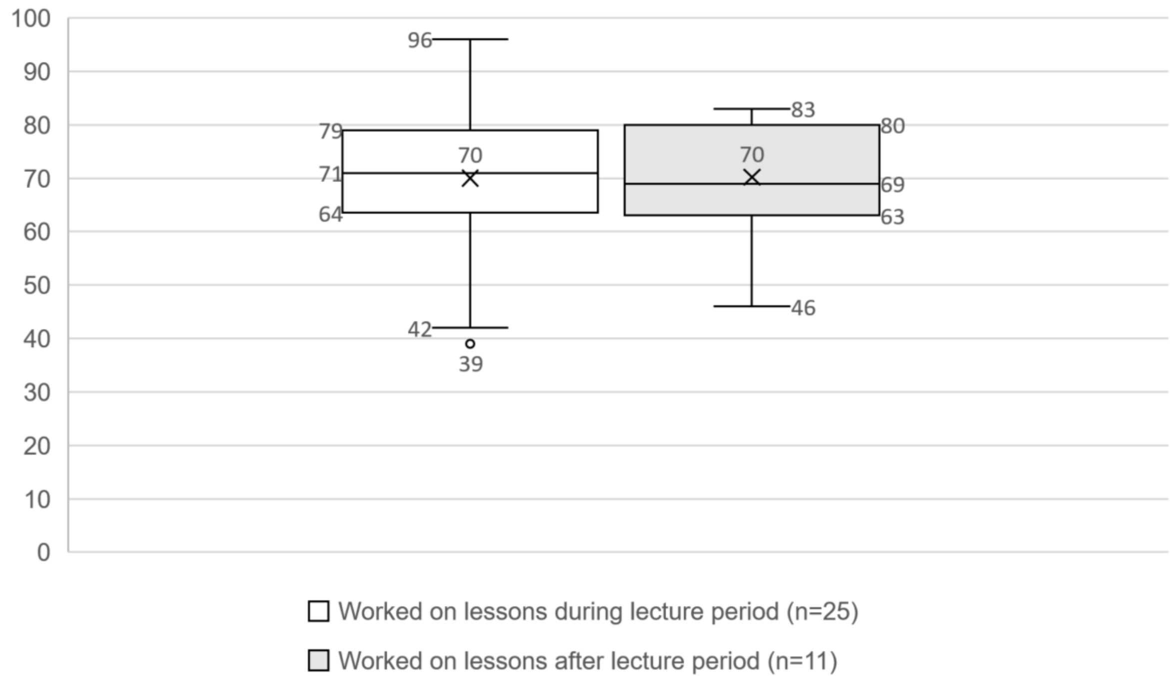

Fig. 4. Participation period and exam grade

The evaluation of the participation period (i.e. when students worked on the lessons) shows that 25 of the 36 students who accomplished the lessons did so during the lecture period. The remaining 11 worked on the lessons after the lecture period. Despite the different periods, the average score achieved by both groups is almost identical at about 70 points. Similarly, the median is also nearly the same with 71 points for those who worked on the lessons during the lecture period and 69 points for those who worked on them after the lecture period. Finally, both also have similar interquartile ranges. A main difference is the larger spread of the upper quartile for students who worked on the lessons during the lecture period (see fig. 4).

4 SUMMARY

The results of the student survey show an overall positive evaluation of the lesson activities by the students who participated in the lesson activities. The lesson activities are seen as a valuable addition to the existing learning material. Furthermore, the results of the statistical data about the students' performance show a relation between participation in the lesson activities and exam success. Furthermore, the results show that it makes no real difference when the lessons are worked on (during or after lecture period).

These findings, however, do not establish a causal link between lesson activities and exam success. It could be that students who accomplished a lot of lessons also took more effort in general, e.g. participated in the consultation-hour or used further learning materials. As the course comprises first-semester students who just started their study programme as well as students from previous semesters who have to take the course as a resit, and the first group usually has a lower failure rate and is generally more active, this may at least explain part of the positive relation. To test this assumption data on the overall activities of the students would have to be collected and included as confounding variables. It could also be that students who are more successful are also more open for new learning approaches.

The most crucial element of the lesson activities is the feedback system. Apart from the right sequencing of content, it is the right branching that guides students in their learning progress. For this, lecturers have to forecast possible errors and develop helpful hints to help students understand their errors and find the correct solution. This is by far the most difficult and time-consuming step in designing the lessons.

As a caveat, the results also show that the majority of the students chose not to participate in the lesson activities. As a lot of work goes into designing the lessons (e.g. getting the branching right), lecturers have to decide if the effort is worth the benefit based on the number of students and the student evaluation for their specific courses. Overall it can, however, be said that lesson activities show promising first results to provide aspects of guided learning in online courses with a high number of freshmen, but further tests are needed to establish a clear link between lesson activities and learning success.

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Introducing Ethics by Design in Engineering Education: Designing COVID-19 Tracing Apps

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ABSTRACT

Including ethical concepts and considerations in engineering education has attracted significant interest in recent years, mainly due to the impact of some AI applications in different areas of our life. The use of case studies in teaching ethics is a well-known and useful approach. The debate related with a given case study helps students think about the implications, motivations and foreseeable impact of the technologies. This fact is in contrast with the common easy-thinking that technologies are neutral and that an engineer should not bother about ethics and does not have any responsibility at all. While many basic technologies may be considered neutral, more developed and complex systems are not so neutral; they have a motivation and some foreseeable impact and consequences. Thence, the main message is that engineers have a responsibility when developing these systems.

This paper presents a case study used in a course for Ph.D. students in a Technical University to introduce the concept of ethics by design and to stress the idea of responsible conduct in engineering. The case under study is the design and development of tracing applications for fighting against the Covid-19 pandemic in 2020. The analysis of the case requires to understand the basic technologies proposed, the different alternatives considered at that time, the basic facts related with the contagion chain and the main factors to be addressed, the consideration of the balance between public health rights and individual privacy rights, and the social aspects related with the acceptability by citizens.

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1 INTRODUCTION

1.1 Introducing ethics for engineers

The first challenge addressed is how to introduce a topic such as ethics in a Technical University where there are no other degrees than strictly engineering ones (including electrical, mechanical, civil engineering, computer science and architecture). There are no major and minor degrees. Students have never taken a course on philosophy, history or anthropology, to mention some subjects, at the University. This fact limits the concepts and terms that may be used in the class.

For the experience presented in this paper an optional course offered to Ph.D. students is selected. The main target are students in any of the Doctoral Programs of the University, so that a broad view of many areas in engineering are covered. Also, being Ph.D. students from different countries, their background knowledge and cultural environments are diverse. This approach helps to cope somehow with the intrinsic limitation of the lack of humanistic formation provided by the Technical University and provides a much richer discussion with different points of view than with a more homogeneous group.

The method presented and the same case study, or a similar one, may be used for undergraduate students.

1.2 The use of case studies

Using case studies for teaching ethics is a common practice and there is a general agreement that they are very useful. Discussing cases helps students to recognize ethical issues, to foster their analytical skills in ethics, to stimulate students' ethical imagination, to promote a sense of responsibility and to help students to deal with disagreement about ethical issues [1].

The first issue to be addressed, at least based on my experience, is the general perception that engineers deal with technology only and their job is neutral from the point of view of ethics. Despite the students enrolled in this optional course may have some curiosity about ethical implications, the underlaying perception is that technology is neutral and this easy-thinking approach is dominant among engineering students.

The analysis of cases allows students to recognize the presence of ethical problems where initially we saw only technical issues, help them to develop their reasoning and assessment skills about the consequences and impact, help them to stimulate their moral imagination looking for possible alternatives, help them to acknowledge the limitations of the codes of ethics and regulations, and help them to understand that sometimes there is no best solution [2].

The use of case studies is of utmost relevance in teaching ethics because, as commonly agreed, "ethics is not so much taught as caught".

The case study selected is the development of tracing systems for Covid-19 that was the hot topic during spring 2020. This case presents a variety of approaches and requires understanding the technical background; this catches the attention of engineering students.

The development of tracing applications for Covid-19 was undertaken immediately once the pandemic was declared worldwide. The design of these systems took many different paths, perhaps as many as countries, because politicians and healthcare authorities were overwhelmed by the impact on the pandemic and the need to have a tool to help cutting its spread was urgent.

2 METHODOLOGY

The main objective of the discussion of this case is to mimic to some extend the situation of the development of the tracing systems since their early conception and design choices. This implies to work with the information available about the pandemic and the behaviour of the virus, information that was evolving, and the considerations about the feasibility of real deployments of the new systems.

In order to highlight the importance of the interdisciplinarity of the problem the debate is introduced step by step. First of all, a deep understanding of the contagion chain and the conditions to stop its spread is required. Next, a sound assessment of the technology available and of the different alternatives is a key aspect that must be analysed. Then, the view of the healthcare staff involved, the capacities and participation required from the citizens (social impact), the existing regulations about how the information is managed and who has access to the data (which may depend on each country), and the analysis of privacy aspects are introduced in the discussion. The objective of the debate is to follow the whole design process of the system, impersonating the roles involved and reassessing past views when required.

The discussion is organized in two sessions in consecutive weeks. For the first session the students should read a short paper with the basic concepts about the spread of the infection and the requirements to cut the spread chain together with the technological approaches available. Before the discussion they are asked to fill a questionnaire to get an idea of the comprehension of both the health-related aspects and the technological ones.

The first session is dedicated to reach a common agreement about what is needed from a tracing system and what alternatives may be available from the technical point of view. Nowadays, how the infection spreads is mainly understood but some of the technical approaches considered at that time require some detailed explanation in order to assess their relevance and the effectiveness of the tracing system.

This session is sought to be very interactive, discussing the different points of view and understanding of three main issues: how the contagion spreads and how the identification of groups at risk may be done, the information needed by healthcare staff to undertake the notification process, and the possibilities provided by the technology using a smartphone.

Before the second session the students read a longer paper. This article introduces some ethical issues and, in particular, the consideration of rights: public and individual health and safety, and privacy. Also, it includes some references to documents published during spring 2020 about the ethical issues of tracing systems [3], [4], [5], [6]. Again, students are asked to take the questionnaire before the discussion in class. The comparison of the answers allows to assess how the first session helped the students to understand the technical requirements and how introducing new aspects modify their previous assessment.

2.1 The questionnaire

The first part of the questionnaire aims to make an assessment about how a better understanding of the problem and of the techniques changes the answers of the students and their initial assessment. The poll is anonymous, so individual changes of opinion cannot be analysed.

A set of questions in the questionnaire deals about the understanding of the effectiveness of different technologies used for the identification of the close contacts of a new diagnosed patient. Another set of questions introduces the issue of privacy and asks for a comparative assessment of the alternatives considered.

The goal of the questionnaire is to compare the opinions of the students about the effectiveness and privacy issues of the proposed tracing approaches before discussing about the ethical challenges and after doing so. The expected result is that when ethical issues are included in the discussion some design options are discarded or avoided while others may require some changes in their design.

2.2 The main aspects to be addressed during the discussion sessions

A list of the different aspects analysed during the sessions follows.

Understanding the effectiveness of testing, not only to detect a contagion but as a requirement for all people identified to be at risk because of being a close contact.

The identification process of the group at risk and its conditions: to be close enough (about 1 or 2 meters) during a minimum period of time (about 10-15 minutes) during the past two weeks.

How automatic identification helps to cut the spread of the contagion and the effect of false positives and false negatives. The accuracy of the technology used for the identification process is a key factor in the overall usefulness and performance.

The importance of the notification process and how an automatic notification can be made preserving the privacy of the patient and of the people detected as close contact. A successful notification requires not only the collaboration of the patient but of the notified people too, as they should go voluntarily to take a test as soon as possible.

Next comes the analysis of the effectiveness of different technical approaches: mobile operators may be required to provide the locations of user’s phones (this aggregated information allows to follow the spread of the contagion but cannot identify close contacts); the collection of venue QR codes, the collection of personal

QR codes (these may not work well enough as many people may be in the same place but not close to each other); the use of GPS geo-location to track people (this may be seen as a massive surveillance system and it may not work properly indoors); the use of Bluetooth for detecting nearby devices during a continuous period of time and estimating their proximity (to do this an improved version of the drivers is needed and it may be easily distributed in an update of the smartphone's operating system).

In a broad sense there are two approaches for developing a tracing system. The centralised approach collects routinely all the information provided by the applications (basically, location, date and time, and user's or device identification) in a central server. The information is available to the healthcare staff at any time.

On the other hand, the decentralised approach keeps all the information stored in the mobile device. This information will be used to help tracing possible groups of people at risk only if the owner of the device is diagnosed as infected. Respect for privacy depends on how the information provided by the tracing application is managed and used.

The idea of using non-personal identification is introduced and the effectiveness of this "ideal" approach should be assessed. Though no personal identification is used the effectiveness of the identification and notification processes may be the same as implementations using personal identification which may lead to privacy issues. The privacy-preserving tracing concept is introduced.

The last set of questions in the questionnaire asks for an assessment of the privacy of the technical alternatives considered before.

At this point, while analysing the answers of the questionnaire it is the time to introduce other technical and non-technical aspects, such as the accuracy measuring the distances using Bluetooth, the relevance of false negatives, some characteristics of decentralized and centralized systems, the necessary level of social acceptance (that is, the required percentage of citizens using the tracing application for the system to be useful) and some other issues related with privacy rights.

It is expected to be the turning point of the discussion that requires a back step and reconsider the previous alternatives to make a proper assessment.

3 RESULTS

The results of this experience are presented following the discussion of the answers of the questionnaire. This section is organized in three subsections: effectiveness of the methods, identification of privacy issues of the methods under study, and an assessment of the privacy issues of the methods and systems proposed.

3.1 Effectiveness of the technology used for tracing

Table 1 presents a comparison of the results of the first and second questionnaires (labelled as “a” and “b”) related to the effectiveness of the eight different technologies proposed. The answers grade from “not useful” (1), “somewhat useful” (2), “useful” (3), to “very useful” (4).

Due to space limitation, a detailed description of each of the methods (identification and notification processes) are not included.

Table 1. Effectiveness of the method as a percentage of the answers

Method	Answers	Questionnaire 1 (a)	Questionnaire 2 (b)
1- Collect phone id from Base Station	2	50%	50%
	3	25%	7%
2- Collect personal QR at venues	1+2	58%	49%
	3	25%	50%
3- Collect QR of the venues in the phone	1+2	67%	43%
	3	16.5%	43%
4- GPS coordinates sent to a server	1+2	68%	50%
	3+4	32%	50%
5- Store GPS coordinates in the phone	1+2	67%	43%
	3+4	33%	57%
6- Collect BT data in a server	3	41.7%	21.4%
	4	8.3%	57%
7- Store BT data in the phone	3+4	33%	57.2%
8- Store BT anonymous data in phone	3+4	58%	50%
	4	17.7%	35.7%

As expected, a better understanding of the method is reflected in the answers of questionnaire 2 (b). For instance, collecting phone numbers in the coverage area of a mobile base station is not really useful (7%). The effectiveness of QR codes depends on the continuous effort of the citizens to scan the codes. That is why the effectiveness of the method cannot be really assessed. On the other hand, it is difficult to explain why storing GPS coordinates in the phone is considered more efficient than sending them to a server (57% vs. 50%). Finally, using anonymous Bluetooth identifiers is perceived as less efficient than using the real Bluetooth identifier (50% vs. 57.2%). This suggests that the complete mechanism was not well understood even after reading the second article.

The discussion during the second session confirms this point. A detailed explanation about how using random identifiers for the devices may allow the identification and notification of close contacts took a significant amount of time.

3.2 Identification of privacy issues

The questionnaire includes several situations and asks for an assessment about privacy respect in each case. The answers are graded as: “no issues”, “some issues”, and “not acceptable”.

There are some surprising results. For instance, asked about the privacy of collecting the name, date, location and the name of nearby people (potential close contacts) is seen as acceptable by 25% of the students before the first session and it drops to 14% only after the session. Clearly, privacy has different perceptions in different cultures. It is seen as unacceptable by 50% of them in questionnaire 1 (a) and raise slightly to 57% in questionnaire 2 (b).

Other results are as expected. For instance, making public the list of tracks of infected people (including location, date and time, but not the name) is considered to be unacceptable (91.7% and 100%, respectively).

3.3 Assessment of the privacy issues of the methods proposed

Figure 1 shows the assessment about the privacy issues raised by each of the eight methods proposed. The assessment about the privacy has four options: i) no privacy issues, ii) health rights prevail over privacy, iii) a balance between health rights and privacy rights is required, and iv) there are serious privacy issues and the method must be avoided. The method is numbered from 1 to 8 (as in Table 1). Answers in questionnaire 1 are labelled as “a” and the ones in questionnaire 2 as “b”. That is, column 8b corresponds to the results of questionnaire 2 about the method “store Bluetooth anonymous data in the phone”.

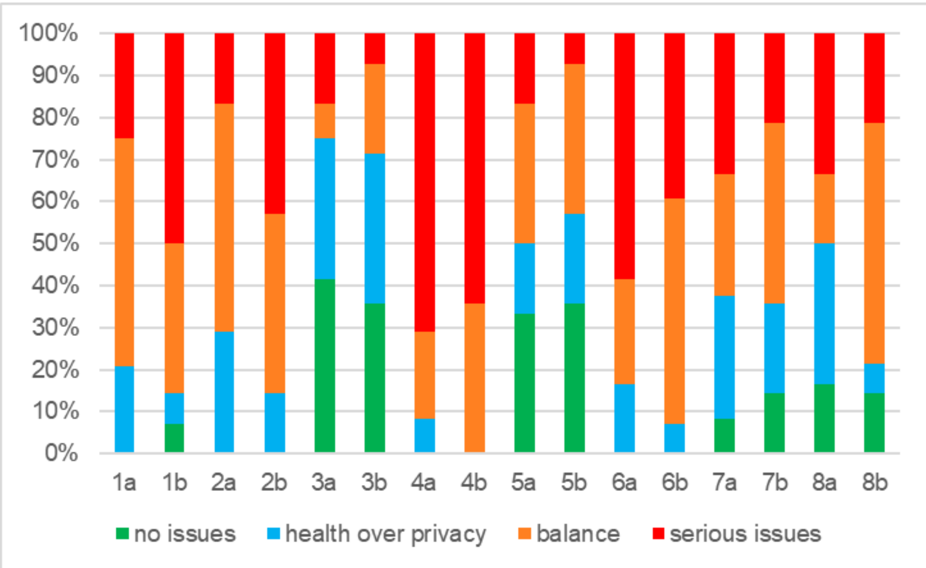

Figure 1. Assessment of the privacy issues

Centralised systems (columns 4 and 6) show a significant level of rejection (serious privacy issues). This corresponds to the social rejection of anything that may be used as a mass surveillance system.

Column 8b shows that the use of anonymous Bluetooth identifiers was not really understood after reading the papers. At the end of the second session the majority of the students agreed that some privacy aspects should be balanced but basically privacy is properly preserved.

4 SUMMARY

The discussion sessions highlight the difficulty of understanding the details of the problem and its real requirements. Also, the description of the characteristics of the different technologies requires to go into some detail about the possible implementation of the tracing system.

In particular, the privacy preserving approach using random Bluetooth identifiers is not intuitive and requires some effort to understand that it can provide the same information that the approach using personal identifiers while preserving personal privacy from the very beginning. A useful explanation may be found in [8] and [9].

The consideration of the social impact is related with the voluntary collaboration of the citizens, first installing the tracing application and afterwards accepting to provide their information to identify close contacts, and second, the collaboration of close contacts for taking a test. This point raises the key issue of trust. Citizens must trust healthcare authorities, politicians, and developers of the system. Without trust the acceptance ratio is too low for the system to be useful as a tracing tool. Trust includes also that the data collected will be used only for the declared purpose and by authorized staff only.

During the discussion, a detailed comment of the statement published by ACM [5] helps to understand the concrete requirements derived from the personal privacy right in order to design and deploy a privacy-preserving tracing system.

Including the assessment of the privacy issues in the different approaches helps to avoid some of them or, at least, some of the possible implementations. Imposing a high requirement for privacy lead to groups of engineers to find privacy-preserving methods that were implemented in the most common support for tracing systems developed jointly by Apple and Google for their mobile operating systems [9].

This is a nice example of “ethics by design”. Ethical considerations were put at the starting point of the design and that allowed to find an innovative way to implement the system.

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ANALYZING STUDENT-TEACHER INTERACTIONS IN CHALLENGE-BASED LEARNING

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ABSTRACT

Challenge-based learning (CBL) exposes students to the complexities of open-ended and real-life challenges and encourages them to be in the lead of their learning. The role of teachers remains important but shifts from being the expert to the role of a coach who gradually scaffolds students into becoming independent learners. Accordingly, the interplay between teachers' and students' regulation of

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teaching and learning can result in friction and influence students' learning experience. This study explores incidents of constructive or destructive friction between student and teacher regulation during a 9-week CBL course for first-year engineering students. Thematic analysis is employed to identify critical incidents of friction during students' learning via analyzing students' weekly learning portfolios. Results suggest that students' experience in CBL is not linear, and there is a constant interplay between students' ability to regulate their learning and teachers' scaffolding. Initial exposure to CBL was characterized by friction in student and teacher interactions. Several students increased their self-regulated learning skills by resolving the initial friction by adopting a more proactive approach to their learning by actively asking questions and feedback from their teachers. The findings of this study are particularly relevant for CBL, where much attention is paid to students' autonomy, self-directedness, and collaboration. Building on the insights of this research, we make recommendations for further research and educational practice.

1 INTRODUCTION

Engineering universities are increasingly adopting active learning pedagogies to foster students' disciplinary and professional knowledge and skills [1]. Challenge-based Learning (CBL) is a pedagogical approach that engages students in learning knowledge and skills through open-ended and real-life challenges [2]-[5]. The concept of self-regulated learning (SRL) is central to CBL [2]. Learners in CBL are expected to show increased agency, autonomy, and self-directedness individually and as a group [3].

Given the self-directedness expected by students in CBL, the role of the teacher is different compared to traditional teaching approaches [2]. The teacher is viewed as a coach and subject expert who guides students toward self-regulated knowledge construction [2],[3].

Currently, little is known about students' SRL in CBL and teachers' role in this process. A recent systematic review on the implementation of CBL in engineering curricula highlighted that teachers have various roles in a CBL course. These include designing the challenge and developing learning material to provide students with theoretical input, coaching students and providing feedback, and assessing students' achievement in terms of competency development and project outcomes [6]. However, one of the main challenges experienced by teachers and students was the imbalance between expected SRL from students and teachers' provided guidance and scaffolding [6].

Thus the present study aims to assess how students experience the friction between their regulation of learning and teachers' regulation in CBL.

1.1 Theoretical framework: interaction between students' and teachers' regulation of learning

In CBL, students are expected to be in the lead of their learning [1]. Self-regulated learning is a process that describes how students manage their thoughts, behaviors, and emotions in order to successfully navigate their learning experiences and attain learning outcomes [7].

Vermunt and Verloop [8] identified three categories of learning functions that students engage in during a course. These include cognitive, meta-cognitive, and affective/motivational functions. Students engage in cognitive processing functions to process the subject matter, and those activities can directly lead to learning outcomes in terms of knowledge, understanding, and skills. Metacognitive regulation functions are those used by students to regulate and steer their learning processes and lead indirectly to learning outcomes. Finally, affective/motivational functions involve regulating emotions that arise during learning and lead to affective states that may influence students' learning process and progress in a positive, negative or neutral way.

SRL develops through the interaction between the student and the learning environment [9]. The role of the teacher is crucial in students' development of SRL and influences students' learning and motivation [8],[9]. The interplay between students' self-regulation and teachers' regulation can have various forms. For example, in complex learning environments, where the uncertainty and complexity of learning tasks are high, tension and friction can arise [9].

This friction can promote (constructive friction) or hinder (destructive friction) students' learning [9]. For example, constructive friction can occur when students experience the course requirements challenging enough but feel they have the necessary skills to match the requirements. On the other hand, destructive friction occurs when the learning environment does not provide support, but students have a problem in self-regulating their learning.

1.2 Research objectives

In this study, we aim to understand better how students regulate their learning in a CBL course and how they perceive their interaction with teachers in cases of friction. The research questions we formulated include:

- What incidents of friction do students experience in a CBL course?
- How does the interaction between students' and teachers' regulation in incidents of friction influence students' development of SRL?

2 METHODOLOGY

2.1 Context and participants

This study focuses on one CBL course, taking place in Eindhoven University of Technology. This course is part of the educational initiative E3 (Eindhoven

Engineering Education). The course E3-Challenge2 is a 10 ECTS course, with 5 ECTS on the ethics of technology and 5 ECTS on data analytics. The course took place during the academic year 2021-22 and it lasted 11 weeks. Forty-three first-year bachelor students from different engineering departments were enrolled. Students were asked to apply and contextualize the data analysis skills and ethical considerations to a real-life challenge related to smart grids, smart health, and smart mobility. Students in E3- Challenge 2 course worked in multidisciplinary groups consisting of 4-5 members.

2.2 Teaching and learning activities

SRL is a core principle of the E3- Challenge 2 course. Students were expected to be proactive and act autonomously, individually, and as a group. The course consisted of an interdisciplinary team of teaching staff (one ethics lecturer, one data analytics lecturer, three coaches, five expert generalists, and nine teaching assistants (TAs) supporting students in their learning process.
The course included different learning activities to support students' learning. The Ethics workshops brought in ethics materials and evoked ethics discussions. The teaching assistants provided feedback to student groups. Students could ask the remaining questions in the expert meeting and stakeholder meetings. An assigned coach met weekly with each group of 4 students for 30 minutes to discuss matters related to their professional development and individual and group learning process. Fig 1, provides an overview of a typical week of the course. To support students' self-regulated skills, students had to write at the end of every week a 1-page reflection on a learning experience that was important for them during the week and discuss their learning development with their assigned coach every week.

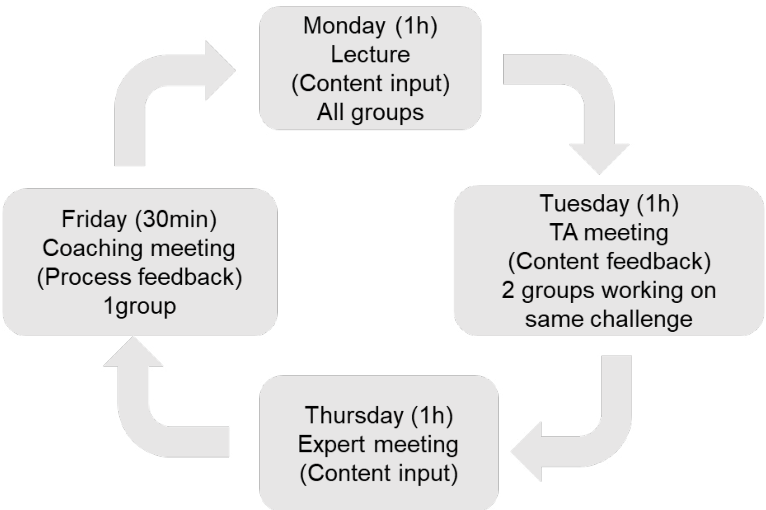

Fig. 1 Weekly cycle of learning activities in E3Challenge2

2.3 Data collection

Students participating in the Challenge-based course E3-Challenge 2 were invited to participate. Forty-three students participated in the course, and thirty-nine of them have permitted us to use their weekly learning portfolios as input for this research. Each student's portfolio consisted of 9 weekly reflections and 1 final reflection, which resulted in 10 submissions per student and in total in 380 submissions, as some students skipped some submissions during the course. The Ethics Review Board of the University has approved this study.

2.4 Data analysis

Thematic analysis was used to identify, analyze, and report patterns within data [10]. Our analysis included a balance of deductive coding (derived from the theoretical framework developed by Vermunt and Verloop [8] and inductive coding (emerging from a student's portfolio). For the analysis, the portfolios were read, and emerging codes were assigned to segments independently by the first author. We identified 1) all incidents of friction where students described their interactions with the teaching staff, 2) identified learning functions that students described in those interactions, and 3) reported tecahers'regulation of the aforementioned learning functions. The data analysis was conducted using ATLAS.ti [10]. The main researcher analyzed all portfolios, and an auditing procedure among all researchers was conducted to discuss the results of the coding process.

3 RESULTS

3.1 Students' SRL through their weekly reflections

The portfolios provided a good way to assess students' skills in regulating their learning and their development throughout the course. For most students, the initial weeks were characterized by **a) uncertainty** related to the **content of the course** and how to apply ethics and data analytics in the challenge and **b) uncertainty** related to **the learning process** and how to navigate such an open-ended course individually and as a group.
Among the most frequently mentioned difficulties for students in the course included 1) establishing an understanding as to what is expected in the course 2) narrowing down the broad challenge to a specific problem to focus on and setting clear goals 3) applying content knowledge (ethics and data analytics) to the challenge 4) diving the tasks among group members 5) managing the time 6) managing group processes.

3.2 Incidents of student-teacher interactions

We analyzed 92 reported interactions between students and the teaching staff involved in the course. Students engaged with all teaching staff during the course, but interaction with teaching assistants was the most frequently mentioned (see Table 1).

Table 1. Summary of reported interactions between students and teaching staff

Student- Teacher interactions	N
Teaching Assistants	67
Coaches	13
Experts/lecturers	12
Total	92

3.3 Experienced friction in CBL

After carefully analyzing the 92 reported interactions, we identified sixty-six incidents that offered in-depth information about friction experienced by students**.** When analyzing the incidents of constructive and destructive friction, we identified which learning function students needed support with and what was teachers' regulation. Table 2 summarizes the most important

Table 2. Reported frequencies of learning functions and teachers' regulation activities as reported in students' weekly reflections

Learning function	N	Teacher regulation
Cognitive	89	• Feedback on reports, and presentations (N= 22) • Answering questions related to the challenge purpose (n=19) • Helping students narrow down the problem they had to tackle (N=9) • Providing support on data analysis or ethics applications (N=16) • Providing explanations of concepts/examples/ (N=9) • Teaching new concepts (N=9) • General discussion on topics related to ethics and ethics application (N=5)
Motivational/affective	10	• Dealing with students' frustration (N=6) • Dealing with students' lack of motivation (N=4)
Meta-cognitive	15	• Provide support in goal setting (N=7) • Provide support in the planning of tasks and activities (N=5) • Provide support/coaching on team functioning and task division (N=3)

The majority of incidents represented ***incidents of constructive friction***. They were related to a) perceived unclarity of the course in terms of what was expected from students and how to apply content knowledge and b) perceived lack of guidance by teachers. More specifically, the openness and freedom of the course were appreciated by students but in reality, in combination with the limited time frame, many of the students wished for more guidance and clarity on what they were expected to deliver.

We identified 89 references to ***cognitive functions*** where students received support from teaching assistants and experts/lecturers. The most frequent topic of interaction among students and teaching assistants or experts/ lecturers was asking for feedback on ongoing progress and deliverables or asking questions. Teachers supported students by asking questions, clarifying concepts, teaching new ones, and helping students with knowledge application. Support from experts and lecturers was experienced as helpful in learning.

> *I did not know where to start so I asked for help during the TA Session. TA and some fellow students explained the concept of business ethics and gave me the hint to start with writing down the vision of XXX. In that way, I could write an ethical issue based on XXX vision. This was a good tip that helped me to get started. Eventually, I wrote about how to protect the users' privacy and how to prevent discrimination when tracking the users' data because in my understanding, business ethics is about the rules a company has to follow to be ethically responsible. However, when finishing my first draft, I still doubted if I did implement business ethics in our report as it should be. Therefore, I asked [the ethics expert] for feedback (Student 1, Challenge A, week 5).*

When students reported difficulties related to ***motivation and metacognitive functions***, students discussed that with teaching assistants or the coaches. In these cases, teaching assistants and coaches provided support to students to make necessary changes in the working plans, discussed different ways to deal with team processes, set goals and make appropriate plans, and define all necessary tasks to be completed. For example, one student reported

> *My learning experience occurred during the coaching session: my teammate and I had a key discussion with our coach. We were explaining how confused we still felt about the course, not knowing clearly in which direction to move forward. We were suggested to take the initiative of choosing our own challenge, rather than waiting for precise instructions from the professors, as in most courses. This gave us the freedom to choose our own goals: we decided on two main objectives, one ethics-related and the other concerning the data analysis. As the week evolved, we gathered feedback from the experts about our ideas (Student 2, Challenge B, week 2)*

Teachers emphasized the importance of self-regulation, but many students, especially at the start of the course, were not capable of demonstrating SRL skills.

Incidents of destructive friction were mainly reported in the first few weeks due to perceived uncertainty and stress related to the course's overall aims and inability to go from a broad and vague challenge to defining a specific problem to tackle. Below is an example of destructive friction where students feel that their concerns about uncertainty are not addressed and that the provided set-up of the course does not meet their need for clarity and guidance.

> *This course started, though, because we were all so confused about the goal of the challenge and about what it was the client wanted from us. Therefore, the first two/three weeks were a bit unpleasant. We did not really like the set-up of the course, which resulted in less motivation for this course (at least this was the case for me). The TA and expert sessions were very time-consuming and not helpful (because we did not really have so much to share at those moments) (Student 4, Challenge C, week 4).*

Destructive friction was also experienced when students showed reluctance to share with their teachers their uncertainty and ask for guidance. Below, a student described an incident of destructive friction arising from his fear of asking questions.

> *During the coaching session, the question that was brought up was, "Why didn't you talk to the TA?". I find this question very difficult to answer, but the first answer that comes to mind (I also learned this is often the best one) is "respect". I always look up to teachers and TAs and they deserve a lot of respect in my opinion; that's why there was (and probably still is) some mental barrier that is stopping me from just reaching out and telling them my concerns or struggles (Student 3, Challenge B, week 3)*

3.4 Resolving the friction and development of SRL

Several students increased their self-regulated learning skills by resolving the initial friction and by adopting a more proactive approach to their learning. Students realized the importance of being proactive in asking questions to get better feedback, showing a proactive attitude as a group, spending time establishing a common understanding with other group members, and establishing teamwork processes early in the course.

> *The first week was intimidating in terms of the lack of structure provided by the organizers. The expected outcome was not clear, and I was expecting more input to proceed. However, this week I figured that this was not the right approach. During the TA Session, I stepped out of my comfort zone by asking questions and suggesting ideas without worrying about their quality of them. The improvement in my understanding was significant. I now have a direction,*

> *and I am aware that I will not be fed with the information that I need. This acknowledgment taught me to be confident in my opinions also when talking to authorities. (Student 4, Challenge B, week 2)*

Final reflections were analyzed for references to students' interactions with teachers and SRL development. Students mentioned a positive overall experience with teachers as supportive during the course and they appreciated the multiple opportunities and sources of feedback they had on a weekly basis.

4 DISCUSSION

This study aimed to explore the student-teacher interactions reported in students' weekly portfolios in a CBL course. The role of teachers was very important, especially at the beginning of the course, when students needed more scaffolding in terms of content and working processes. The greatest need for support was related to students' cognitive functions, This finding can be explained because the content students had to learn as well as the challenge they had to tackle was new to them. On the other hand, students reported fewer incidents of interaction with teachers related to motivational/meta-cognitive functions by the teachers. This can be because students who selected this course were already intrinsically motivated and had prior experience with group work and planning group work from previous courses or because they relied on themselves and their peers to regulate those functions and did not expect teachers' support.

The majority of students gradually adopted a more proactive attitude by asking actively for help when things were unclear, going better prepared for meetings with teachers, and using the feedback more critically.

Within the duration of 11 weeks course, it is not possible to identify significant changes in students' SRL, but the portfolios revealed that students at the end of the course were much more aware of the proactive attitude students need to exhibit in CBL as well as how to make use of all the available resources.

To conclude, the interplay between teachers' regulation and students' self-regulation in CBL can be complex [11], [12]. Friction can arise especially if students have no prior experience with the increased autonomy that CBL entails. Given the autonomy and self-regulation expected from students, the role of teachers is also different compared to traditional teaching approaches [6]. The teacher in CBL is viewed more as a coach than an expert who guides students through the process [3], [5], [6]. The role of teachers in CBL courses is essential to reduce the gap between teaching and learning by providing the right amount of scaffolding and guidance by supporting cognitive, meta-cognitive, and motivational aspects of students' learning [12].

4.1 Recommendations for practice

The study suggests that SRL is important in CBL, but students need more support and scaffolding in regulating their learning, especially cognitive functions. Therefore, the study highlights the importance of teachers' role to support students' regulation of

learning via frequent feedback activities, especially at the early stages of learning [14]. Depending on students' educational level and prior experience with CBL, teachers should set clear boundaries in the project and within those boundaries adapt the amount of support and scaffolding they provide to students [12]
In addition, we found that reflective assignments can provide opportunities to dive deep into the processes that allow students to take control of their learning [13].

4.2 Limitations and Future directions for research

The study focused on a specific course, and the included sample was small. Thus more general conclusions can not be drawn. Another limitation of the study is the focus on SRL within the limited time of one course. In addition, learning in CBL is not only individual but also collaborative. Thus, other forms of regulation, which occur with a group of students, are also relevant and should be explored. Future studies should explore the influence and experiences of the aforementioned social types of regulation as well [15]

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Mathematics education in engineering: a triple discontinuity?

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ABSTRACT

This paper focuses on the study of discontinuities in the teaching of mathematics in engineering within the framework of the anthropological theory of didactics (ATD) and, in particular, attempts to characterize the internal discontinuity between the teaching of mathematics and the role of mathematical activity in engineering subjects through an interview campaign with mathematics and engineering teachers. The first step of this research was the work piloting the interview protocol [12]. We now try to improve this protocol to overcome the fact that, even when both engineering and mathematics teachers seem to talk about the same content (solving linear systems, for example), the activity they are addressing is very different. Splitting the interview into two separate parts has allowed us to have a first online questionnaire that gives an explicit introduction about the notions of praxeology, the type of tasks and the technique of ATD to the interviewer and allows him/her to internalize them before conducting the live interview. The first analysis of the results shows that the interviewees are able to describe the mathematical activity (existing and desired) in terms of types of tasks and techniques previously introduced and seems to indicate that there is an important level of consensus on the important contents to be taught in the first year courses. However, some differences appear in the applicationist conception and its justification. Mathematics teachers seem to agree on a conception in which mathematics is a tool to be applied in engineering courses while engineering teachers see mathematics as an intrinsic component of engineering.

1 INTRODUCTION

1.1 Transitions and discontinuities in engineering education

Numerous research works take as object of study phenomena associated to discontinuities and transitions between institutions. For example, there are works addressing the epistemological differences in different courses in engineering schools [1] or others analysing the existing discontinuities in mathematics education [2]. In fact, this field of study is not new: in 1908 Felix Klein announced its famous double discontinuity concerning the professional development of future mathematics teachers [3]. The first discontinuity announced by Klein concerns the transition problems that students experience when they enter at the university, and the second discontinuity relates to the transition between the university and their activity as secondary teachers.

The first discontinuity has been widely addressed, not only in mathematics education but also in engineering education, particularly because of the high level of dropout rates in this field [4] [5]. The second discontinuity in the engineering education - between engineering schools and workplace- has also been extensively addressed and reveals diverse challenges to soften the existing gaps between the institutions [6] [7].

The work presented here addresses the study of phenomena associated with discontinuities and mathematical education in engineering. Discontinuities are associated to a transition between institutions (defined in a wide sense, see theoretical approach section). The starting point of our work is that we hypothesise that the path followed by engineering students' experiences what we could call a triple discontinuity (see Figure 1), making an analogy with Klein's famous double discontinuity. The first and third discontinuities are homologous to those announced by Klein in mathematics teacher education. The second is the one that would be more specific to engineering education: it is an internal discontinuity in engineering education institutions due to the transition between the mathematical courses for engineers and courses in engineering courses, in line with what has been observed in previous studies [8].

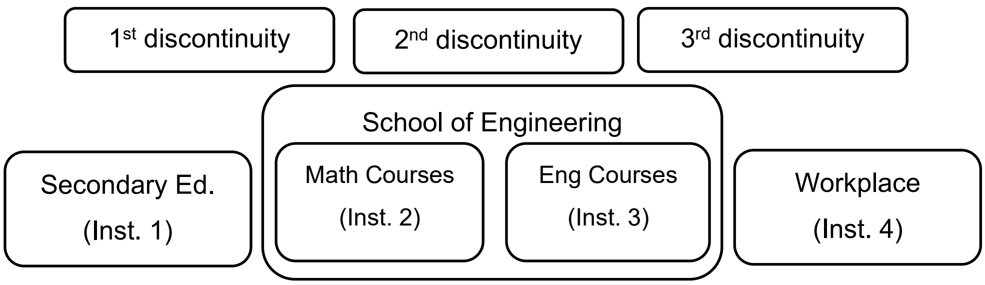

Fig. 1. Triple discontinuity in engineering education

1.2 Previous works

There are diverse works that have studied the differences in the mathematical activity existing in mathematics and in engineering courses. For example, González-Martín and Hernandes-Gomes [9] have studied the role of integrals in mathematics courses and in courses of mechanics of solids, in the same line, Hochmuth and Peters [10] conducted a study analysing the different discourses in mathematics and in signal theory courses. Both studies are framed within the ATD and mobilise the notion of praxeology [11] to model the existing mathematical activity in each course.

The first work developed to study our hypothesis was a qualitative study that allowed us to pilot an interview protocol addressed to both mathematics and engineering teachers at an engineering school in Barcelona (Spain). The study wanted to characterise the epistemological conception of these two positions: first-year mathematics teachers and engineering courses' teachers and to analyse to what extent these conceptions revealed a discontinuity [12].

The crucial fact that appeared as one of the main findings is that both mathematics and engineering teachers show an elevated level of consensus in the selection of the important contents in the fields of linear algebra and analysis. However, an analysis of statements of each collective reveals that under the "label" of "solving linear systems" or "finding the derivative of a function" the targeted activity is very different.

2 THEORETICAL FRAMEWORK

Our work is framed within the ATD initiated by Yves Chevallard during the decade of 1980s in the field of mathematics education but that has widely spread in the field of sciences and engineering education during the last 10 years. Particularly, in this work we use two theoretical developments of the ATD: the notions of *institution* (and institutional relativity of knowledge) and that of *praxeology*.

In the ATD an *institution* is any created reality of which people can be members (permanent or temporary). Accordingly, the group of teachers of engineering courses and the group of teachers of mathematics courses are institutions under the ATD conception. In addition, ATD considers that knowledge conception is institutional-dependent. In other words, in the same engineering school, the kind of activity existing in mathematics courses under the label "functions" differs heavily on what is considered under the same label in engineering courses.

The second notion is that of *praxeology.* To present the concept, we rely on this statement by Bosch and Gascón [13, p. 68]: "ATD postulates that any activity related to the production, diffusion, or acquisition of knowledge should be interpreted as an ordinary human activity, and thus proposes a general model of human activities built on this key notion of praxeology". A praxeology is formed by a quadruplet [T/t/θ/Θ] consisting of a type of tasks to perform T, a technique t which allows the completion of the task, a discourse (technology) θ that explains and justifies the technique, and a theory Θ that includes the discourse. The praxeology consists of two blocks: the praxis block (including T and t) and the logos block (including θ and Θ).

Characterising the mathematical activity in praxeological terms allow us to detach from the knowledge described in terms of contents that in our previous work hided relevant differences between interviewees.

3 RESEARCH QUESTIONS

The research questions we address in our work are:

- RQ1: To what extend the modification of the initial interview protocol in terms of praxeologies allow us to characterise the differences in the epistemological conceptions of engineering and mathematics teachers?
- RQ2: Characterise and identify the characteristics of the 2nd discontinuity in engineering education through a qualitative study.

4 METHODOLOGY

4.1 Questionnaire and interviews design. From pilot to the final version.

We present a qualitative study that intends to characterise the internal discontinuity in the mathematical education in engineering degrees. The first step of this research was the work where the interview protocol was piloted [12]. In this work we figured out that the interviews were too long (more than 1h) and that the analysis of the answers revealed important differences at the level of the targeted activity while the selection of the contents showed up high levels of consensus. The structure of the interview was not able to make these differences emerge.

The original interview protocol had four sections (personal background, research background, mathematical elements, and their role in engineering subjects, and mathematical contents in the course teached).

In the new interview protocol, we have decided to split the interview in two parts to shorten the face-to-face interview: a first moment where the interviewee fills in an online survey and a second part of a semi-structured interview. The online survey has 4 sections:

1. Personal background (including research background)
2. Evaluation of the applicationist conception of mathematics education in engineering according to the work of Barquero and colleagues [14]. The characterisation of the applicationist conception is done through the level of agreement (5-level Likert scale) to five statements proposed in [14]. In addition, we allow the participants to add a short text field justifying their answer.
3. Mathematical contents in engineering: selection of common subjects in linear algebra and analysis in terms of relative importance (five level Likert scale ranging from “I do not consider it a critical content; it belongs to the 10% less relevant” to “I consider it a crucial content; it belongs to the 90% more relevant”)

4. Regarding the teaching activity. In the survey we asked the participants to choose one of the taught courses and to select the mathematical content that they consider as more relevant.

The semi-structured interviews had 4 sections. In the first one (1) we introduced explicitly to the interviewees the notions of praxeology, type of tasks and technique from the ATD. The interviewees were asked to describe the mathematical activity in these terms and to avoid the classical labels of contents to avoid the fake consensus found in the first edition. In the second section (2) we introduced two mathematical activities that had been proposed in first-year courses and we asked them to identify potential type of tasks and techniques that would emerge.

In the third section (3) the interviewee was confronted to the results of the third block of the online survey, and we asked them to describe the contents selected as more important in terms of type of task and techniques. Finally, the fourth block (4) the interviewees were asked to propose three types of tasks and techniques that they consider important but which they believe are absent in engineering education. The entire interviews are available at https://sites.google.com/euss.cat/sefi2022

4.2 Description of the interviewees and institutions of origin

The interviews were carried out at the Escola Universitarià Salesiana de Sarrià (EUSS) and the Institut Químic de Sarrià (IQS). Five engineering degrees are taught at EUSS (Electronics, Mechanics, Automotive, Industrial Organisation and Renewable Energies and Energy Efficiency) whereas IQS offers degrees in Chemistry, Chemical engineering, Biotechnology, Pharmacy, Biomedical Sciences and in Industrial engineering. Both Institutions are strongly interested in the implementation of teaching innovation processes and have extensive experience in this field.

Mathematics teaching in all EUSS degrees is concentrated in three subjects: two in the first year and one in the. second one. Mathematics is offered in the first semester with 7 ECTS, calculus in the second semester with 8 ECTS and statistics in the fourth semester with 6 ECTS.

The distribution of mathematical content in the IQS depends to a greater extent on the degree programme studied, but if we focus on engineering studies, we can see that all three degrees (in Biotechnology, in Industrial Engineering and in Chemical Engineering) offer a 12 ECTS subject called mathematics during the first two semesters. Chemical engineering students also see a 6 ECTS course in computer science and numerical methods in semesters 1 and 2 and an additional 6 ECTS in applied statistics in semester 4. Biotechnology students take a 5 ECTS course in statistics in semester 4 whereas for industrial engineering students there is a 6 ECTS course in statistics in the 1st semester, and 2 courses of 4,5 ECTS each in the 3rd and 6th semester named mathematics II and III. The syllabi of each degree can be consulted in detail on the centre's websites: www.euss.cat. or www.iqs.edu.

The first institution, formed by the group of teachers of mathematical courses, has the following profiles. The first mathematics teacher (MT1) has a degree and a PhD in Mathematics and has always been involved in university teaching and research, with more than 30 years of experience. MT1 teaches mathematics, calculus, and statistics at EUSS. The second lecturer (MT2) has a degree and a PhD in Chemistry, and, except for a one-year break, he has always worked in the academic field, where he has been teaching for the last 9 years. He teaches mathematics and other engineering subjects. The third teacher (MT3) has a degree in Mathematics and a master's degree in Applied Mathematics. MT3 teaches mathematics, calculus and statistics and has more than 30 years of teaching experience. The fourth lecturer (MT4) is an Industrial Engineer with a PhD in Chemical Engineering with more than 18 years of teaching experience and involved now in mathematics II and physics teaching at IQS. The fifth one (MT5) has a Mathematics degree and is currently a doctoral student in Philosophy. MT5 has been teaching only for one year and he currently teaches mathematics I at IQS.

The second institution, made up of the teachers of engineering subjects, has the following profiles. The first teacher in the engineering field (ET1) has a degree in Physics and holds a PhD in Materials Engineering. She has always worked in the field of research and university teaching in the degree of Mechanical Engineering, specifically in the field of strength of materials, elasticity, and structures. ET2 holds a PhD in Telecommunication Engineering and after his doctorate he worked for a short period in industry and then returned to research in supercomputing. He currently teaches in the degree of Electronic Engineering, specifically in the field of industrial computing and communications. ET3 is a Mechanical Engineer and holds a PhD in Material Science. He started his professional career as a laboratory technician and ended up developing a PhD in Biomaterials. He teaches in all the school's degrees in the field of materials, manufacturing processes and strength of materials. ET4 has a degree in Industrial Organisation and a PhD in Business. He only teaches on the school's Industrial Organisation Engineering degree. His professional career has always been in academia, and he teaches strategic management and quantitative methods for management. ET5 is an engineer with a PhD in Civil Engineering. She has developed her professional career in academia and teaches in all degree programs, specifically in physics, strength of materials, machines and mechanisms and fluids. ET6 has a degree and a PhD in Marine Sciences. After a period of 9 years in the field of research and university, he worked for 7 years in industry, as a consultant, as data Analyst and modelling expert. He come back to the University 4 years ago, teaching in all the school's degrees in the field of electrical physics, manufacturing processes and fluid engineering.

4.3 Analysis of results: surveys and thematic analysis

The results of the online survey have been analysed qualitatively while the interviews have been fully transcribed and will be analysed using deductive thematic analysis [15].

The deductive coding is based in the identification of different types of tasks and techniques and their justification. Specifically, includes the identification of the following themes: (1) paper-and-pencil techniques, (2) computer-based techniques, (3) calculator-based techniques, (4) research-based techniques, (5) tasks involving the solution of short mathematical exercises, (6) tasks involving contextualized mathematical exercise, (7) tasks involving the use of engineering models, (8) justification based on cognitive effects on students, (9) justification based on the application, (10) justification as a way to introduce engineering models. The thematic analysis is now being conducted and only partial results will be presented in this paper.

5 RESULTS

5.1 Online questionnaire

The main results of the online survey reveal important differences between the mathematics and the engineering teachers in diverse items. Regarding the second block, that related with the applicacionist, one of the differences that appear concerns the conception of mathematics as a tool to be used in engineering courses. The positions to the statement “A relatively deep study of engineering phenomena and models could be done without using mathematics” are very different in mathematics and engineering teachers. While mathematics teachers fully disagree, considering that any study of engineering phenomena could be done without mathematics, engineering teachers have a less consensual position. For example, ET6 complements her answer with the following statement: “many engineering phenomena or models can be understood without a deep understanding of the mathematics backing them” (translation by the authors).

Another interesting aspect where the answers between engineering and mathematics teachers diverge is about the position on the following statement: “In education, mathematics is generally introduced independently of physical or engineering systems that can be modelled mathematically.” Engineering teachers show full agreement on that: for example, ET1 states: “Mathematics are treated as an entity of their own, detached from other disciplines. At most, they are presented as a tool, but just as detached from the other disciplines” (translation by the authors). However, mathematics teachers present less consensus and one (MT2) states that “it is necessary to learn some mathematical mechanisms and concepts in order to apply them in engineering courses. I think that application examples in each chapter might help…” (translation by the authors).

In the third block of the online survey, where participants had to prioritize a list of contents, the level of agreement is very high, in coherence with was already observed in the piloting survey. Solving Linear Systems with Matrices, Derivation and Integration are the contents considered as more important in both groups. These results, again, are very close to the previously obtained during the piloting of the study.

5.2 Interviews

As said before, the full coding of the transcripts is still in process, and we will present, for now only preliminary data. One of the main goals to introduce the notion of type of tasks and technique to the interviewees was to make the description of the mathematical activity more explicit. The introduction of the notions was clear enough to all of the interviewees and after the first block no one showed any problem when describing mathematical activity in praxeological terms.

Regarding the second block of the interview, it seems that some differences appeared. For the first activity, the type of tasks identified were the same: “find the derivative of the function”, “solve the equation of the derivative equal to zero”, “find the second derivative”, etc. Regarding the techniques, both groups of teachers identified similar techniques and both groups assign paper-and-pencil techniques to the first-year courses while allow other techniques in engineering courses. For example, ET6 stated: “in first-years mathematics, they would find the derivative by-hand, using derivation rules, however in engineering subjects we would never do that, and we would use a calculator or maybe an online symbolic calculator…”. Other statements from mathematics teachers showed up these differences: “in first -year courses we would calculate derivatives and solve the equations using paper-and-pencil…but I am quite sure that in other courses, the students would graph the function using google…”.

Concerning the second activity (about population growth) and with and inquiry-based approach, the answers start to diverge between the two groups. ET1 stated, for example that considers that this second activity “allow to show mathematics involved with other disciplines, such as biology to solve a real or close-to-reality problem”. In a very close line, ET6 states that the students would mobilize tasks that do not appear usually in the first-year mathematics at her institution. She highlighted the data analysis, forecasting and validation of the results against a real setting.

When the teachers were asked about the type of tasks and techniques that do not appear in the mathematics courses, it is particularly interesting the answer of MT4; he is aware of the prominence of the algorithmic approach in their courses (paper-and-pencil work) but he considers that it is a matter of resources. He states: “I think that the manual calculation can have a value for itself, but I am aware that devoting more time do work with modelling would be better for engineering training…however I cannot see how to make a lot of students work on modelling…the mechanical work is a way to deal with a big number of students”. Another mathematical teacher states (MT5) that “I think that in engineering the students see very little algebra, however, I do not really know to what extent what algebra is needed for engineers…”.

6 CONCLUSIONS

The first analysis of the results, especially the interviews transcripts, show that the interviewees are able to describe the mathematical activity (existing and desired) in terms of type of tasks and techniques. This fact allows us to, at least partially, answer RQ1. The statements and the discourse analysed to the point confirm that the modification of the survey and of the protocol overcomes the limitation of describing mathematical knowledge in terms of contents. We hope that the further analysis of the data will help to make differences and similarities between groups emerge.

Regarding de second question we only can answer it preliminary using data from the online survey. The results obtained and their justifications seem to indicate that there is an important level of consensus on the important contents to be taught in first-year courses. However, some differences appear in the applicationist conception and its justification. Mathematics teachers seem to agree on a conception where mathematics are a tool to be applied in engineering courses, engineering teachers see mathematics as an intrinsic component of engineering. This dependency between mathematics and engineering models is not coherent with the detachment between mathematics and engineering courses.

Further analysis work will be conducted, incorporating more data with participants from other engineering schools in order to validate this preliminary results.

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MINDFULNESS FOR ENHANCING LEARNING IN ENGINEERING EDUCATION

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ABSTRACT

Technology is evolving at a rapid rate, thereby introducing more complex problems that engineers must be able to engage with. Increasingly complex problems require new ways of thinking, and more innovative, creative, and collaborative responses. To lead this technological evolution, engineers are challenged to engage with lifelong learning and ongoing problem solving. The learning and creative thinking skills needed for innovation relies on an open and receptive mindset – a key component of mindfulness. Mindfulness has previously been shown to enhance creativity, focus, mental clarity, and divergent thinking skills required for problem solving. Furthermore, mindfulness has been shown improve interpersonal relationships and communication – paramount to effective collaboration when working on solutions to complex problems as a team. In this paper, the perceptions of mindfulness and its effects on engineering professionals in the workplace are explored. Data were collected using structured interviews with a purposive sample of practicing South African engineers, and a survey sent out to a larger sample. Data were analysed using content analysis for the interviews and statistical regression analysis for the survey. It was found that engineers believed that consistent learning was a vital aspect of job performance. Findings revealed that mindfulness was correlated to lower stress, fatigue, and turnover intention, while improving productivity, innovation, emotional intelligence, and communication. Results indicate that through cultivating mindfulness, engineering professionals will be more equipped to continuously learn, create, and innovate in a productive manner. The study proposes that mindfulness is introduced at undergraduate level in engineering education as a key skill in preparing graduates for the workplace.

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1 INTRODUCTION

1.1 Background to the Research

The rapid rate of technological evolution is likely to continue for the foreseeable future. As technology progresses, more complex challenges and problems present themselves. Engineers play an important role in technological evolution, and as challenges become increasingly complex, and work environments change, engineers must be able to adapt and engage with change in an effective, generative, and productive manner. Such change may require certain knowledge and skillsets possessed by engineers, so that they can continue to contribute with the latest knowledge and advancements while still being able to offer valuable input [1]. This can enable engineers to be suitably equipped when engaging with the increasingly complex challenges, which require new ways of thinking, as well as more innovative, creative, and collaborative responses. Lifelong learning, problem solving, and divergent thinking skills are vital in empowering engineers to continue to lead the technological revolution, while offering creative and innovative solutions to challenging problems.

The learning and creative thinking skillsets needed for innovation rely on an open, curious, and receptive mindset, which includes divergent thinking. Instead of focusing on the development of these skills, engineering education mostly focuses on narrow, analytical, and convergent thinking skills [2]. This comes at the expense of learning creative, divergent thinking skills which are essential in aiding engineers in developing innovative solutions to increasingly complex engineering problems. Rather than focusing solely on developing narrow, analytical and convergent thinking skills, engineering education should begin to focus on the cultivation of creative, innovative, and divergent thinking skills [3]. This does not mean that analytical, convergent thinking skills should be ignored, but rather both sets of skills should be emphasised to ensure that graduate engineers are well-equipped to deal with a rapidly changing industry.

Mindfulness is a practice that has its roots in ancient Buddhist psychology and philosophy. The practice of mindfulness has been adopted as a way for individuals to quieten the mind, which can lead to a range of mental, emotional, physical, and physiological benefits. Previously, there have been negative stigmas attached to mindfulness and meditation, and many academics and scientists previously perceived it as an esoterical and spiritual practice. In recent decades however, research into mindfulness has increased exponentially. Empirical research and studies have demonstrated that a wide variety of benefits can be experienced by individuals through engaging in mindfulness practice (e.g. Rieken, et al. [2], Good, et al. [4], Kersemaekers, et al. [5]). Furthermore, developments in Magnetic Resonance Imaging (MRI) have allowed researchers to observe the effects that mindfulness practice can have on the brain. Existing research has proven that regular mindfulness practice leads to new neural pathways growing, as well as the beneficial altering of the size and structure of the brain, such as an increase in grey matter (responsible for the processing of memory, emotions, sensory perceptions, speech, self-control, and decision making), the thickening of the hippocampus (responsible for helping memory and learning), and a reduction in the size of the amygdala (which leads to a reduction in stress) [6]. More objective data, such as those offered by brain scans through MRI, have led to increased interest in mindfulness amongst scientific communities and therefore an increasing number of mindfulness-related studies emerging as time progresses.

Existing research has indicated that regular mindfulness practice can enhance individuals' learning ability [7], innovation and divergent thinking skills [2], and wellbeing; while reducing stress and emotional exhaustion [8]. Mindfulness can therefore equip practitioners more effectively for dealing with the challenges of a dynamic, changing work environment that engineers often face. Moreover, engineers with experience in mindfulness will improve their learning ability, innovation, and divergent thinking skills, which can give them an advantage when it comes to learning new concepts and keeping pace with the rapidly advancing technological evolution.

1.2 Value of the Research

Through ongoing learning and the development of innovation, and creativity skills, engineers are more likely to be able to produce effective solutions to complex challenges that society faces. The nature of these challenges are likely to become more complex with time, as natural resources begin to dwindle, new ways of doing things need to be established, and new challenges present themselves as society adapts and evolves.

Mindfulness has been shown to enhance learning ability, creativity, divergent thinking, innovation, job satisfaction, employee well-being and overall perceived quality of life. Through the cultivation of these skillsets and traits, engineers will be more suitably equipped to engage with complex challenges and commit to a process of lifelong learning. Graduate engineers with mindfulness practice experience are more likely to produce more innovative, creative, and novel solutions to the challenges faced by an evolving society and rapidly advancing technological industry. This has the potential to enhance their careers, as they will not only be able to provide more value to the engineering industry but will also be more suitably equipped to managing and reducing their stress levels and mental health, while improving their overall wellbeing and job satisfaction.

1.3 Research Aims and Questions

This paper reports on a study that investigates the relationship between mindfulness and learning in engineering professisonals. The following research questions were addressed:

1. *How does mindfulness enhance learning in engineering professionals and students?*
2. *How can mindfulness practice be used to enhance lifelong learning, creativity, and innovation in engineering professionals and students?*

2 CONCEPTUAL FRAMEWORK

2.1 Mindfulness

A widely used definition for mindfulness in scholarly literature was formulated by Kabat-Zinn [9], and states that mindfulness is: *"the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally to the unfolding of experience moment by moment."* (p. 145). Dane [10] proposed a definition for mindfulness that also included an aspect of presence, describing it as "*a psychological state in which one focuses attention on events occurring in the present moment*" (p106). Evidently, fundamental aspects of mindfulness include presence and attention to present-moment experiences. Going forward, when the term 'mindfulness' is used, Kabat-Zinn's definition of mindfulness will be referred to as his definition holistically encapsulates the foundations of mindfulness in a clear, unambiguous manner. For the purposes of this research study, mindfulness will be viewed as a state, as proposed by Dane [10].

In most scholarly literature, the fundamental bases of mindfulness are attention and awareness. Almost all conceptual models of mindfulness include these characteristics. Brown, et al. [11] describe awareness as "*the conscious registration of stimuli, including the five physical senses, the kinaesthetic senses, and the activities of mind*". While attention and awareness interact, they are still distinctive from one another – attention is engaged when a stimulus is strong, and it is possible to lack awareness while paying attention. Conversely, it is possible to be aware that one is paying attention or paying attention to being aware of a phenomenon. Good, et al. [4] used a conceptual model that suggests the key pillar of mindfulness is solely attention, and that all benefits that arise are due to the cultivation of attention; namely in the areas of stability (how consistently one can hold focus), control (directing attention amid competing demands), and efficiency (referring to the economical use of cognitive resources). For the purposes of this research study, the conceptualised model of mindfulness will include aspects of attention and awareness, with a focus on present-moment awareness, owing to Kabat-Zinn's (2003) definition of mindfulness.

The attention and awareness that arises when an individual is in a mindful state should be non-judgmental and non-discriminatory in nature, and rather as objectively as possible without attaching any emotional value to any events unfolding. In other words, when mindfully processing phenomena, there is no comparison, categorisation, or evaluation on the current experiences that are unfolding; nor is there any contemplation, reflection, or rumination on events or experiences based on memory or preconditioning. Instead, mindfulness promotes non-interference and non-judgment towards any experience that may arise, and simply allows inputs to enter an individual's field of awareness by simply *noticing and observing* what is taking place. Mindfulness involves experiential processing of phenomena unfolding [11], which refers to phenomena occurring in both one's internal world (consisting of thoughts, feelings, and emotions) as well as one's external world (consisting of external stimulus and sensations) while simply *observing and noticing* what may arise. It is important, however, not to judge or to attempt to assign meaning to anything. In addition to these qualities, the attention and awareness that is cultivated due to mindfulness is also flexible, meaning the field of awareness can be adjusted accordingly – it can move back to gain a larger perspective on what is taking place (known as clear awareness), or it can 'zoom' in on situational details (focused attention) [11]. This feature can allow mindful individuals to alter their perceptions and limiting thoughts to obtain greater clarity and understanding in certain situations where it is required that the bigger picture is seen.

When the topic of mindfulness is discussed, the construct of past, present, and future is taken into account. Brown, et al. [11] suggests that humans' minds oscillate between memories of the past and projections into the future. Too seldom, do humans experience the present moment for what it is. This is often caused because humans 'forget' that we only exist in the present, and that there is no tangible, direct contact with either the past or the future – they are both simply constructs of our imagination. While this 'oscillatory time travel' serves a useful biological purpose of protecting, maintaining, and improving the self, or one's identity (which is a set of ideas about oneself that defines *who* they are in relation to the world), it often comes at the detriment of one's mental and emotional well-being (by dwelling on painful past memories or excessively worrying about future outcomes). Mindfulness helps to increase the amount of mental time spent being aware in and of the present moment, through the cultivation of *present-oriented consciousness*. Zimbardo and Boyd [12] importantly point out that this is not to be confused with 'living for the present', which is associated with hedonism, impulsiveness, and fatalism. On the contrary, mindfulness has been inversely related to these characteristics.

2.2 Salutary Effects of Mindfulness in the Context of Learning, Wellbeing, and Performance

An open, receptive mindset, necessary for learning and creative thinking, is a key component of mindfulness. Mindfulness has previously been shown to enhance creativity, focus, mental clarity, innovation, and divergent thinking skills required for problem solving. Existing research has revealed compelling evidence that there is a causal relationship between mindfulness and creative innovation achievement, and therefore learning [6]. However, psychologists are still attempting to establish the exact mechanisms through which mindfulness can aid innovation [13]. Mindfulness may be able to enhance learning indirectly as one of its most common applications is for stress reduction [14]. Vogel and Schwabe [15] found that stress can limit an individual's ability to retrieve memories and learn effectively, suggesting that mindfulness could be used as an effective tool to counteract stress-based learning difficulties.

The effects of a changing and challenging environment, such as the environment that presents itself in the e engineering workplace in the face of rapidly evolving technology, can be mitigated in employees through mindfulness. It has been shown that organisational mindfulness held value for organisations to help respond to a changing and challenging workplace, while mindfulness also provided benefits to organisations which included improved learning, increased job satisfaction, and reduced employee turnover and absenteeism [16]. Mindfulness has been shown to enhance individual learning ability, as it leads to increased activation in the prefrontal cortex – the region of the brain responsible for higher-order thinking, judgment, decision-making, and planning. Researchers found in long-term meditators that the cortical regions responsible for processing sensory input were thicker, and that meditation increased brain activity involved with learning and memory processes, emotional regulation, self-reflection, and perceptiveness [6]. Ching, et al. [7] conducted a study involving 359 university students who engaged in regular meditation practice. Results showed that through regular meditation, students possessed improved mental and physical stamina and school performance, enhanced learning ability, increased memory, and faster reaction times.

Mindfulness has been shown to enhance personal well-being, both directly and indirectly. Well-being can be directly enhanced as mindfulness can add clarity and vividness to current experiences; encouraging closer sensory, moment-to-moment contact with life without first interpreting, analysing, and judging everything that is going on. This can reduce the emotional and mental distress that could arise due to the judgment and discrimination towards current events unfolding, thereby allowing a state of peaceful equanimity to arise – a quality that significantly enhances an individual's sense of well-being.

Indirectly, mindfulness can lead to enhanced individual well-being by improving self-regulating functioning that comes with sustained attention and awareness of psychological, somatic, and environmental stimuli [11]. These claims of improved well-being have been backed up by studies, where significant correlations have been found between mindfulness and: mental health, lower levels of emotional disturbance (such as depression, anxiety, and stress), higher levels of subjective well-being (higher positive effect and satisfaction with life), and eudemonic well-being (vitality and self-actualisation) [17]. Baer, et al. [18] found that mindfulness was negatively related to neuroticism, while Walach, et al. [19] proved that mindfulness was negatively correlated to psychological distress. Furthermore, mindfulness is associated with greater general awareness, understanding, acceptance of emotions, and improved ability to correct mood states [17]. It has been shown that mindful individuals were less likely to be emotionally volatile and less negatively reactive, and that an 8-week mindfulness intervention training program reduced participants' neural reactivity and negative reaction to sadness-inducing stimuli [20]. This has been proven not only through empirical research, but also neurologically through brain scans of the amygdala and prefrontal cortex associated with threat response [21]. When individuals experience higher levels of well-being, they are more likely to feel motivated satisfied at their workplace, enabling them to produce higher quality work in an efficient manner. Therefore, through improving employee well-being, mindfulness is likely to improve individual's workplace performance, including engineering professionals.

Considerable research has gone into the field of mindfulness and its relation to cognitive performance – including both cognitive flexibility (the generation of new perspective taking and responding instead of reacting based on previous mental conditioning) and cognitive capacity (the fluid intelligence of individuals) [4]. Contrary to popular belief, Good, et al. [4] states that working memory and fluid intelligence is malleable, and that these qualities can be cultivated and improved within individuals through mindfulness training. Through improving cognitive flexibility and capacity, engineering professionals could benefit as it would enable them to develop new perspectives when solving problems. Additionally, the improved working memory and fluid intelligence would mean that professionals could recall information more quickly and may offer better insights through fluid intelligence.

3 METHODOLOGY

3.1 Research Approach

This research study aims to investigate topics that are personal to individuals, such as learning, mindfulness, and creativity. These states are subjective, and are experienced differently between individuals, each of whom possess differing mental constructs, beliefs, and understandings of the world. It was therefore deemed most applicable to adopt a constructivist- and interpretivist-based philosophical stance, which lends itself to subjectively experienced phenomena. This was more suited to the research study compared to an objectively rooted positivist philosophical standpoint.

A mixed methods case study approach was adopted for this research study, where the cases were engineering professionals in South Africa. This approach allowed for rich data and descriptions to be obtained from the participants.

The goal of this research study was to clearly understand the current situation in the engineering workplace context, in terms of mental health, mindfulness, job performance, and employee well-being. This was achieved with an in-depth study with individuals as cases. The perception of mindfulness as an effective practice to improve mental health among engineers was also explored.

This research study required an appropriate sampling design. A probability sampling design was used for the survey, and Simple Random Sampling was used for this part of the research. The population was identified as professionals working at an engineering firm in South Africa, as an engineer or otherwise. The important aspect was that the respondents were employed by an engineering company, as all employees working in this sector would be able to offer valuable insights into the nature of mental health and mindfulness within this context.

Purposive sampling was used for the structured interviews. Participants who were interviewed were not randomly selected from the sample, as they were selected based on their work experience, job position in the organisation, and their perceived contribution to the research study. To ensure that a suitable sample group was selected, a mixed purposive sampling approach was used.

3.2 Data Collection and Analysis

A 40-item self-report survey was used in conjunction with an open-questioned semi-structured interview, consisting of 16 questions. The survey consisted of five sections: Mindfulness, Fatigue, Stress Levels, Productivity, and Well-being in the workplace. The survey questions helped to elicit a score for each of the respondents in every one of the five sections. The survey provided clarity when addressing the aim of gaining insight into the mental health situation in the corporate engineering sector in South Africa, and assisted in answering the research questions pertaining to mindfulness. Additionally, relationships could be established between each of the sections in the survey through regression analysis, which helped gain valuable insights into the research aims and questions. The survey was a unique combination of existing survey questions dealing with mindfulness, fatigue, stress, wellbeing, and job satisfaction. The structured interview made up the qualitative aspect of the mixed methods approach. The interviews directly questioned the mental health situation in the engineering sector in South Africa, as well as the perceptions of mindfulness among engineers working in South Africa. In addition to this, the interview also helped in answering the research questions directly.

Statistical analysis was used to analyse the surveys. The numerical survey data was exported into *Statistica*, a statistical analysis software tool. This software was used to conduct regression analysis of the survey data, which would help establish relationships between the variables (different sections of the survey). A combination of both Linear and Multiple regression was used to establish relationships between the five main categories from the survey (Stress levels, fatigue, job satisfaction, mindfulness, and productivity), which offered insight as to how the variables related to one another, as well as the strength of the correlations.

Audio recordings of the interviews were transcribed and imported to *NVivo 12*, which was used to conduct the qualitative data analysis. Content analysis was used to analyse the data, which were coded using an inductive approach. Transcribed data was analysed for any emergent themes and categories, allowing the data to naturally unfold and tell their own story. The emergent codes from the transcribed interview data were then categorised into broader themes and categories. The same process was used to code relationships between categories. Whenever an interviewee related two or more themes/categories together in some way, a relationship emerged. Through coding the relationships, a clearer picture could be painted of what was being said by the interviewees, and how various categories related to one another.

Since the research study involved human participants, ethics approval was obtained from the Faculty of Engineering and the Built Environment at the University of Cape Town.

4 RESULTS AND CONCLUSION

The findings from the analysis of data from the 10 participants interviewed, and 65 survey responses are presented below. While 10 interviews may be too few to obtain true representativeness of the entire population being studied, the diverse range of individuals who were interviewed and each participants' insights into collective problems faced by engineers means that the data collected should be sufficiently generalisable. Furthermore, additional survey responses are required to obtain true statistical significance, the responses collected so far are proposed to represent trends that emerge from the sample population.

4.1 Perceptions of Mindfulness and its Effects on Job Performance Amongst Engineering Professionals in South Africa

Among the participants who were interviewed, 60% of them believed that mindfulness revolved around an aspect of awareness. A further 20% understood mindfulness as being aware of and absorbed in the present moment. Both of these beliefs are supported by existing literature on the topic of mindfulness (e.g. Kabat-Zinn [9], Brown and Ryan [17]). Other participants believed that mindfulness included aspects of gratitude, mental health, physical health, and finding a healthy balance to life.

When questioned about how mindfulness could be used to enhance job performance as an engineer, a wide range of responses were elicited from participants. A majority of participants (60%) claimed that mindfulness was an effective way of reducing stress, while 40% of participants believed that learning was an important aspect to being a successful engineer. The former statement suggests that mindfulness could enhance learning in engineers, as several participants believed that in order to learn effectively, it was important to have low stress levels. This is supported by Vogel and Schwabe [15], who found that high stress levels correlated to a lower rate of memory retrieval and effective learning in individuals. Through a reduction in stress, and therefore improvement in learning, an individual is predicted to be a more successful engineer professional.

Half of the participants believed that mindfulness practice would enhance productivity in individuals, meaning they would be more efficient when engaging with the task at hand, and therefore more efficient at their workplace. A further 20% of the participants suggested that mindfulness would result in an improvement in time management, which ties in to productivity. Regardless of what the task is, an improvement in productivity would mean that an individual can complete it more effectively with greater attention to detail and fewer errors being made – a sentiment that was reflected by a participant who was interviewed. This would apply to a task such as learning too, suggesting that through improving productivity in individuals, mindfulness can indirectly enhance an individual's ability to learn, and therefore function more effectively and successfully as an engineering employee.

30% of participants stated that mindfulness could lead to an improvement in interpersonal skills and emotional intelligence, which would be likely to lead to an employee's success in the engineering workplace. These skills tie in to effective collaboration and communication in an organisational context, and can enhance a team's ability to work together to find innovative and creative solutions to complex problems that present themselves through the advancement of technology and an evolving society. An additional 20% of participants suggested that mindfulness would lead to an improvement in one's self-confidence and self-perceived workplace identity. When an individual appears more self-confident in the workplace, they are more likely to elicit respect, come across as more trustworthy and reliable, and gain credibility in their organisation, thereby increasing their chances of success, promotion, and notable influence within their organisation [22]. Self-confidence relates to positive self-image, which suggests that individuals with higher self-confidence would be more adequately equipped to deal with setbacks, such as those experienced during the learning process when aiming to understand new concepts.

Other perceptions of mindfulness and its effects on job performance, which were proposed to a lesser extent by participants, included decreased burnout, less rumination, and fewer mental health issues. In contrast, participants believed that mindfulness could lead to an increase in quality of work, enhanced mental clarity and capacity (thus leading to improved job performance), better quality of life, increased focus, improved self-awareness, and enhanced intellect.

4.2 Learning, Job Performance, and Mindfulness

Of the participants interviewed, 40% of them indicated that learning was a key aspect to successful job performance as an engineering professional. Participant 3 suggested that learning and upskilling oneself, even when it was not part of the job description, could enhance an individual's job performance as an engineer and would enhance workplace identity and self-esteem as it would '*make your day-to-day life at the job easier, and with that, you get less depression, you get less resignation…'*. Participant 5 believed that learning was strongly linked to personal growth, and that as a junior engineer, learning was critically important to adapting to the working environment. This was reflected by participant 8 too, who stated that learning was paramount to job performance, particularly as an engineer who is new to the work environment, as it is expected that there is a lot that new employees would not know. Lastly, participant 9 believed that as new, more novel ways of completing tasks evolved with time, it was important for engineers to be dedicated to learning and adapting as technology progresses. This participant also indicated a concern that older engineers in the workplace were often unwilling to adapt and use newer, more efficient ways of doing things, which reflects a closed, narrow mindset. Mindfulness is a means to cultivating an open, receptive mindset that enhances creativity, innovation, and flexibility [3], which would likely assist senior engineers in opening themselves up to newer ways of doing things in a creative, innovative manner.

Participants believed that mindfulness could actively improve learning skills in individuals. Participant 3, who had had experience in mindfulness practice, believed that mindfulness could enhance mental clarity, which in turn, could improve one's rate of learning as one is able to engage more fully with the task at hand since there is less mental clutter and external thoughts. Participant 5 stated that *'when one is stressed and under a lot of pressure, learning falls out the window*'. The same participant went on to explain that they believed that mindfulness could improve ones quality of life, productivity, and time management, and that this could indirectly enhance an individual's learning ability. Participant 8 suggested that mindfulness could reduce the rate of errors when an engaging with a task, which could increase the rate at which learning could take place. Participant 9 believed that learning was made significantly harder when experiencing a state of stress, and that mindfulness could be used as a means to reduce stress. This was supported by Vogel and Schwabe [15]. In this way, it is believed that mindfulness could enhance learning.

4.3 Collaboration for Problem Solving and Mindfulness

A significant proportion of participants believed that interpersonal skills, including communication, teamwork, and emotional intelligence, was an indicator of successful job performance in the engineering sector. Participants 1 and 9 indicated that teamwork was a crucial trait to determine successful job performance, participants 3 and 10 cited communication, and participants 6 and 10 suggested emotional intelligence was an important trait. All of the aforementioned traits are conducive to effective collaboration in a team-based environment. Through improving interpersonal dynamics, and therefore enhancing effective communication and collaboration, engineering organisations would be more suitably equipped to working together to find solutions to increasingly complex challenges.

Participant 1 stated that being able to rely on and ask for help from others in a team was important when collaborating on finding a solution to a problem, and participant 9 believed that people skills and being able to effectively work in a team was paramount to successful job performance as an engineer. Participant 3 indicated that communication and responsiveness was important to succeeding in the workplace, and participant 10 claimed that being able to communicate '*large ideas in a simple and easy to understand way*' was a vital aspect to effective collaboration and job performance. Participant 5 explained that by being emotionally intelligent, and if *'you know yourself, you know what your capabilities are, capacities are, you don't have to… you won't overcommit yourself, you'll be able to say no, you'll be able to manage your relationships*', that individuals would be able to perform and collaborate more effectively in an organisational, team-based environment. Participant 5 went on to state that they believed that younger engineers coming in to the workplace were generally more eager to learn, as well as being more emotionally intelligent to senior engineers. In doing so, this participant believed that younger engineers were contributing to a more productive and collaborative workplace environment for engineers.

When questioned about how mindfulness could enhance teamwork, communication, or emotional intelligence, participants all believed that there existed a positive relationship between mindfulness and the abovementioned interpersonal skills. Participant 8 believed that engineers generally '*have a lot of IQ but not a lot of EQ*', and that mindfulness could be used as a means to enhance emotional intelligence (EQ) in engineering professionals. Participant 9 highlighted that '*Mindfulness is very important, especially with the people skills, especially if you're a manager'*, and that managers who were more mindful were more adequately equipped to managing teams and facilitating collaboration amongst employees. This agrees with existing research carried out by Shonin, et al. [23], who found that managers who had received mindfulness training showed significant improvements in job performance (as rated by supervisors) compared to a control group and their initial performance. Participant 10 claimed that in order to communicate effectively, individuals require a certain level of mental clarity and mindfulness. Without these states being active when communicating, the participant claimed that one is more likely to be closed off and consumed with one's own thoughts, and therefore more likely to miss cues and lack coherent emotional understanding.

Through effective collaboration, which requires coherent communication, teamwork, and emotional intelligence, engineering professionals are more likely to be able to develop creative and innovative solutions to complex problems that present themselves as technology continues to advance. Findings suggest that mindfulness can enhance communication, teamwork, and emotional intelligence, and therefore improve collaborative efforts within an engineering organisation.

4.4 Statistical Analysis of Survey

Statistical analysis of the survey revealed relationships between the five variables, namely Fatigue, Stress, Job Satisfaction, Productivity, and Mindfulness. The table below highlights the findings, which were obtained through linear and multiple statistical regression analysis:

Dependent Variable	Independent Variable(s)	Correlation (R)	p-value (statistical significance) [<0.05]	Correlation Type/Significance
Mindfulness	Fatigue	0.311	0.0116	Negative (significant)

Mindfulness	Stress	0.171	0.173	Negative (insignificant)
Mindfulness	Job Satisfaction	0.153	0.223	Positive (insignificant)
Mindfulness	Productivity	0.345	0.00486	Positive (significant)
Mindfulness	Stress and Fatigue	0.311	0.0424	Significant
Mindfulness	Productivity and Job Satisfaction	0.349	0.0178	Significant
Mindfulness	Stress, Fatigue, Productivity, and Job Satisfaction	0.400	0.0310	Significant

The statistical linear regression analysis revealed that there were statistically significant relationships between mindfulness and fatigue, and productivity. The relationship between mindfulness and fatigue, and productivity, showed that there were moderate correlations between mindfulness and the independent variables mentioned. This suggests that mindfulness can effectively be used as a practice to reduce fatigue while enhancing productivity amongst engineers. Statistically insignificant relationships ($p>0.05$) emerged between mindfulness and stress, and job satisfaction. A weak correlation existed between mindfulness and stress, and job satisfaction. These findings suggest that higher levels of mindfulness cannot be used to predict lower stress levels and higher incidences of job satisfaction among engineers. Based on the review of existing literature and the data obtained through the structured interviews, it can be concluded that the statistical relationship that emerged between mindfulness and stress in incorrect, and this may be due to the relatively low number of survey responses gathered at this point in the research study.

Multiple regression analysis revealed that statistically significant relationships emerged between mindfulness and stress/fatigue, mindfulness and productivity/job satisfaction, and mindfulness and stress/fatigue/ productivity/job satisfaction. All the aforementioned relationships between mindfulness and the respective independent variables demonstrated a moderate correlation between the variables. This suggests that higher levels of mindfulness can be used to predict lower rates of detrimental variables investigated (stress/fatigue) among engineering professionals, and that higher levels of mindfulness can be used to predict higher rates of beneficial variables investigated (job satisfaction and productivity) in the survey.

5 CONCLUSIONS AND RECOMMENDATIONS

Based on the findings presented, the following conclusions and recommendations can be made:

- Mindfulness can be used by engineering professionals to assist engineers in adequately coping with a challenging and changing workplace environment.
- Mindfulness can be used as an effective practice to enhance job performance and lifelong learning as an engineering professional.
- Mindfulness practice should be introduced to undergraduate engineering students to improve academic performance, reduce stress, and enhance learning ability.
- Mindfulness can be used as a practice to enhance individual well-being, productivity, and job satisfaction, while reducing stress, fatigue, and turnover intention.
- A higher number of interviews should be conducted to ensure representativeness, and a larger survey response is required to ensure that the sample data accurately represents the population.

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6 APPENDIX

6.1 Interview Questions

1. How would you describe your own mental health in the workplace environment? 1.1. How would you describe the broad mental health situation in the engineering sector?

2. What do you consider the three most important indicators to determine job performance in the engineering sector?

3. What can you comment on stress and fatigue levels in this sector? 3.1. Do you think they are related to one another?
3.2. How would these states affect job performance in your opinion?

4. What can you say about employee well-being in the engineering sector? 4.1. Do you feel as if companies do enough to ensure the well-being on their employees?
4.2. Are you satisfied at your place of work? Do you expect to find new employment in the next 2 years?

5. How would you describe your own productivity in the workplace? 5.1. What do you understand by the term 'productivity'?
5.2. What is your general perception of productivity in the engineering sector in South Africa?

6. What does the term “mindfulness” mean to you? What do you understand by it?

7. How do you think mindfulness could affect the three most important job performance indicators mentioned above?

8. How do you think mindfulness could affect job performance in the engineering sector, if at all?

9. Please add any additional comments or reflections on the questions posed in this interview.

10. Would you be interested in partaking in a mindfulness intervention running over 8 weeks, to observe what effects it has on your job performance?

6.2 Survey Questions

Mindfulness Section

1. I am able to appreciate myself.
2. I see mistakes and difficulties without judging them.
3. I accept unpleasant experiences.
4. I am friendly to myself when things go wrong.
5. In difficult situations, I can pause without immediately reacting.
6. I am patient with myself and others.
7. I rarely break or spill things due to carelessness, not paying attention, or thinking of something else.
8. I find it easy to stay focused on what's happening in the present.
9. I always remember a person's name after I've been told it for the first time.
10. I am aware what I'm doing, and always feel in control.
11. I take time when engaging in activities, and am fully attentive to them.
12. I listen to someone fully, without doing anything else at the same time.

Fatigue Section

1. Work brings on fatigue.
2. Fatigue interferes with carrying out certain duties and responsibilities.
3. Stress brings on my fatigue.
4. My motivation is lower when I am fatigued.
5. Long periods of inactivity bring about my fatigue.
6. Resting does not reduce my fatigue.
7. Sleeping does not lessen my fatigue.
8. Positive experiences do not lessen my fatigue.
9. I am easily fatigued.
10. Fatigue causes frequent problems for me.
11. Fatigue interferes with carrying out certain duties and responsibilities.
12. Fatigue interferes with my work, family and social life.

Job Satisfaction and Turnover Intention Section

1. I am satisfied with my job.
2. I feel valued, and my contribution appreciated, at my place of work.
3. I look forward to going to work.
4. My managers always value my feedback and contributions.
5. I am likely to remain with the same employer for the next next 2 years.

Productivity Section

1. I am productive at my workplace.
2. My mood has little effect on my levels of productivity.
3. Others would describe me as being productive and hardworking.
4. Being at work increases my productivity.
5. Stress has little effect on my productivity levels.

Stress Section

1. I am frequently stressed at work.
2. I often find myself worrying about things that have not happened yet and are not likely to happen.
3. After a stressful situation arises, it takes me a long time to no longer feel stress.
4. I find it difficult to feel relaxed.
5. I struggle to find a healthy work-life balance.
6. I feel like I have little control over my life at work.

UNDERSTANDING OF DIFFERENTIAL EQUATIONS IN A HIGHLY HETEROGENEOUS STUDENT GROUP

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ABSTRACT

Differential equations (DEs) are an important mathematical concept for a wide variety of disciplines in engineering. Hence, students need to develop a good understanding of the basic concepts of DEs. However, they encounter many difficulties when studying DEs and often exclusively focus on procedural knowledge. This study therefore investigates the difficulties concerning DEs encountered by engineering students at a university of applied sciences in Germany.

In contrast to previous studies on this topic our investigation differs in two aspects. First, the group of first-year engineering students at this university is highly heterogeneous; e.g. while some begin their studies immediately after secondary school, others have completed vocational training and joined the workforce for some time. Second, the engineering study programs considered here provide for only two semesters of mathematics and do not include specific courses on (ordinary) differential equations. The subject of DEs is dealt with in a three- to four-week period at the end of the second semester.

We conducted think-aloud interviews lasting about 45 min with 9 students after completion of the relevant course. We found that the main difficulties students

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experience are connected to: substantial lack of prior knowledge, attempting (sometimes unsuccessfully) to apply memorized procedures, and a failure to understand both the difference between a DE and a function and what a solution to a DE is.

The results shall be used to design three to four collaborative-group worksheets that build on students' ways of thinking and aim at improving students' conceptual understanding.

1 INTRODUCTION

1.1 Importance of Differential Equations

Differential equations (DEs) are an important mathematical concept for a wide variety of disciplines in engineering (e.g. mechanical, electrical, chemical and green engineering, applied chemistry, and applied computer science at our university). Students need to develop a deep understanding of the basic concepts of differential equations so that they can assign meaning to DEs from their field later in their study programs and apply them correctly. Literature and our experiences show, that students encounter many difficulties when studying DEs [1-3] and often exclusively focus on procedural knowledge.

1.2 Distinction of Common Difficulties with DEs

The difficulties with DEs can roughly be divided into those with the equations themselves and those with respect to the solutions of DEs [2]. Distinctions of difficulties in literature are first according to different comprehension levels, e.g. action, process or object level understanding in APOS theory [5], and second according to different representations like graphical, verbal, numerical, symbolic or physical [6]. We refrain from a detailed listing of common difficulties and misunderstandings connected to DEs here, but include them in the results section.

1.3 Students' Background

Previous studies on students' understanding of DEs focused mainly on students enrolled at universities in mathematics, physics, teaching mathematics and teaching physics programmes. The students attended several mathematics modules before entering a (full) course on ordinary differential equations. In some cases, students had to fulfil certain requirements (e.g., minimum grade in other math courses, passed algebraic tests) to be considered within the studies.

In contrast, (1) the composition of the students at our university of applied sciences (Hochschule) is very heterogeneous and (2) hardly any prior knowledge can be assumed. Nevertheless, a basic understanding of differential equations should be imparted to all students.

(1) The group of first-year engineering students at our university is highly heterogeneous since more people are allowed to study here compared to regular universities. Not only "Abitur" (high school degree) but also work experience, a good

vocational degree, and others qualify for a study programme. Some students have (very) little knowledge of physics and mathematics. Difficulties to work / learn self-dependent, to organize themselves and to study continuously are also common. In addition to the large differences in prior knowledge and abilities among students, there are large differences in personal qualifications as well that can affect the studying itself: children, difficulties with the German language, financial problems and / or work which is not related to their studies.

(2) The engineering study programs considered here provide for only two semesters of mathematics (5 ECTS each) and do not include specific courses on (ordinary) differential equations. The subject of DEs is dealt with in a three- to four-week period at the end of the second semester where three weeks is the standard and four weeks is the exception.

1.4 Teaching Differential Equations

There are various approaches to increasing students' deep understanding. All have in common that activating methods are used. The methods range from guided task sheets [4] to computer-based, numerical approaches [7] to project work on topics chosen by students themselves [8]. Various approaches attempt to achieve at least a basic conceptual understanding and usually focus on specific representations, especially graphical and / or numerical understanding.

With this study, we want to find out what essential difficulties prevent (our) students from understanding what makes differential equations special, how to "read" or get an overview of them, and what a solution to a differential equation is. The step-by-step analysis of the students' thinking process is necessary to design collaborative-group worksheets (like the McDermott Tutorials in Introductory Physics [9]). The worksheets will be designed to build on students' ways of thinking allowing students to arrive at a (deeper) conceptual understanding of DEs.

2 METHODOLOGY

2.1 Semistructured Interviews

We conducted think-aloud interviews lasting about 45 min with 9 students after completion of the relevant course. The purpose of the interview was communicated to the interviewee, and it was thereby made clear that the research objects were their thinking processes and their difficulties, and not their performance in terms of a correct response to the questions asked. Students were asked to solve two tasks and to communicate their thoughts. The interviewer did not intervene to tell students whether a thought or an answer was correct or wrong. All she did was asking questions about the specific reasoning, how students gained certain answers or what they would do next, e.g. “How did you determine that graph xy is not a solution?”, “How did you realize that …”, “How would you proceed with that?”, or “Restate the task with your own words.”

The interviews were recorded and transcribed. To find out students' difficulties, the correctness of answers was assessed as well as their reasoning and the relevance and strengths of the argument's given.

2.2 Tasks of the Interviews

The interviews consisted of two tasks:

1.) Which graph could be a solution to the differential equation $y'(x) = -a \cdot x \cdot y(x)$? (Fig. 1)

2.) The number of fish[2] in a lake increases the faster the more fish there are in that lake. A certain number of fish is taken from the lake each year to sell.

Can this problem be described by a differential equation?

Set up the differential equation for the fish problem.

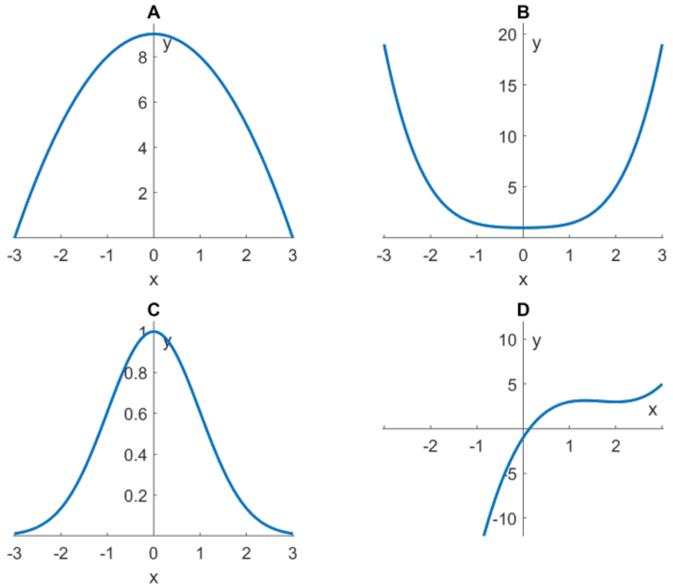

Fig. 1. Which graph could be a solution to the differential equation $y'(x) = -a \cdot x \cdot y(x)$? [10]

There are multiple ways to answer the first task. Some of them are:

First, the differential equation could be solved ($y(x) = a \cdot e^{-\frac{1}{2}x^2}$) by separation of variables. The graph that fits this function can only be C.
Second, y' is the slope, so "values" (the signs, the magnitudes and its courses) for x and y could be read from the graphs and put into the formula.
Or third, the algebraic functions for A to D could be set up and then be inserted into the DE. If a true statement is obtained, the graph is a solution.

The fish problem in the second task can be modelled by a DE since the growth rate of fish depends on the number of fish in the lake. The DE is $y'(x) = ay(x) - c$ with the constants a and c. y describes the number of fish, x the time passed and $y'(x)$ the growth rate of fish.

3 RESULTS

3.1 Categorization of Student Difficulties

We found that there are several substantial difficulties that students experience when dealing with the topic of differential equations. Those difficulties are connected to

i. substantial lack of basic knowledge from algebra and calculus,

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[2] Initially, "fish population" was used instead of "number of fish", which caused language difficulties for some students.

ii. applying memorized procedures,
iii. understanding the difference between a differential equation (DE) and a function, and
iv. the understanding what a solution to a DE is.

Difficulties connected to other areas also exist e.g. with regard to homogeneous / inhomogeneous DEs, initial conditions or obtaining solutions of DEs.
We think, that many difficulties are associated with key concepts. Key concepts are concepts that have to be understood in order to be able to proceed within the field. To overcome difficulties related to DEs a good understanding of those key concepts, especially from the categories iii. and iv., would be necessary. Once those key concepts are understood and internalized, difficulties might not appear at all or can easily be overcome.

3.2 Subdivision of student difficulties

Students can understand key concepts as well as face difficulties on different levels and within different representations. We want to call those levels basic, advanced and comprehensive. They are inspired by, but not identical to the action, process and object levels in APOS theory [5]. Typical representations are graphical, verbal, numerical, symbolic or physical [6].

For this paper we use the levels in the following way:

Basic level understanding of a concept in a certain representation is more or less procedural knowledge that does not necessarily require a deeper understanding. In extreme cases mathematical procedures can be applied without any mathematical understanding at all. Students can perform the action e.g. on a sheet of paper (external) but need not to be able to perform it purely mentally. Students do not need to know why the procedures are applied nor need to make general statements nor switch representations.

Advanced level understanding of a concept in contrast is more comprehensive. Students can make generalisations within the same representation, work with different inputs (e.g. different numbers, variables, graphs, or physical contexts) and manipulate the concept. They recognize when and how the concept can be (properly) applied and make first connections to different representations. Students can perform the actions internally. For a particular concept and representation understanding can be complete at the advanced level.

Comprehensive level understanding means that students can deduce more comprehensive, general statements. They do this by encapsulating multiple (key) concepts and / or by combining different representations. Students switch appropriately between different representations, as needed. Comprehensive level understanding is very abstract and examples are not needed anymore for explanations.

In the next sections, the levels basic, advanced and comprehensive were assigned to the difficulties. The assignment is not yet final. It occurs that a difficulty is assigned to two levels. For example, an assignment to basic and advanced level may occur when certain aspects of these difficulties could also be worked through procedurally but in order to really use the key concepts behind that difficulty an advanced level understanding is necessary. If difficulties are assigned to the advanced as well as the comprehensive level, the actual classification of this difficulty depends on whether it is related to only one representation or to the interaction of several ones.

3.3 Basic knowledge from algebra and calculus

i. Difficulty rearranging equations (*basic level*)
Some students make serious mistakes when rearranging equations. For instance, one student rearranged $y'(x) = -xy(x)$ to $y'(x) - y(x) = -x$ and another one did not know how to transform $-\ln(10)$ $(= \ln\frac{1}{10})$.

ii. Difficulty remembering and applying differentiation rules (*basic level*)
Some students struggle to remember differentiation rules. Some could not remember how to differentiate x^n, one student wrote $(a^{-x})' = -xa^{-x-1}$ (correct would be $a^x \cdot \ln(a)$ for positive a), and one student did not remember how to differentiate e^{-ax}. When students realise that they cannot remember the rules, they feel very uncertain, get stuck with the whole problem and cannot concentrate on continuing with the problem anymore.

iii. Difficulties in dealing with diagrams (*basic level, advanced level*)
Some students do not know what exactly is shown in a diagram or how to get the relevant data like x, y, or y' from it. For instance, one student said in task 1 where graphs A to D were given (Fig. 1) "… because I don't know, A to D, are they $y(x)$ or $y'(x)$?" and another one said "… but I don't know, what $y(x)$ looks like; it could have any sign." A third student put $x = 2$ into the equation from task 1, got $y'(2) = -2 \cdot y(2)$ but then did not know how to get information about $y(2)$ and $y'(2)$ from the graphs.

iv. Difficulties with infinitesimal quantities (*advanced level, comprehensive level*)
The difficulties relate to the understanding of infinitesimals and can occur in different representations (e.g. symbolic, graphical or verbal). Some students do not seem to know the difference between a variable y and an infinitesimal small change of that variable dy, as well as the difference between $\frac{dy}{dt}$ and $\frac{y}{t}$. dy is sometimes considered to be the same as y and sometimes to be $d \cdot y$. E.g. one student put the wrong equation $y'(x) = \frac{y(x)}{dx} + c$ (correct is $y'(x) = \frac{dy}{dx}$) into $y'(x) = -a \cdot x \cdot y(x)$, (omitted c) and obtained $\frac{y(x)}{dx \cdot y(x)} = -x$. He rearranged this to $\frac{1}{dx} = -x$ and to $\frac{1}{d} = -x^2$. Another one said for the fish problem: "The number of fish is growing per time, so it is $\frac{y}{t}$." Then he compared it to the velocity of a car which he said would be $v = \frac{s}{t}$ (correct is $v = \frac{ds}{dt}$).

v. Difficulties in dealing with mathematical problems
Many students think, a given problem must be solvable in an easy and quick way

with one correct solution. They cannot imagine that there are multiple very different correct solutions or that a problem requires quite some effort. If they do not find an answer in one way, most cannot stop at that point and try to find a different way of solving the initial problem. It seems, that many students do not have a basic confidence in their mathematical abilities.

3.4 What is a differential equation?

vi. Difficulty in characterising a differential equation correctly (*basic level*)
Many students forget very quickly after the mathematics course how to characterise a DE that is given in an algebraic form, e.g. linear – nonlinear, homogeneous – inhomogeneous (and correctly naming the disturbing function), and constant – non-constant coefficients.

vii. Difficulties with text-based problems (*basic level, advanced level*)
Many students do not recognize whether a given text-based problem describes a DE or not or think it is a DE for the wrong reasons. They cannot correctly assign variables (e.g. independent variable, dependent variable, derivative) to physical quantities nor assign the correct meaning to terms and variables in the DE.
E.g. for the fish problem (task 2) at least one student thought it was a linear problem because the growth in the number of fish was not recognized as the first derivative of the number of fish. ("[When I say the number of fish doubles every year] then I would already have [writes y=2x+50].") One student thought he would need specific values and only then it would be a DE (which would correspond to the initial value problem).

viii. Difficulty seeing how functions and DEs are related to each other (*comprehensive level*)
DEs are a (for students new) way to describe functions compared to the explicit form they are familiar with from school or preceding mathematics courses. For some students, however, DEs and functions are fundamentally different. If something can be described as or be graphically displayed as a function known to them (e.g. a parabola or straight line in a diagram) it is no longer associated with a DE. For instance, they think that there is "no need" for a DE if something can be described by a "regular" function. Students said "With a parabola, the slope is not dependent on the function itself, so a normal parabola does not form a DE.", or "The slope is always the same for a straight line. I would not need to work with a differential equation."

ix. Difficulties regarding the dependencies of variables (*comprehensive level*)
Many students, intentionally or unintentionally, consider independent or dependent variables as (positive) constants.
E.g. in the DE $y'(x) = -a \cdot x \cdot y(x)$ either x or $y(x)$ are considered to be constant (one student said "y must be negative so that the sign on the left is correct." and thereby kept x and y' as positive constants). Students are not clear about the serious implications of the dependence of y' on y. Sometimes the function is associated with symmetry solely because y' is dependent on y (which is a wrong

argument).
Some students also do not understand, that the dependence on the independent variable, e.g. on time, is implemented into a DE already by $y(x)$ and need not appear explicitly. Therefore, students often explicitly took the time into their DEs (not realizing what this actually would mean).

x. Difficulty setting up the differential equation for a certain problem and checking its validity (*comprehensive level*)
Students do not explicitly think about variables and assign them consciously before setting up a differential equation. They set up wrong equations that, in the fish problem, e.g. explicitly include the time ("Of course I need the time in my equation because I want to know, how many fish there are at a certain time.").
Students e.g. wrote $y'(x) = e^{y(x)}$, $y' = y^x$ or $y' = e^x$ since they "knew" the number of fish is growing exponentially with time. One student thought, a DE must be differentiated in some way.

3.5 What is a solution to a differential equation?

xi. Difficulty using memorized procedures to solve a DE (*basic level*)
Some students cannot remember the rules to solve a DE. This is because they did not understand them but only learned the procedures by heart. Soon after the exam this knowledge is forgotten. E.g. no student remembered how to solve the DE in task 1.

xii. Difficulty verifying that a given (or found) algebraic function is a solution to a DE. (*basic level, advanced level*)
Some students do not know the goal of putting $y(x)$ into the DE (results in true or false statement). One student got the (correct) result $-2x = x^3 - 9x$ in task 1 when putting the squared function $y(x) = -x^2 + 9$ into the DE and said "Now I have a cubic function. That's a new context and I would need to interpret that." He did not realize that the equation is a false statement. Another one said at that point "I can rearrange this any way I like. So how would I know if this is a solution?"

xiii. Difficulty understanding that functions are the solutions to differential equations. (*advanced level*)
Many students make a fundamental distinction between a solution of a DE and a function as they know them. Some students cannot imagine that the solution of a DE is represented in a diagram and looks like a "normal" function. Some students do not know at all, what a solution to a DE is – neither in an algebraical, graphical nor physical representation. The difficulties regarding this concept overlap with those in item viii.

Note that we concentrated on the most basic concepts and most fundamental difficulties that could realistically be covered in an introductory mathematics course in the second semester. There are many more difficulties connected to solutions of differential equations and difficulties in all representations. Examples are the concept that an algebraic function can be solution to multiple differential equations, that one

DE will have multiple solutions (and therefore multiple graphs in a diagram), and the concepts behind different characterisations of DEs.

4 OUTLOOK

Through interviews we revealed major difficulties students face when dealing with differential equations and solutions of differential equations. Those insights shall be used to design three to four collaborative-group worksheets (tutorials) that build on students' ways of thinking. The tutorials will aim at improving students' conceptual understanding. The learning goals for the tutorials are that students understand

- what the difference between a function and a differential equation is,
- what the terms and variables in a differential equation mean and do (mathematically),
- how to set up a differential equation from a given problem, and
- what a solution to a differential equation is and how it differs from the DE.

The tutorials shall use as little recourse to (memorized) prior basic knowledge from calculus and algebra, as possible, but students shall learn this necessary knowledge along the way. Classroom observations as students work through the tutorials will indicate whether difficulties are addressed and lead to fruitful discussions. In a future publication we hope to go more into the details about creating and presenting the tutorials.

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COURSE CLUSTERING BASED ON THE PHYLOGENIC TREE OF STUDENTS' GRADES IN ARCHITECTURAL DEGREE (RESEARCH)

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Keywords: *Architecture Education, Grade Correlation, Academic Results, Educational data mining, Data Visualization*

ABSTRACT

A large-scale correlational analysis was conducted on the grades of the students who completed their studies in the 1994 curriculum in the Barcelona School of Architecture. The study included the passing grades of a total of 3910 students corresponding to all 47 compulsory subjects, as elective courses were excluded. The objective of the research was to explore whether courses with related content were associated with the corresponding grades at an aggregate level, and identify similarities and dissimilarities in their clustering. The correlation between the grades in all courses was computed pairwise, and used as a distance measure to quantify the grade of affinity between them. Using this distance metric, the results were processed using hierarchical cluster analysis producing a tree structure according to this similarity/dissimilarity measure. The clustering results were visualized in a phylogenic tree, identifying the optimal number of clusters and coloring the results accordingly. The visualization of this tree matched very closely the grouping of

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courses according to departmental divisions, indicating a strong association between the grades obtained and specific areas of knowledge. The lowest marks were also found to be concentrated in the first years and among the graphic and design subjects. These results reinforce previous studies that have investigated the relationship between academic performance during the degree course and the entry grade. The great discontinuity between them and the fact that PBL is characteristic of the degree course and less common in secondary school could be the reasons for these results.

1 INTRODUCTION

Architecture studies have as their backbone the active methodology of Project Based Learning (PBL). “Learning by doing projects” connects with the methodology that is being implemented in the learning environments of early childhood and primary education cycles, and which is less frequently applied in secondary and higher education. Architecture studies are a prime example of how training is based, precisely, on practical workshops where designs are developed and integrate other disciplines such as construction, structural engineering, history or representation, and which involve skills such as teamwork, creativity, communication or social commitment. These design workshop courses do not have a parallel in secondary education, which causes a discontinuity between university admission scores and the grades obtained during university studies [1].

More specifically, the 1994 curriculum, which we analyze, was the first that include the course of Architectural Design in the first academic year. Unlike other schools, at the Barcelona School of Architecture (ETSAB-UPC) it was included from the first semester and was present until the capstone project in the fifth year. The course of “design” and its characteristic “architecture workshop” –understood as both the setting and teaching modality– becomes the most distinctive teaching practice within the studies, both in the beauxartian and the polytechnic traditions that began in the 19th century. Learning is not only "by projects", but "making projects", an aspect that defines the teaching-learning dynamics of the degree. However, this study is not restricted to the group of design courses, but contextualizes them within the framework of other technical and theory subjects, more related of humanistic studies, as well as science and polytechnic studies.

Therefore, based on previous studies that analyzed the low correlation between the university admission score and the grades throughout the career, we now focus on the relationship between the 47 compulsory subjects in the degree, which as explained before were very diverse. Specifically, the research questions are:

1. Is there any relationship between the different courses and the academic year in which they are taught? It could be assumed that the discontinuity between the learning methodologies prior to entering the degree and the different skills and abilities that are valued in Architecture (creative thinking, and design of

forms and spaces) should have an impact on the quantitative academic performance of the first years.

2. Is there any correlation between the courses that make up the 7 areas of knowledge in the curriculum: Construction, Composition, Physics, Mathematics, Urban and Territorial Planning, Architectural Design and Graphic Representation? It should be noted that, despite the fact that this plan was developed prior to Bologna and the process of homogenization of all university studies (which became degrees), the very polytechnic structure of the university in which the ETSAB is included already entails the inclusion of training activities and assessment systems common to all degrees, regardless of their particularities. This circumstance, in the field of Architecture and such heterogeneous curriculum, makes it especially relevant to analyze to what extent the diverse nature of the areas of knowledge correlates with the quantitative results of learning. A learning that also responds to PBL in some subjects, while others work with more classical, behavioral and passive approaches.

2 METHODOLOGY

2.1 Data processing

All data was processed using the R programming language [1] because of its wide availability of packages for data analysis [2], and following the principles of reproducible research [3].

Source data was stored as a Microsoft Excel file that contained 3910 records corresponding to the grades of the students that graduated within the 1994 Plan of Study in the Barcelona School of Architecture, excluding the elective courses. For each record, the passing grades of each of the 47 compulsory courses were stored as columns.

This data structure was not suitable for analysis, and following the principles of tidy data [4] where each variable should form a column and each observation should form a row, was converted from this “wide” format to a “long” format table structure, resulting in a table with 183,770 rows for each pair of student-course, and a column with their corresponding passing grades.

Because the collected data corresponded to compulsory courses that were a requirement to graduate, by definition there was not any missing data in the dataset. There were, however some grades that were below the passing grade of 5, because some grades above or equal to 4 could be “compensated” with higher grades in other courses.

2.2 Grade distribution

The mean of all the grades was 6.22, and the standard deviation was 1.12 grade points. The distribution was right-skewed with a moderately positive skew of 0.73. Since the normality could not be computed using the Shapiro–Wilk test because the sample size was larger than 500, the Kolmogorov–Smirnov test was used to check the grade distribution against the normal distribution, resulting in a D value of almost 1 with a p-value very close to zero, rejecting the hypothesis that the grades were normally distributed.

The density of each of the 47 courses in the degree were plotted in a single chart to visualize their distributions, using the overall density plot corresponding to the combined grades in the whole degree as a reference (Fig. 1, left). The bandwidth of the smoothing kernel was 0.5, about half the standard deviation of the population, which was considered an adequate value of the uncertainty of the grades, as most grades clustered in increments of half a grade point in a 0 to 10 scale.

The results showed that the distribution of the grades in the degree does not follow a normal distribution, and that almost none of the grades obtained in the courses appear to be normally distributed. There is a large variation in the grade distributions per course, with some courses having a peak near the passing mark, and others almost symmetrically and normally distributed around the 6 to 7 marks.

To investigate this variation in the distributions, the courses were grouped according to the academic year where they belonged within the five years of the architecture degree, using the global distribution as a reference (Fig. 1, right), using the same bandwidth parameter as the previous figure. The results showed that the grades become progressively more normal in the later years, while the initial years concentrate most of their grades near the passing grade.

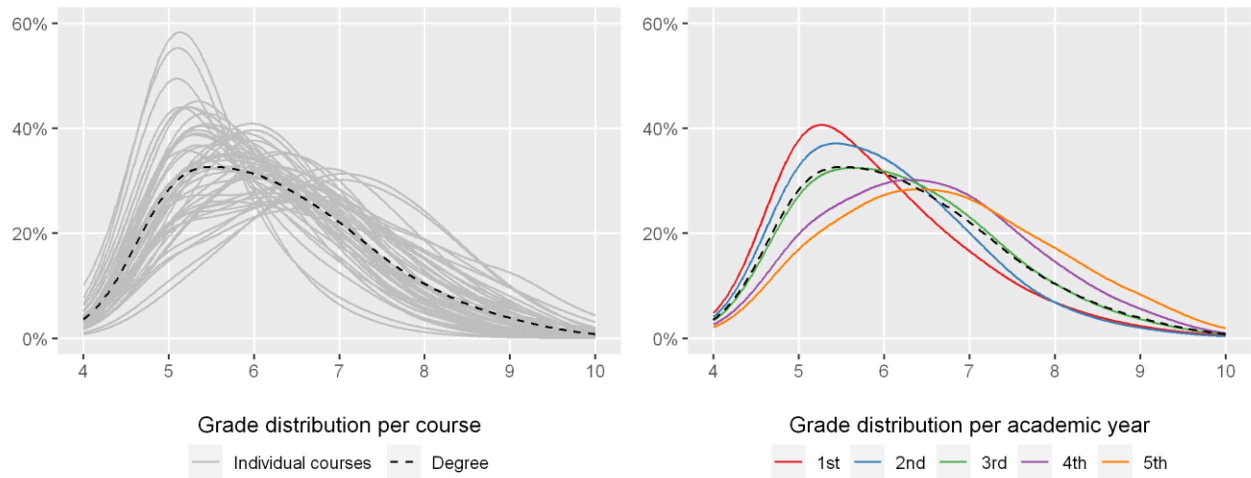


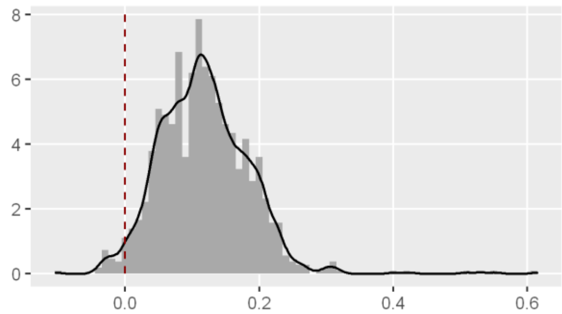
Fig. 1. Density plots for all 47 individual courses analyzed (left) and grouped according to their academic year (right), compared to the density plot of all the grades in the degree (overlaid as a dotted black line)

2.3 Correlations

The table of all grades was converted to a matrix, where each student was assigned to a row and the corresponding passing grades of each course were assigned to the columns, resulting in a 3910x47 matrix. The pairwise Pearson's correlation coefficient was computed for all pairs of columns using the *rcorr* function in the *Hmisc* R package. The function returned a symmetrical 47x47 matrix with the pairwise correlation coefficients, with ones in the diagonal as the grades in every course were perfectly correlated with themselves. In addition to the correlation matrix, the function also returned a matrix with the asymptotic p-values required to compute the statistical significance for each pair of correlations.

The correlation values corresponding to a single triangle and excluding the diagonal were extracted and plotted as a combined histogram and density plot (Fig. 2, left), with the same value of 0.1 for both binwidth and bandwidth. The result show that almost all courses are positively correlated, but also that most of the correlations are very weak, with a range of -0.10 to 0.61, and a peak near the 0.1 value.

In addition, the correlations below the statistical significance threshold ($p < 0.05$) were overlaid with a cross. Interestingly the courses of “Structures II” (E I) and “Descriptive Geometry I” (GD I) showed a much higher number of non-statistically significative correlations than expected (Fig. 2, right), with 27 and 16 respectively, followed by “Sketching I” (D I) with 12. The mean number of non-significant correlations per course was 3.2.



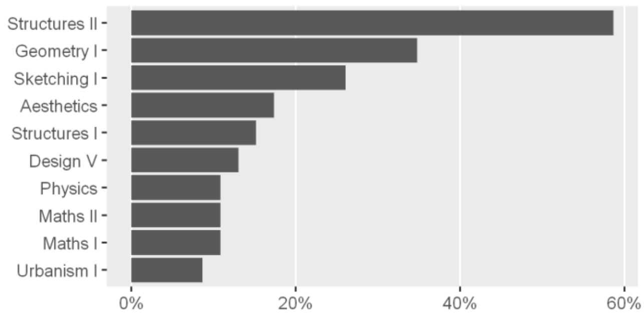


Fig. 2. Combined histogram and density plot of the pairwise correlation between courses (left). Outstanding courses with more than 3 non-statistically significant correlations (p > 0.05) with any other courses in the degree (right)

2.4 Heatmap

Since the correlation matrix was difficult to interpret visually, the results were plotted as a heatmap using the *corrplot* R package (Fig. 3). The heatmap colors used diverging color scale using a cold-hot representation (red for lower values, gray for near-zero values, and blue for higher values), with most of the values appearing in light orange colors. This heatmap revealed that some course correlations exhibit clustering, which is directly observable in blocks of courses that share a similar name when sorted in alphabetical order, and is discussed in the following subsections.

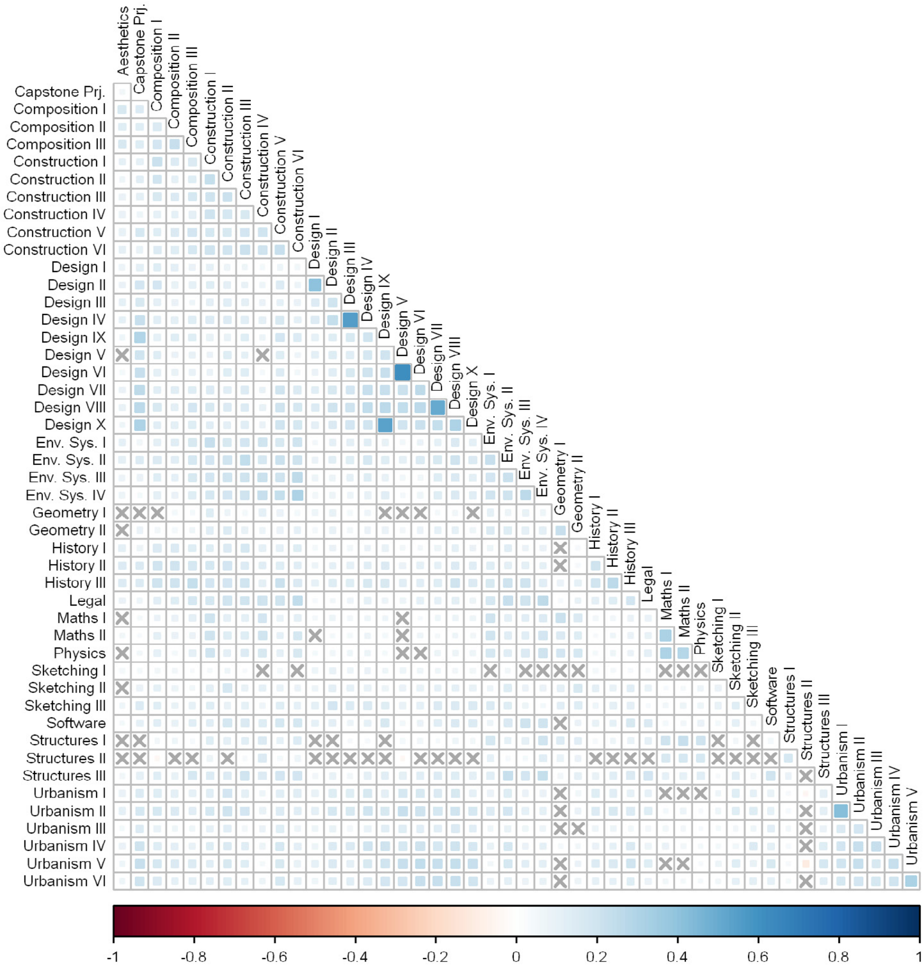


Fig. 3. Pairwise correlations between courses from the passing grades of all 3910 students. Results below statistical significance (p > 0.05) are shown with a black cross overlaid

2.5 Distance metrics

The matrix of Pearson's correlations was interpreted as distances using the *distanceMatrix* function in the *ClassDiscovery* R package, using the "pearson" metric with the following formula of distance between course *i* and course *j*.

$$distance(i,j) = \frac{1 - correlation(course_i, course_j)}{2}$$

Since the Pearson's correlation has values in the [-1, 1] range, this distance metric can only have values in the [0, 1] range. The distances were stored in a 47x47 distance matrix, symmetric because $d_{ij} = d_{ji}$ and the diagonal was populated with null values to replace zero distances for the cases when *i=j*.

The representation of this distance matrix was produced with the *pheatmap* R package, reordering the rows and columns according to the distance metric to place more affine courses together, separating clusters into rectangular partitions of the heatmap (Fig. 4), and placing a dendrogram at the margins of the heatmap.

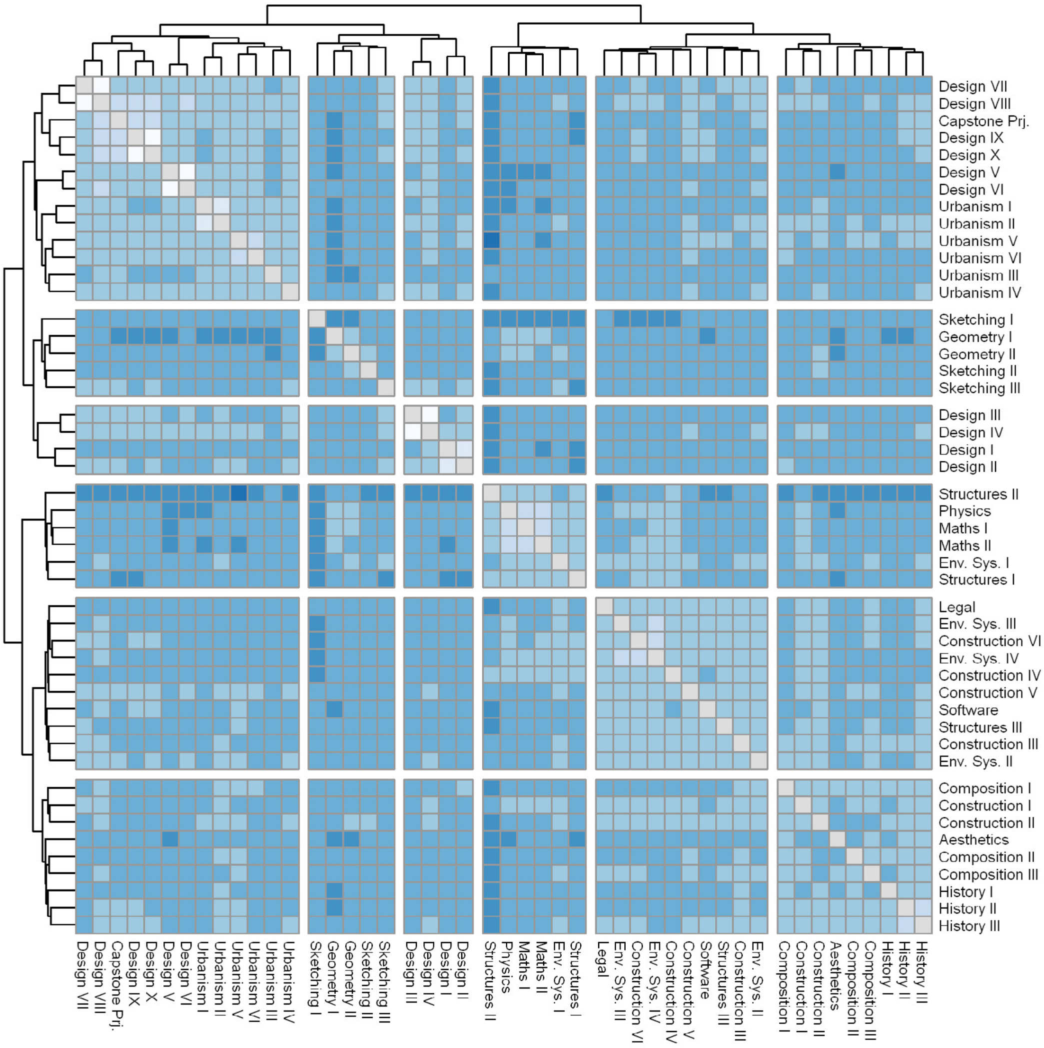


Fig. 4. Distances computed from the Parson's correlation with the cluster separation

2.6 Clusters

The distances in the matrix were clustered using agglomerative hierarchical clustering with the *hclust* function in the *stats* R package using the “ward.D” method. The results were visualized using the *fviz_dend* function in the *factoextra* R package (Fig. 5).

This tree-like representation allows partitioning the dendrogram into clusters according to their distance (height) to the “trunk”, summarizing multiple possible clustering results into a single diagram. In the case of the degree of architecture, the number of clusters chosen were 6, but from the figure it is clear that there is another possible partition around height=1 into two clusters, and around height=0.7 into four clusters. The distribution of the grades within the identified clusters was also plotted (Fig. 6) for comparison.

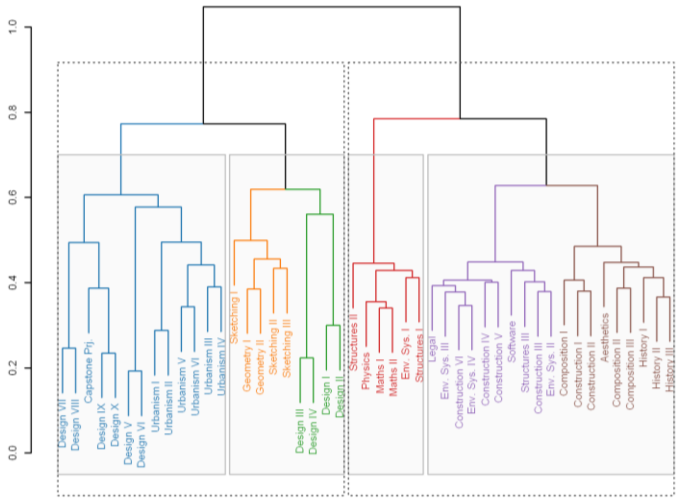


Fig. 5. Dendrogram representation of the results of the hierarchical clustering, depicting partitions into 2 clusters (dotted rectangles), 4 clusters (shaded rectangles), and 6 clusters (color labels)

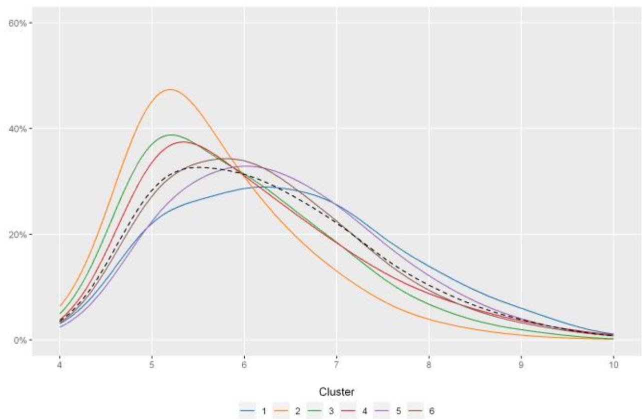


Fig. 6. Distribution of the grades within the identified clusters

3 RESULTS

The results obtained through the discussed methodologies, point to three very specific conclusions:

First, as Fig. 1 shows, the correlation of grades across the degree shows a quantitative increase in the average grades as the years advance. Therefore, the discontinuity with prior pre-university training is confirmed, which may imply that adaptation to studies structurally based on PBL and with a great emphasis on creative abilities entails greater difficulty in passing the initial courses, despite that many of them are propaedeutic.

Second, the correlation between the 47 courses shows a grouping (dendrogram in Fig. 5) that practically reproduces the organization in the different areas of knowledge of the curriculum. Moreover, an analysis at a more global level allows us to organize them into two large groups: the graphic and propositional subjects (design, urban planning and drawing) and the non-graphic ones (the rest). This distinction has been the classic way of organizing the degree in the different curriculums since the 19th century, and it seems to be ratified at the level of quantitative results, despite the rigid polytechnic structures in which the ETSAB has been circumscribed since the 1970s. Therefore, the PBL associated with workshop subjects condition not only the learning-teaching methodology, but also the type of grades.

Third, we can also observe in Fig. 6 that if we analyze the distribution of grades of the 6 clusters, and more specifically in the graphic-propositional block, the projects and drawings subjects of the first and second years (Design I-IV, Geometry I-II, Sketching I-III) have the lowest grades. From the second year onwards, the grades are not always lower in the workshop subjects, as is the case at the beginning. The process of adapting to the PBL of the students can explain this progression and suggests the necessity to reinforce university orientation that previous studies also pointed out, and even the possibility of establishing a specific admission test that assesses the competencies of the degree and the methodologies of active work developed in design subjects, present in all semesters.

Finally, one might wonder about the hypothetical results that a parallel study would generate in post-Bologna ETSAB study plans, such as the 2010 and 2014 curriculums. The research question would focus on whether the implementation of ECTS credits has had an impact on the correlation of grades between the different core subjects of the degree (which continue to have a very diverse nature); or if the pre-university training and the new pre-entrance models of recent years have led to greater preparation to enter Architecture, and therefore the first and second grades are no longer the lowest of all studies.

4 SUMMARY AND ACKNOWLEDGMENTS

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LEARNING AND PROGRESSION IN (TOO MUCH OF?) AN ENTREPRENEURIAL CHALLENGE DURING COVID-19

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ABSTRACT

A venture creation programme (VCP) is an academic programme in which students' creation of a new entrepreneurial venture is a central vehicle for learning. A VCP puts students in the role of entrepreneurs with real opportunities and challenges. The entrepreneurial journey is a bumpy ride, and COVID-19 has added significant challenges for entrepreneurs, including students in VCPs. Previous research emphasises how entrepreneurial learning occurs through handling entrepreneurial challenges. The purpose of the present paper is to investigate the role of COVID-19-induced challenges in VCP students' learning. We applied fuzzy-set qualitative comparative analysis (fsQCA) to data from students in a technology-oriented VCP in Scandinavia, collected in April 2021. FsQCA offers the opportunity to investigate complex logic combinations of factors that explain an outcome and is particularly suited for small samples. Multi-item measures assessed (1) the progress of students' ventures, (2) entrepreneurial learning and (3) perceived challenges from COVID-19. We also asked whether students had entered or exited an entrepreneurial project and whether these projects were run by a team or only the individual student. We found that COVID-19-induced challenges impeded VCP students' learning and that students' individual progress was important for learning during crisis situations. Thus,

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entrepreneurship educators should help students get ‘back on the horse—which means being involved in new entrepreneurial projects—if their challenges lead them into stagnation and inactivity. Progress, both in students’ ventures and for students as individuals, should be nurtured by entrepreneurship educators.

1 INTRODUCTION

Liguori and Winkler [1] emphasised the impact of the pandemic on teaching practices in entrepreneurship education, as entrepreneurship educators worldwide are transitioning from physical ‘offline’ to virtual ‘online’ teaching practices. However, developments in entrepreneurship education have also moved towards not only facilitating students’ learning about entrepreneurship in the classroom but also learning through actually undertaking entrepreneurship [2], feeding the growth and interest in practices for experiential entrepreneurial learning [2,3], action-based entrepreneurship education [4] and courses and programmes in which students create their own ventures as an integrated part of their education [5,6].

A venture creation programme (VCP) is an academic programme in which students’ creation of a new entrepreneurial venture is a central vehicle for learning. A VCP puts students in the role of entrepreneurs with real opportunities and challenges. The entrepreneurial journey is a bumpy ride, and COVID-19 has added significant challenges for entrepreneurs, including students in VCPs. Previous research emphasises how entrepreneurial learning occurs through handling entrepreneurial challenges [7] and even failures [8]. In this respect, COVID-19 could be expected to foster significant learning for student entrepreneurs in a VCP, and recent research has found that entrepreneurs learn from crisis experiences during the pandemic [9].

However, the adversity presented by COVID-19 may also lead entrepreneurs to pursue reactive and protectionist strategies [10], meaning that activities may halt, which may negatively impact entrepreneurs’ learning processes. Therefore, the present paper argues that when ‘real-world’ entrepreneurial activity [3] is introduced as an essential part of the educational process, the potential impact of crises such as the COVID-19 pandemic is likely to go far beyond the transition from offline to online education. Being part of local, regional and even global business life, student entrepreneurs are direct subjects of abrupt restrictions put on their businesses, customers, partners, financers and stakeholders. The purpose of the present paper is thus to investigate the role of COVID-19-induced challenges in VCP students’ learning.

The next section develops a research model for the present paper, outlining factors that are expected to influence students’ learning in VCPs. The research model is empirically investigated using questionnaire data from students in a technology-oriented VCP in Scandinavia. Fuzzy-set qualitative comparative analysis (fsQCA) is applied for data analysis. The present paper contributes to entrepreneurship education research by suggesting that learning from failure should be followed by new entrepreneurial endeavours [8] and by pinpointing that learning through being active in a new venture is essential for entrepreneurial learning [5]. Moreover, the present paper relates to developments in challenge- and problem-based engineering education [11].

2 FRAME OF REFERENCE: LEARNING IN STUDENT VENTURES

Learning is central to all entrepreneurship [12], and entrepreneurial learning has emerged as a core concept in entrepreneurship research over the last few decades. In essence, entrepreneurial learning can be understood as the process through which experiences from entrepreneurship are transformed into knowledge that informs future entrepreneurial actions [13]. Entrepreneurial learning builds on experiential learning theory [14]; hence, being involved and active in a new venture is a key factor for entrepreneurial learning [7]. Learning also occurs in situations that are detrimental or even fatal to a new venture, such as different degrees of failure [8]. Thus, the event of entering or exiting a new venture is considered relevant for explaining entrepreneurial learning.

Since entrepreneurial learning is seen as the process informing new entrepreneurial action that is developed or improved over time [14], progress in a new venture is also relevant for entrepreneurial learning. The new venture's progress is a sign that entrepreneurial learning has occurred in the past and that new situations, tasks and challenges are presented to the entrepreneur, which, as mentioned, is key to entrepreneurial learning |7]. Hence, new venture progress is to be considered relevant for explaining entrepreneurial learning. Experiences of challenges in the entrepreneurial process, such as the crisis situation represented by COVID-19 [9], are also relevant for entrepreneurial learning, and challenges from COVID-19 are therefore considered relevant for explaining entrepreneurial learning alongside new venture progress.

The four factors found to be relevant in explaining entrepreneurial learning—challenges from COVID-19, new venture progress, entrepreneurial entry and entrepreneurial exit—may be combined in a research model, as presented in Eq. (1). The research model states that entrepreneurial learning can be expressed as a function of the four abovementioned factors.

$$entr.learning = f(challenge, venture\ progress, entr.entry, entr.exit) \quad (1).$$

The next section explains the research methods applied to empirically investigate the research model presented in Eq. (1).

3 METHODOLOGY

3.1 Research context and data collection

This research builds on empirical data collected from a cohort of students in a technology-oriented VCP in Scandinavia. The VCP is a two-year MSc programme and includes courses in strategy, business management, engineering and social sciences, alongside the facilitation of students' venture creation processes. In April 2021, we collected our research data through an online questionnaire administered to students in the VCP. Twenty-seven students responded to the survey, representing a 73% response rate. The following paragraphs explain the measures we used in the survey and how we proceeded with the data analysis.

3.2 Sample and measures

Multi-item measures assessed (1) entrepreneurial learning, (2) challenges experienced from COVID-19 and (3) progress of students' ventures. We also asked whether students had entered or exited an entrepreneurial project and whether these projects were run by a team or only the individual student.

Entrepreneurial learning was measured using four items adapted from Funken et al. [15] and rated using a seven-point Likert scale, where 1 = Not at all and 7 = To a very large extent. The questionnaire items were: 'In the last year, I have…' (a) '…learned to develop and implement business strategies', (b) '…developed my capability to make a great deal of progress towards building a viable business venture', (c) '…learned to run the new venture more effectively' and (d) '…learned to read the signs of whether the new venture has difficulties'.

Challenge from COVID-19 was measured using a custom-made scale for the present paper, since the COVID-19 pandemic represents a unique and novel situation. For each item, the respondent was asked to answer using a seven-point Likert scale, where 1 = Not at all and 7 = To a very large extent. The questionnaire items were: 'In the last year, the pandemic has given me problems in relation to…' (a) '...discussing with others in the study programme', (b) '…participating in lectures', (c) '…communicating with my new venture team' and (d) '...getting/keeping in touch with customers and partners'.

New venture progress was measured using three items adapted from Funken et al. [15] and rated using a seven-point Likert scale, where 1 = Not at all and 7 = To a very large extent. The questionnaire items were: 'In the last year…' (a) '...the new venture has made good progress', (b) '…the likelihood for new venture success has been enhanced' and (c) '...the new venture has developed substantially'.

Entrepreneurial entry was measured with yes/no (yes = 1) alternatives to the question, 'In the last year, I have started or involved myself in at least one new venture'. Entrepreneurial exit was measured with yes/no (yes = 1) alternatives to the question 'In the last year, I have exited at least one new venture'. Table 1 presents the descriptive statistics for the variables.

Table 1. Descriptive statistics

Measure	Chro.a	Mean	SD	Min.	Max.	FNT	CP	FMT
Entrepreneurial learning	0.91	4.78	1.56	2	7	2.75	4.60	6.25
Challenge from COVID-19	0.83	4.14	1.32	2	7	2.75	4.00	5.25
New venture progress	0.96	4.35	2.05	1	7	1.33	4.66	6.33
Entrepreneurial entry	–	0.79	0.41	0	1	–	–	–
Entrepreneurial exit	–	0.42	0.50	0	1	–	–	–

SD=standard deviation, FNT=full non-membership threshold, CP=crossover point, FMT=full membership threshold [19]

3.3 Fuzzy-set qualitative comparative analysis

To be consistent with the research model, we included only students who were involved in a start-up, and three responses were thus removed from the sample. We applied fuzzy-set qualitative comparative analysis (fsQCA) to analyse our data. FsQCA offers the opportunity to investigate complex logic combinations of factors that explain an outcome and is particularly suited for small samples [17]. The package 'fuzzy' by Longest and Vaisey [18] was used in STATA/MP version 17.

FsQCA requires that values of all variables range from 0 to 1, where 1 represents 'full membership', meaning that a condition is fully in place, and 0 the opposite. While already dichotomous variables are ready for fsQCA, Likert-scale variables need calibration before analysis. We used the direct approach described by Ragin [18]. The values for full non-membership thresholds, crossover points and full membership thresholds are presented in Table 1. Solution consistencies indicate a well-fit model (solution consistency > 0.9).

4 RESULTS AND DISCUSSION

The results from the fsQCA are presented in Table 2, which reveals three sets of how the included factors combined explain students' entrepreneurial learning or the absence thereof. One set (Set 1) explains entrepreneurial learning (Entr.learn = 1) and two sets (Sets 2 and 3) explain the absence of entrepreneurial learning (Entr.learn = 0).

Table 2. Truth table from the fsQCA

Set	Chall.	Vent.prog.	Entr.ent.	Entr.exit	Entr.learn.	R.Cov.	U.Cov.	S.Con.
1	0	1	1	1	1	0.192	0.192	0.901
2	1	0	0	–	0	0.149	0.094	0.916
3	1	–	0	1	0	0.055	0.000	0.982

R.Cov.=raw coverage, U.Cov.=unique coverage, S.Con.=solution consistency. '1' means that a factor is present, '0' means that a factor is absent and '–' means that the factor is not relevant in the set.

Using the notation from the research model in Eq. (1), the solution leading to entrepreneurial learning in Set 1 (in Table 2) may therefore be expressed as in Eq. (2). '~' denotes the inverse of a condition, which is the absence of a factor.

$$entr.learning = {\sim}challenge * venture\ progress * entr.entry * entr.exit \quad (2).$$

Similarly, the solutions leading to the absence of entrepreneurial learning in Sets 2 and 3 (in Table 2) may be simplified to Eq. (3).

$${\sim}entr.learning = challenge * {\sim}entr.entry * ({\sim}venture\ progress + entr.exit) \quad (3).$$

Eq. (2) shows that new venture progress and entrepreneurial entry and exit, as well as an absence of pandemic-induced challenges, were necessary for entrepreneurial learning. Using Eq. (3), we found that pandemic-induced challenges and the absence of entrepreneurial entry were necessary for the absence of entrepreneurial learning. Entrepreneurial exit during the pandemic hindered entrepreneurial learning. Additionally, either the absence of new venture progress or entrepreneurial exit completes the two pathways that explain the absence of entrepreneurial learning. Thus, one finding of the present paper is that all four factors in the research model in Eq. (1) were relevant for explaining entrepreneurial learning.

Even though fsQCA operates with the existence or non-existence of an outcome, entrepreneurial learning is, in practice, not either-or but rather relatively more or less learning. Thus, the results suggest that the combination of factors on the right side of Eq. (2) facilitates entrepreneurial learning, while the combination of factors on the right side of Eq. (3) prevents entrepreneurial learning. Challenges from COVID-19 are therefore found to counteract entrepreneurial learning to some degree, while new venture progress, as expected, facilitates entrepreneurial learning. Interestingly, the combination of entrepreneurial exit and entrepreneurial entry, in addition to progress in the new venture, was found to be necessary for entrepreneurial learning. Assuming that the progress is in the new venture that was entered, this finding points to some interesting dynamics. For instance, some ventures may be severely impacted by COVID-19, to the point that a student entrepreneur chooses to exit that venture. However, the process of experiencing and handling that process could potentially facilitate the student's learning. In contrast, a lack of new venture progress or entrepreneurial exit without entrepreneurial entry (see Eq. (2) and Eq. (3)) did not facilitate learning to the same degree, given that the student had experienced high levels of COVID-19-induced challenges.

The present paper cannot prove causality between, for instance, new venture progress and entrepreneurial exit or entry, between COVID-19-induced challenges and new venture progress, or between COVID-19-induced challenges and entrepreneurial exit. Thus, there may be processual dynamics that can provide clearer models and conceptualisations of how crisis-induced challenges influence the entrepreneurial learning of students in VCPs. However, the results of the present paper suggest that while challenging events such as exiting and entering a venture facilitate learning as long as there is progression in the new venture, challenges combined with stagnation prevent learning. Not only is new venture progress important for entrepreneurial learning in VCPs, but also progression for individual students. In other words, it is important that VCP students get ‘back on the horse’ during a challenging situation to avoid passiveness and stagnation. For action-based entrepreneurship education in which students learn through entrepreneurship, faculty should be aware of how active progression for the individual student is important for learning and ensure that students who experience difficulties handle those difficulties within their current venture or choose to become part of another venture in which progress can be made and experienced. Faculty providing challenge- and problem-based engineering education should balance the levels of challenges that students are exposed to, strive for some degree of progression and help students avoid too much stagnation in the activities and projects they are involved in [11].

5 SUMMARY

The purpose of the present paper was to investigate the role of COVID-19-induced challenges in VCP students’ learning. Through an empirical study of students in a technology-oriented VCP in Scandinavia, the present paper found that COVID-19-induced challenges prevented VCP students’ learning. Interestingly, the findings of the present paper further suggest that students’ individual progress was important for learning during crisis situations. An implication for entrepreneurship educators is to help students get ‘back on the horse’—involved in new entrepreneurial projects—if challenges in the current venture lead to stagnation and inactivity. The adversity presented by COVID-19 is an example of what could present too much of a challenge for VCP students. The present paper therefore contributes to entrepreneurship education research by suggesting that learning from failure should be followed by new entrepreneurial endeavours [8] and by pinpointing that learning through being active in a new venture is essential for entrepreneurial learning regardless [5].

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WHEN PROBLEM-BASED LEARNING BECOMES ENTREPRENEURIAL – A FACILITATOR'S VIEW ON STUDENT CHALLENGES

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ABSTRACT

Integration of entrepreneurship in current engineering education emphasises the need for engineers to initiate and drive innovation processes that transform ideas into societal value. Learnings from the history of engineering and the at times unsustainable impact of technology on society have drawn attention to user

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requirements and the societal context of technological innovations. In addition to this view, entrepreneurial education underlines the need to move beyond reactively addressing user requirements and societal developments to proactively creating opportunities and realising their potential to change societal patterns and trajectories. Grand challenges, such as climate change and the recent COVID-19 pandemic, have indeed confirmed the need for such abilities. This paper argues that when integrating entrepreneurship in engineering education, the pedagogical approach to how we teach entrepreneurial engineering will inevitably have to be revisited. The study aims to explore the facilitation of entrepreneurial projects in a problem-based learning (PBL) environment. Design-based research (DBR) was conducted to co-develop and test guidelines and models for entrepreneurial PBL based on existing PBL approaches. In this process, ten facilitators of entrepreneurial PBL projects were continuously challenged to change their perspective from being facilitators to students and from being practitioners to reflective practitioners. In this paper, we especially report on the part of the study investigating the following question: What challenges do students experience when PBL becomes entrepreneurial? The paper concludes with insights into the nuances of entrepreneurial PBL and closes with a short discussion on the need for more research to ensure integration and not the addition of entrepreneurship in engineering education.

1 INTRODUCTION

“We live in a rapidly changing society where it is essential that everyone has the capacity to act upon opportunities and ideas, to work with others, to manage dynamic carriers and shape the future for the common good. To achieve these goals we need people, teams and organisations with an entrepreneurial mindset, in every aspect of life.” [1, p. 3]

On this note, the European Commission presented the European Entrepreneurship Competence Framework (EntreComp), distinguishing between three pillars of entrepreneurial competencies in the following way [1]:

1. ideas and opportunities, including the competencies related to spotting opportunities, creativity, vision, valuing ideas and ethical and sustainable thinking;
2. resources, including competencies related to motivation and perseverance, self-awareness and self-efficacy, financial and economic literacy, mobilising others and mobilising resources;
3. into action, including learning through experience, working with others, planning and management, taking the initiative and coping with ambiguity, uncertainty and risk.

This framework for competencies relates to the whole entrepreneurial process from idea to value creation, and the focus on going “into action” captures both the learning “about”, “for” and “through” entrepreneurship [2]. Thrane et al. [3] argue for a learning ”through” strategy, where the learning experience is seen as a co-evolutionary process. Mäkimurto-Koivuma and Belt [4] suggest adding learning “in” entrepreneurship to underline the importance of experiencing entrepreneurship in a real-life context. Aligned with this approach, Mäkimurto-Koivuma and Belt [4] highlight active learning methods for learning “in” and “through” entrepreneurship, with reference to Graaff and Kolmos [5].

Problem-based learning (PBL) is one of the approaches which makes use of active learning methods. A PBL curriculum combines specific cognitive, collaborative and content-related strategies [6]. From a cognitive point of view, learning is based on experiences with real-life problems, and learning is collaboratively organised in participant-directed teams working on projects. Content-wise, learning is interdisciplinary and exemplary and emphasises theory as well as practice.

The focus on real-life problems as the starting point in PBL will offer students the opportunity to experience entrepreneurship in a real-life context, and the focus on collaborative learning embedded in PBL is aligned with the view of entrepreneurship as a co-evolutionary process. However, as with any other pedagogical model, there is, and should be, sensitivity towards the context of use, and in this case we are specifically interested in distinguishing PBL and entrepreneurial PBL to address specific concerns for the entrepreneurial project. More specifically, we work from the following research question:

What challenges do students experience when PBL becomes entrepreneurial?

2 METHODOLOGY

Challenges for students in entrepreneurial PBL are addressed as a part of a longitudinal design-based study. This study has as its primary purpose to clarify principles for facilitating students who want to pursue an idea by initiating a start-up project with a view to creating value and business, or at least a business plan, based on an idea. In the following, the overall research design of this longitudinal design-based study is presented together with the more specific context and methods used to study students’ challenges in entrepreneurial PBL.

2.1 Research design – a longitudinal design-based study

This study follows the conduct design-based research (DBR) presented by Reimann [7] including the following three phases:

1. preparing the experiment, including clarifying instructional goals and starting points, envisioning a learning trajectory and placing the experiment in a theoretical context;
2. experimenting to support learning, including collecting data in cycles of design and analysis, applying interpretive frameworks and formulating and testing domain-specific instructional theories;
3. conducting retrospective analysis, including argumentative grammar, establishing trust in the findings and ensuring repeatability and generalisability.

Specific for DBR are multiple iterations, the development of learning theories along with innovative real-life practices, development of design principles and, last but not least, collaborative partnerships between researchers and practitioners [8].

This longitudinal DBR has as its main purpose to improve the facilitation of entrepreneurial PBL by an improved awareness of the distinct types of competences, problem design and project organisation needed for entrepreneurship as well as the following implications for teaching practice. An overview of the first part of the study (co-creating the guides) is pictured in figure 1.

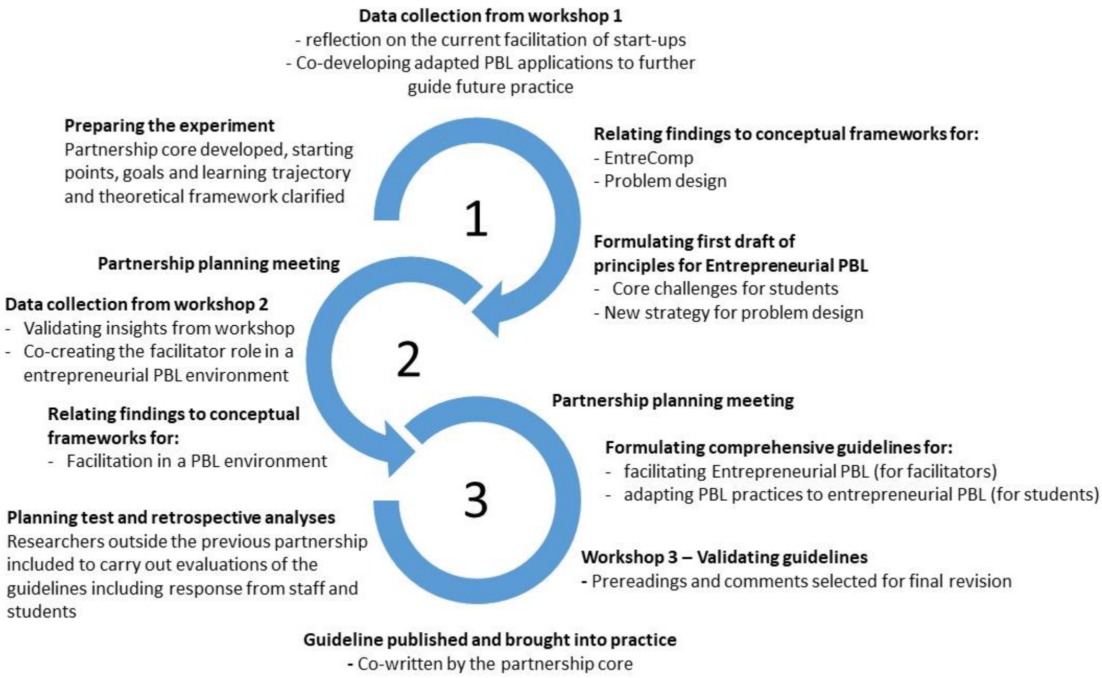

Fig. 1. Overview of the first part of the longitudinal design-based study; the second part of the third iteration includes evaluation and revision of the guides to be carried out in 2022/2023.

A guide for staff to facilitate entrepreneurial PBL and a guide to support students in carrying out a problem-based and entrepreneurial project have served as the main boundary objects to formulate actual design principles for the facilitation process. The ambition has been to co-construct the guide in a partnership between PBL researchers and facilitators.

From 2019 to 2020, ten facilitators of entrepreneurial PBL projects were continuously challenged to change their perspective from being facilitators to students and from being practitioners to reflective practitioners. They were introduced to cases and asked to reflect on the challenges students typically face in different phases of a project and the themes, questions and advice in which this would likely result. They were challenged to put themselves in the role of the students making a problem design and thereby to identify, analyse and formulate the problem using PBL methodology and to provide input to matches and mismatches, which informed new adapted instructional models. They were challenged to reflect on their own role as a facilitator in the entrepreneurial project and to reflect on their own learning style and differences in the way they (to their surprise) advised students during the different phases of the entrepreneurial project. Furthermore, they were challenged to view facilitation as an impact on organisational learning and to consider the importance of collective interpretations and shared-meaning structures in entrepreneurial project groups.

Data were primarily collected by feedback sheets, on which groups of participants as well as individuals were asked to provide short written statements summarising their main concerns and reflections. These feedback sheets followed a previously fixed structure with themes and overall questions for the groups/individuals to fill out. After the workshops, the data were collected and summarised to be presented at the subsequent workshops. Furthermore, when writing up the guides [9,10], the insights from participants were supplemented with other sources.

In this paper, we report in particular on the part of the study investigating the challenges students experience when PBL becomes entrepreneurial. The empirical base for this part was created during the first iteration at workshop 1. The group was working from a fictive case, picturing a group of media technology students having the idea of creating an intelligent walker to assist walking-impaired persons in new ways. The start-up was integrated in a half-year problem-based project of 15 european credits according to the european credit transfer system (approx. 450 working hours per student). In three groups, the participants were asked to decide on the core challenges that students would most likely experience at the beginning, middle and end of the semester project. All participants were experienced facilitators of entrepreneurial projects. The findings were validated in the second iteration at workshop 2 and were further used to guide facilitation practices in the third iteration.

3 RESULTS

Table 1 presents the key challenges that facilitators noted as common for students working on entrepreneurial projects. Based on these insights as well as the follow-up questions related to the themes, questions and advice in which such challenges would most likely result, the challenges where grouped according to three themes. One theme centres around the power of the idea, another around the need to cross traditional borders and, last but not least, a final theme relates to the resilience needed on the part of students to work on insecure ground.

3.1 Challenge 1: Tunnel vision – the power of the idea

This first challenge centres around one of the more fundamental barriers to entrepreneurship, that is reluctance to “kill you darlings”. The idea is, as such a darling, it holds an embedded promise and perceived greatness that make students risk actually engaging in a start-up. As can be seen from Table 1, unrealistic expectations about the potential of the idea and blind spots related to already similar solutions are symptoms of an idea-generated tunnel vision.

Table 1. Key challenges at the beginning, mid and final stage of the start-up project. The challenges are presented directly as noted by facilitators (translated into English).

Beginning	Mid-term	Final stage
- Unsure about what it takes and where to start – need help to proceed - Unrealistic expectations about the potential of the idea - Insecure about a lot of things – resources, competencies, benefit/potential, impact on personal life - Too far in the process considering what they actually need (they lack insight) - Having a hard time approaching users/customers (validation)	- Having a hard time understanding what they have signed up for - Having a hard time defining the business model - Lack of professional competencies - Lacking an overview of how to present their idea to external panels - Are blind to knowledge suggesting that the idea “exists” and no further iteration is possible - Having a hard time making a time schedule and setting up targets - There is (still) a typical lack of validation	- Motivation to do enough and the right things (move into execution mode) - Developing a prototype - Prove concept and test business model - Access to user groups - Lack of resources - Lack of funding in general and for prototyping - Lack of “squid” competences - Having a lot of excuses why it was not possible (for me) including personal/private circumstances - They are stuck – no progress

The impact of not questioning the idea can furthermore have a negative spin-off effect on the motivation to validate the market potential of the idea. Why validate what is already perfect, and why question potential consumers when it is just a matter of convincing them about the brilliant prospects of this idea? The facilitators experienced that such an attitude, although caricatured in this context, can be a barrier, can bypass or slow down the process of validating market potentials and outlining value propositions in the business modelling process. However, as competence frameworks like EntreComp [1] do not specifically highlight the importance of critical thinking, it can also be argued that this is a more general blind spot in the outline of an entrepreneurial mindset.

3.2 Challenge 2: Intensified boundary work

The overview of student challenges provided by facilitators show that students have to cross different boundaries during their entrepreneurial project.

First of all, the process of entrepreneurial PBL is different from more traditional PBL processes due to the central focus on the idea in the problem-design process. Facilitators experience the problem-design process as challenging for students, as they have a hard time planning the process and getting an overview of expected deliveries. This challenge for students to transfer planning experiences from a PBL project to entrepreneurial PBL was, nevertheless, also considered a challenge for the facilitators. In the guideline [9,10], a specific focus was therefore on providing a road map of the problem-design process in entrepreneurial PBL, not as a matter of fact but as a frame of reference to guide student-directed entrepreneurial projects.

Secondly, the increased focus on business modelling in entrepreneurial PBL outlines a process that calls for interdisciplinary interaction; as in any business, different professions are needed to generate value out of ideas. Furthermore, there is an intensified need for transdisciplinary collaboration as interaction with potential user groups is considered a necessity in the entrepreneurial mindset. Facilitators reported the need to push students out of their comfort zone of the university. The challenges in the last phase of the process (see Table 1) indicate that such a lack of drive can result in some rather extensive and comprehensive challenges in the last phase of the project. Stakeholder interaction is needed in order to validate assumptions of user needs, provide proof of a concept, make a prototype and test the business model, etc. The iterative nature of entrepreneurship calls for not just one but continuous interaction with key stakeholders.

3.3 Challenge 3: Lacking resilience

Finally, Table 1 also illustrates the personal dimension of entrepreneurship. These identified challenges relate very much to competences stressed in the EntreComp framework, such as self-awareness and self-efficacy, motivation and perseverance as well as coping with ambiguity, uncertainty and risk. It should be noted that in this case these challenges are observed among students who are experienced with self-directed learning and open-ended problem-based projects involving a high degree of uncertainty. This fact puts the insecurity level for an entrepreneurial newcomer into perspective. As noted in Table 1, students in start-ups feel insecure about a lot of things – resources, competencies, benefit/potential of the idea and even about how this will impact their personal life. Facilitators therefore stressed the importance of questioning students to find out what the uncertainty is about, how they feel about it and why. In other words, although entrepreneurship is a co-constructing endeavour, it is also a very personal matter.

With respect to this, it is worth noticing that even though learning outcomes are stated on the individual level and what could be called resilience competence is recognised as important for an entrepreneurial mindset, it is typically not an integrated part of the curriculum. Facilitators reported that when students gave up on their idea, they had a hard time acknowledging the learning outcome of the start-up project. This underlines the importance of increased attention to affective learning outcomes in the curricula of entrepreneurship education and the need for taxonomies to assess students' abilities to establish and uphold resilience.

4 SUMMARY

In this paper, we have argued for the differences between students' challenges in project-based PBL and entrepreneurial PBL, and we have pointed out key differences in entrepreneurial PBL due to the power of the idea, the intensified need for boundary work and the ambiguity and uncertainty of the entrepreneurial problem-based project. From the outset, we have also argued for the need for more research on curricula design for entrepreneurship, and we have highlighted critical thinking, adapted models for problem design and affective learning outcomes as potential areas of research. As entrepreneurship is a fundamental element of technological innovation, our engineering education research communities are, in our view, central players.

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Post-Pandemic Intended Use of Remote Teaching and Digital Learning Media in Higher Education. Insights from a Europe-wide Online Survey.

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ABSTRACT

The COVID-19 pandemic has had a transformational and potentially long-lasting impact on higher education institutions, with the rapid shift to “Emergency Remote Education”. Two years after the begin of the pandemic, institutions are either returning to presence formats with different speed or converging towards hybrid formats, begging the question what remains of

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the newly acquired skills and experience with remote teaching and digital learning media? Here, we present the findings of the first European-Union-wide survey on the potential long-term impacts of COVID-19 on higher education, evaluating over 800 responses from students and faculty members of higher education institutions located in 17 different European countries. Our survey – developed in the context of the ide3a university alliance (http://ide3a.net/) highlights possible differences between students and instructors in their attitude toward retaining digital teaching formats and media, examines which formats have increased in use over the course of the pandemic, and investigates which of them are intended to be kept and consolidated post-pandemic. The tools and formats examined in this survey include tools for communication and collaboration, formats of didactic activity, as well as assessment formats. Survey responses reveal that all evaluated tools and format have significantly increased in use during the pandemic and most of them are intended to be used at lower frequency in the future, while still at significantly higher frequency than before the pandemic. Moreover, attitudes toward long-term use of remote teaching and digital learning media seems to be comparable between students and faculty members, except regarding some tools.

1 INTRODUCTION

1.1 Background

Over the course of the COVID-19 pandemic, remote teaching and various digital learning media ensured that higher education could continue. Two years after the initial shift to ‘Emergency Remote Teaching’, institutions all over Europe are either returning to presence formats or converging towards hybrid formats. As many tools and formats were new to many students and instructors, the pandemic may have provided a glimpse into an entirely transformed educational system [1]. However, the transition to remote teaching was not strategically planned and occurred as an emergency shift in most cases. Thus, the question whether digital education formats will persist in post-pandemic scenarios and, if so, which tools and formats students and instructors will want to use remains unsolved. Other studies to date have evaluated the reception of the shift to emergency remote teaching and pandemic experiences [2],[3]. Yet, to the authors knowledge, none of them examined the attitude of students and instructors toward long-term changes. Their focus on (early) pandemic experiences and limited, sector-specific, samples make it difficult to evaluate whether the pandemic has the potential to cause an overall lasting paradigm shift in higher education in Europe [3],[4].

1.2 Research Objectives and Hypotheses

This paper examines in how far students and instructors alike intend to utilize remote teaching and digital learning media within higher education across Europe in the long-term. Given that the weight of additional effort related to remote teaching and digital learning is distributed differently between the two groups [5], we also investigate whether there is a difference in attitudes toward teaching formats between students and instructors. The two hypotheses tested in this paper are as follows: H1) a large majority of formats used during emergency remote teaching will be kept long-term, post-pandemic (by both students and faculty members); H2) attitudes towards using e-learning formats post-pandemic differ between instructors and students. To test these two hypotheses, we conducted an online survey between August 2021 and January 2022 investigating the attitudes and intended frequencies of use of remote teaching and digital learning media with students and instructors from different universities in Europe.

2 METHODS

2.1 Participants

The sample of survey respondents (after data cleaning) consisted of 658 students from 14 different European countries and 121 faculty members from 13 different European countries. Figure 1 summarizes the geographical distribution of respondents (A and B), as well as participating students' age (C), faculty members' years of teaching experience (D), and faculty members' role in their institution (E).

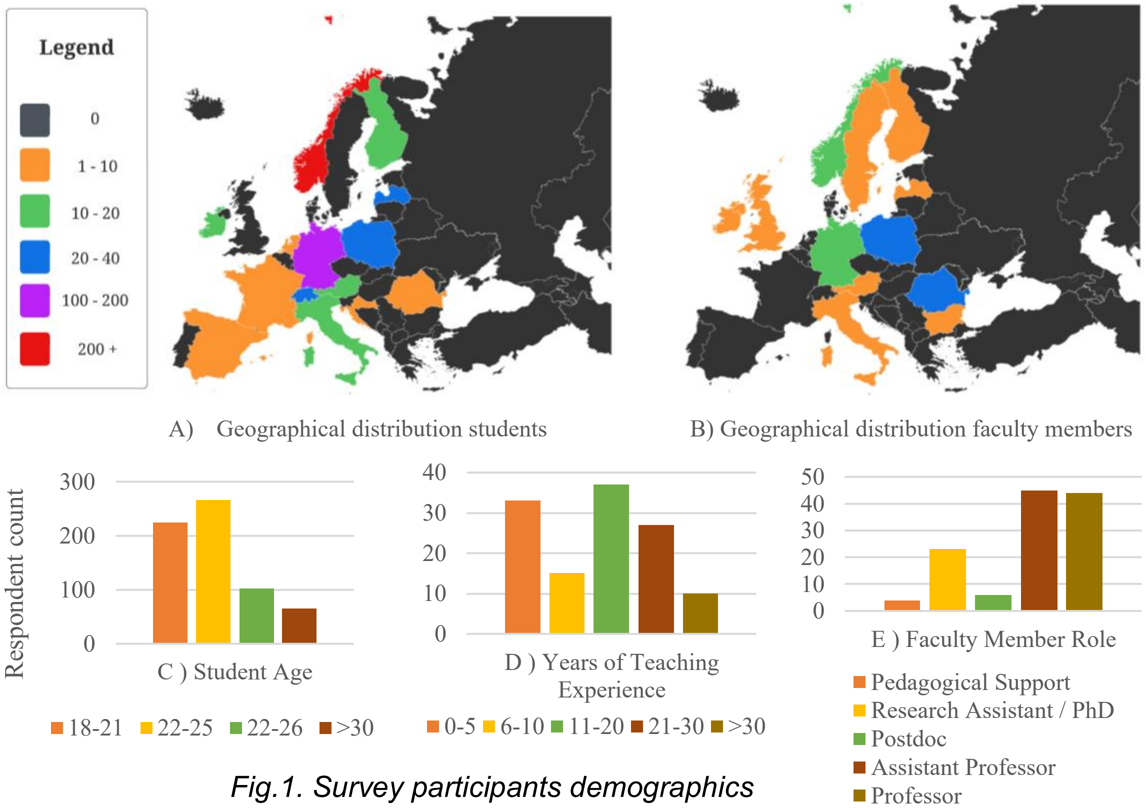

Fig.1. Survey participants demographics

2.2 Survey Design

Our online survey consisted of two sections: (i) one section on demographic data and categorical attitude evaluation and (ii) one section evaluating the frequency of use of remote teaching and digital learning media. Tartavulea et al. [6] investigated how the frequency of use changed for a limited list of tools and formats at the beginning of the pandemic. Our survey builds on that list to compare results. Additionally, given that their study only captured a brief influence of the pandemic as it was conducted in April 2020, we extend its scope to include late-pandemic aspects and post-pandemic intentions.

Participants were asked to indicate their frequency of use for 21 tools and instructional methods, before and during the pandemic, as well as their intended frequency of use after the pandemic. Tools were categorised into those used for communication (6 tools), collaboration (3 tools), formats of didactic activity (6 formats), and assessment formats (6 formats and tools). Tool use frequency was determined on a 4-point Likert Scale (1 = not at all, 2 = rarely, 3 = sometimes, 4 = frequently), while also allowing participants to select that they were 'Unsure' [7].

Within the categorical section, questions were either of 'yes/no' nature or prompted participants to indicate the extent to which a statement was true, out of a given set of options. Participants who were located outside of Europe or were neither a student nor a faculty member at the time of the survey were automatically exempted from continuing the survey.

2.3 Statistical Analysis

To test H1, a two-way repeated measures ANOVA on actual and intended frequency of tool use was carried out using SPSS, comparing both students and faculty members groups. H2 was tested using a one-way between subjects ANOVA on various separate categorical variables [8], [9].

3 RESULTS

3.1 Pre-pandemic, Present, and Intended Post-pandemic Frequency of Use

All evaluated tools and formats increased in frequency of use during the pandemic across both students and faculty members, except from e-mailing, which was equal to pre-pandemic times for faculty members. The intended frequency of use after the pandemic indicates that most tools (16 of the total 21) are intended to be used at lower frequency than during the pandemic, but all 21 tools will be retained with significantly higher frequency than before the pandemic, both by students and instructors (again except for e-mailing, which remained relatively constant across all three time-points for faculty members). The evaluated tools and formats can be categorised into different clusters according to the intended post-pandemic frequency of use by the participant groups. Table 1 summarizes all findings on tool and format frequency use before, during and intended use after the pandemic, reporting the mean and standard deviation (Std. Dev.). It further indicates the different clusters by colour. The clusters are described in the following.

The tools and formats that both groups want to continue using at the same level of frequency as during the pandemic are indicated in pale yellow in Table 1 and consist of crowd questioning tools, asynchronous digital group work, and media production for assessment. These tools and formats show no significant frequency change to during the pandemic. Forum and collaborative text editors also want to be kept at the same level of frequency as during the pandemic, but students want to retain them with significantly higher frequency than faculty members.

Tools which students want to use even more frequently than during the pandemic, while instructors intend to keep it at the same level as during, are indicated in pale blue and contain virtual brainstorming tools (such as miro [10]) and asynchronous interaction with digital tools or plug-ins (such as H5P [11]). Interestingly, these tools are also among those with the lowest intended frequency for instructors (together with online ice-breaking sessions). An evaluation of whether familiarity of these tools and willingness to try new formats correlates with intended frequency of use might be useful to explain difference between students and instructors. Asynchronous plug-ins such as H5P were also the least frequently used tool during the pandemic, suggesting low familiarity across both groups.

Tools that students want to use at significantly higher frequency than instructors, although still at lower levels than during the pandemic are indicated in orange in Table 1 and include chat functions, Learning Management Systems (LMS, e.g., Moodle), online quizzes, and digitally supervised exams.

Likewise, tools that instructors want to use at higher frequency than students, although at still lower levels than during the pandemic, are indicated in pale green and include online office hours and online oral examinations (e.g., virtual presentations).

Lastly, tools that both groups would like to use at lower frequency than during the pandemic are indicated in pink and include video conferences for lectures, virtual whiteboards, synchronous digital group work (such as break-out rooms), media production for knowledge transfer, online icebreakers, online submission of assignments, and online projects.

For some of the tools and formats there are also significant differences between students and instructors for frequency of use during the pandemic, which could be explained by the fact that some tools are more aimed to be used across groups and some are for in-group collaboration or communication. The 'collaborative text editor' for example, would be one tool that students use amongst each other, as well as faculty members with each other, but apparently at different frequency. How relevant and useful a certain tool is to a group might also influence their intended frequency of use.

Table 1. Overview of tool and format frequency use before and during the pandemic, and intended use after the pandemic across survey participants

Tools / Formats		**Before Pandemic**			**During Pandemic**			**After pandemic (Intended)**		
Communication Tools		**Mean**	**Std. Dev.**	**Significant Difference Between groups?**	**Mean**	**Std. Dev.**	**Significant Difference Between groups?**	**Mean**	**Std. Dev.**	**Significant Difference Between groups?**
Chat	Students	2.52	1.202	Yes	3.41(***)	1.193	No	3.24(***)	.930	Yes
	Instructors	2.09	1.083		3.30(***)	.846		2.91(***)	1.042	
Forum	Students	2.22	1.018	Yes	2.92(***)	1.063	Yes	2.88	1.081	Yes
	Instructors	1.94	1.080		2.43(***)	1.230		2.53	1.203	
E-Mail	Students	3.25	0.879	Yes	3.60(***)	.694	Yes	3.51(***)	.787	Yes
	Instructors	3.83	.529		3.83	.545		3.72	.608	
Video Conference	Students	1.50	.819	No	3.92(***)	.382	No	2.93(***)	1.017	No
	Instructors	1.67	.970		3.97(***)	.224		3.13(***)	.801	
Online office hours	Students	1.31	.673	Yes	3.06(***)	1.084	Yes	2.62(***)	1.096	Yes
	Instructors	1.70	.958		3.77(***)	.621		3.15(***)	.943	
LMS	Students	3.14	1.173	Yes	3.67(***)	.767	Yes	3.46(***)	.914	Yes
	Instructors	2.51	1.355		3.17(***)	1.189		2.88(***)	1.300	
Collaboration Tools										
Virtual Whiteboard	Students	1.45	.794	No	3.08(***)	1.070	No	2.64(***)	1.105	No
	Instructors	1.37	.775		2.94(***)	1.182		2.59(***)	1.087	
Collaborative Text Editor	Students	2.59	1.090	Yes	3.18(***)	.990	Yes	3.12	.998	Yes
	Instructors	2.26	1.188		2.88(***)	1.120		2.84	1.147	
Virtual Brainstorming Tools	Students	1.47	.766	No	2.12(***)	1.140	No	2.29(***)	1.104	Yes
	Instructors	1.37	.762		1.89(***)	1.123		1.99	1.156	
Formats of Didactic Activity										
Crowd Questioning	Students	2.37	.949	Yes	2.93(***)	.945	No	3.01	.985	No
	Instructors	1.99	1.074		2.81(***)	1.127		2.84	1.011	
Synchronous digital group work	Students	1.34	.675	No	3.13(***)	.963	Yes	2.34(***)	1.082	No
	Instructors	1.34	.724		2.74(***)	1.229		2.31(***)	1.142	

Asynchronous digital group work	Students	1.46	.738	No	2.11(***)	1.125	No	2.09	1.106	No
	Instructors	1.49	.781		1.90(***)	1.018		2.05	1.111	
Media production for knowledge transfer	Students	2.09	1.027	No	2.55(***)	1.158	No	2.44(***)	1.166	No
	Instructors	1.90	1.074		2.50(***)	1.170		2.30(***)	1.161	
Online icebreaker	Students	1.30	.623	No	2.14(***)	1.063	No	2.01(***)	1.077	No
	Instructors	1.31	.703		2.05(***)	1.158		1.90(***)	1.062	
Asynchronous interaction with digital tools	Students	1.22	.514	No	1.68(***)	1.021	Yes	1.76(***)	1.047	Yes
	Instructors	1.19	.486		1.45(***)	.821		1.47	.882	

Assessment Formats

Online Quizzes	Students	2.36	.950	Yes	3.07(***)	.946	No	2.97(***)	.961	Yes
	Instructors	1.90	1.057		2.88(***)	1.199		2.64(***)	1.106	
Online Submission	Students	3.32	.948	No	3.85(***)	.485	No	3.68(***)	.678	No
	Instructors	3.18	1.069		3.79(***)	.672		3.66(***)	.692	
Digitally Supervised Exam	Students	1.65	.973	Yes	3.12(***)	1.142	Yes	2.57(***)	1.194	Yes
	Instructors	1.40	.842		2.52(***)	1.350		2.03(***)	1.131	
Online Project	Students	1.99	1.001	No	3.24(***)	.947	Yes	2.58(***)	1.086	No
	Instructors	2.03	1.054		2.78(***)	1.275		2.47(***)	1.099	
Media Production as assessment	Students	1.68	.870	No	2.20(***)	1.175	No	2.14	1.139	No
	Instructors	1.57	.959		2.09(***)	1.210		2.08	1.137	
Online oral examinations	Students	1.21	.551	Yes	2.65(***)	1.170	Yes	2.14(***)	1.142	Yes
	Instructors	1.46	.884		3.42(***)	.930		2.48(***)	1.075	

Pre-pandemic, present, and intended post-pandemic frequency of use for several tools and didactic formats was reported in the survey on a 4-point Likert scale (1= not at all, 2 = rarely, 3= sometimes, 4 = frequently). Answers indicating 'Unsure' have been excluded from analysis. N for each tool/format therefore varies. The significant statistical differences at 0.05 level between during vs. before, and after vs. during pandemic are reported as ***. Significant differences at 0.05 level between students and instructors are indicated by 'Yes' or 'No'.

3.2 Attitude towards use of e-learning tools long-term

None of the one-way between subjects ANOVAs conducted on the three questions relating to the analysis of H2 yielded significant differences between students or faculty members. Attitude towards the long-term post-pandemic use of remote teaching and digital learning media therefore appears to be similar.

In response to the question whether participants see the pandemic as an accelerator for the modernization of higher education, response patterns are very similar ($F(1,778) = [.112]$, $p = .738$). The majority (65.8%) of students and faculty members (66.4%) believe the pandemic to be an accelerator for modernization, while 16.1% and 16.4%, respectively do not. 16.1% of students and 13.9% faculty members are unsure, and the remaining 2% and 3.3% are not interested.

Similarly, 62.5% of students and 69.7% of faculty members wish to continue to use remote teaching and digital learning media complementarily to presence teaching, another non-significant difference ($F(1,778) = [.256]$, $p = .613$). Only 12.5% and 8.2% would be glad if teaching stayed mainly remote, also after the pandemic. Also, only

20.2% of students and 19.7% of faculty members believe that these tools are something only to be used in emergencies. A minority of 3.8% students and 0.8% instructors do not want to use remote teaching or digital learning media again. Only 1% and 1.6% respectively are unsure.

Lastly, as for the quality of personal interaction with each other, both groups almost equally agreed that it was worse than before the pandemic (55.7% of students and 60.7% of faculty members). About 26.3% and 31.1% respectively thought it was of adequate quality, and 9% of students and 4.9% of faculty members evaluated it to be even better than before. 9% and 3.3% respectively are unsure. Again, these percentages indicate non-significant differences in attitude between the two groups of interest ($F(1,778) = [.110]$, $p = .740$).

Notably, even though the majorities of both groups indicate the quality of their interaction to have worsened, indicating that certain elements of presence teaching are irreplaceable by its digital counterpart, they both wish to continue using remote teaching elements long-term. The answers to these categorical questions also reflect the desire to decrease entirely digital formats such as video conferences, online projects, and media production for knowledge transfer. While attitude toward long-term use of remote teaching and digital learning media appears to be similar between students and faculty members overall, the results from Section 3.1 indicate that there are differences when it comes to specific tools and formats and how frequently they should be applied.

3.3 Additional Analyses on Respondents' Experience

Analysis of additional categorical questions to account for any prior experience with remote teaching and digital learning media yielded interesting results as well. In response to the question whether participants had knowledge of remote teaching and digital learning media before the pandemic, students indicated significantly more prior knowledge than faculty members, as evaluated using a one-way ANOVA ($F(1,778) = [31.37]$, $p = <.001$). Nonetheless, both groups indicated equally low prior experience with remote teaching or digital learning media.

Faculty members also attended trainings for further education significantly more often than students both before and during the pandemic (($F(1,778) = [14.383]$, $p = <.001$) and ($F(1,778) = [9.919]$, $p = <.001$)) and acquired significantly higher levels of new skills during the shift to emergency remote teaching ($F(1,778) = [50.703]$, $p = <.001$).

4 DISCUSSION AND CONCLUSION

4.1 Discussion and implications

Overall, as evaluated in this Europe-wide online survey, attitudes toward long-term use of remote teaching and digital learning media seems to be comparable between students and faculty members. The majority of students and faculty members would like to use them complementary to presence formats, likely to compensate for the decreased quality of interaction with each other during virtual classes. Evaluating different tools and formats however does reveal differences in preference for frequency of use for certain tools. While the use of remote teaching and digital media increased significantly during the pandemic, almost all evaluated tools and formats want to be used at lower frequency after the pandemic, yet all still more frequently than before the pandemic. This stands in contrast to Tartavulea et al. [6], who, in the beginning of the pandemic, found that certain tools (e.g., virtual whiteboard, pre-recorded videos) would be used at an even higher frequency than during the pandemic.

For a few tools, such as virtual brainstorming software and plug-ins such as H5P, students would even like to use them more frequently than during the pandemic, indicating that instructors should not necessarily follow only their own preferences, but also continue to experiment with tools to cater to their students' needs [12]. The 'winners' of the pandemic tools, which want to be kept at the same frequency of use as during the pandemic, suggest having offered additional pedagogic benefits. These tools were crowd questioning tools, asynchronous digital group work and media production for assessment, as well as the forum function and collaborative text editors. In the context of the ide3a project [13], we have used all of these with great success and believe these tools to be of additional benefit in compensating missing social interaction especially in entirely virtual, international, and collaborative courses.

4.3 Limitations

This study aimed to provide a pan-European perspective on the intended frequency of long-term use of remote teaching and digital learning media. While participants were recruited from 17 different countries, the sample representativity remains somewhat poor. The number of participants per country was neither evenly distributed, nor representative for each country, which is why this study, and its results can only be understood as a glimpse into a European overview, but do not capture country-specific differences or those between different types of study programs (e.g., humanities vs technical). We encourage additional, national, or even local inquiries into the preference of specific tools and teaching formats to complement our aggregated results.

4.4 Recommendations for Further Analyses

Possible interesting additional analyses could include one-way ANOVAs of tools comparing different age groups or different levels of teaching experience to see whether they influence intended frequency of use. It is plausible that especially younger students might be less keen on continuing to use remote teaching, as they are most affected by the lowered social interaction, having never attended presence formats. Additionally, further insights into the psychodynamics of the attitude toward remote teaching and digital learning media could be derived by further quantitative analysis, e.g., using a Technology Acceptance Model (see [14]).

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COMMUNICATION CHALLENGES IN DISTRIBUTED STUDENT PROJECTS

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ABSTRACT

Student projects have been widely adopted in software engineering education. Project teams are composed of students in the same institution, and students can meet and communicate face-to-face regularly. The Covid-19 pandemic, however, forced the student projects to rapidly transition to remote mode and adapt to the virtual team. Virtual teams in distributed environments face challenges due to distance factors that separate collaborators from each other. This study aims at investigating the communication challenges student teams encountered and managed to overcome. We report on an analysis of data collected from reports and interviews in the software project course delivered in fall 2020. There were 57 participants, forming 10 project teams in the study. The results show that remote work negatively affects the social aspects of project teams, especially early communication difficulties in a project. The teams were able to handle most identified challenges but had less interest in tackling those that they did not see as a risk to project completion, which would have most likely caused problems in real-world projects. This study improves understanding of communication challenges in student project teams and the findings serve as a resource for course teachers to design student project courses in the context of virtual teams.

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1 INTRODUCTION

The recent COVID-19 pandemic has forced many software development teams and developers to remote work instead of working in the traditional office environment. For many software development teams, this sudden shift has changed how team members communicate their work [1]. Similar changes happened also to students' software development projects in universities. Lectures were given remotely, groups had their internal meetings virtually, intensive usage of collaboration and communication tools was forced, and customers and course staff participated remotely in review meetings and other project activities.

The goal of this study is to identify challenges, especially the communication challenges in student projects in which students are forced to rapidly transition to a remote mode and adapt to the virtual team in software development projects. The research questions that guided our study are as follows: *What are the communication-related challenges identified in the students' virtual teams for software development?* and *How are the challenges tackled in virtual teams?*

The rest of the paper is organized as follows. In Section 2 we give an overview of communication in virtual teams. Section 3 covers background information of the case study and describes how data was collected and analyzed. Findings are given in Section 4. The last section concludes the work. This paper is based on a master's thesis [2] of the first author.

2 COMMUNICATION IN VIRTUAL TEAMS

Software development is highly collaborative work. To be successful, adequate communication is needed. Lack of communication or poor communication practices can be a significant factor in project failure. Especially in distributed environments where face-to-face communication is limited, effective communication practices become even more important.

In distributed software development, software products are developed by teams with members from different sites [3]. Virtual teams can be defined as geographically distributed collaborations that rely on technology to communicate and cooperate [4]. Based on the definition, virtual teams can be the opposite of collocated teams. Members of a virtual team are distributed across separate sites, but they work on the same tasks as a team [5]. In distributed projects, there can be one or more virtual teams with distributed members [6].

Communication challenges are constraints that decrease the efficiency and effectiveness of communication, and consequently, they can negatively affect the project's success [7]. Alzoubi and others [7] conducted a systematic literature review on communication challenges in globally distributed agile software development to identify communication challenges and solutions to them. They identified a total of 17 communication challenges and categorized them into six distinct categories: distance differences, team configuration, project characteristics, customer communication, organizational factors, and human factors.

Distance differences refer to geographical and temporal distances between team members. Team configuration is related to team size, team structure, and member changes in the team. Project characteristics cover project domain, project architecture, and project type. Customer communication refers to communication between the team and the customer's representatives. Organizational culture, project management processes, communication tools, and infrastructure characterize organizational factors. Human factors refer to personal differences like language, national culture norms, values, and style of communication, and personal attitudes and skills.

Agile software development can be understood as software development that follows the values and principles defined in the Agile Manifesto [8]. Software development projects in industry and university education are nowadays mainly done using some agile software development model or framework, like Scrum [9]. Calefato and Ebert [10] give an overview of collaboration tools used in agile distributed projects, and Ahmad and others [11] give a systematic mapping study on communication channels and practices in agile software development.

3 CASE STUDY: VIRTUAL STUDENT PROJECTS FOR SOFTWARE DEVELOPMENT

3.1 Study context

To answer the research questions, we studied the software project courses implemented at Tampere University in Finland in fall 2020. The course aims at training students the basic skills and competence for software development. Although the study was done with the computer science students, the content of the course was essentially the same as described by Sten and others [12]. The course forms an essential part of the bachelor's degree studies in computer science and computing. In the course, students worked in a team of approximately six members to develop a software system or improve an existing application for real clients. Students typically take the course during the 3rd year of their studies, and therefore, have at least basic skills and knowledge of the techniques and process of software development. For some students, the course also serves as their first experience in solving a real problem in teams. Besides, each team has a master's degree student who acts as a project manager. Project managers have gained a basic understanding of software product and process management in the software project course and other prerequisite studies. The project course lasts 4 months. The development process applied by the project teams can be generally considered agile [8] and iterative.

3.2 Data collection and analysis

There were 57 participants in the course, and 10 teams were formed. Seven teams had six members and the rest had five members. Two of the teams were international and their working language was English, and the rest teams had only Finnish speaking students. The primary channel for data collection was reports required in the course. A final report was for each team to summarize the project performance and the retrospective. Ideally, the entire team participated in preparing the report. In addition, personal reports were required for every individual to report his/her personal discoveries about the learning and the process of the teamwork in the middle of the project and at the end of it. Open-ended questions such as communication challenges the project teams or individuals encountered and how they reacted were used to elicit feedback from the course participants in both types of reports. The final reports were returned by all 10 teams and the personal reports by 56 out of 57 participants.

All project managers of the teams were invited to participate in voluntary interviews. At the end of the course in January and February 2021, semi-structured interviews were conducted with four project managers. The interview lasted between 45 minutes to 75 minutes. Our purpose was to identify challenges that were not necessarily noticed by the project teams. Besides the questions asked in the reports, challenges identified from the literature were also discussed to determine whether the project team has faced such problems or not.

The course participants were informed that the questions would be used for research purposes, and that it is voluntary to answer the questions. The projects were anonymized using an alphabetical identifier. The course participants were referred to as team members or project managers. The course teacher collected and pre-processed the reports by making only the relevant data accessible for analysis. The open coding technique [13] was applied to interpret and analyze the answers based on the perceived similarity and the common challenge categories identified by Alzoubi and others [7].

4 RESULTS AND DISCUSSION

The COVID-19 pandemic has forced teachers and students to rush into the virtual events of teaching and learning, with inadequate preparation for the unique demands the virtual events post. When the software project course was implemented in fall 2020, students still have limited experience in working in a virtual team. The teams were able to decide their communication practices. They managed to organize regular virtual meetings with team members, project clients, and the course teacher. Most meetings last 30-60 minutes, while others reported that sometimes weekly meetings lasted for several hours. Besides, four teams also arranged coding sessions for members to work on tasks together or at least have a possibility to communicate with others while working on individual tasks. The teams relied on text-based communication tools for daily communication. Synchronous communication was possible but often limited because students often had different schedules and were online at different times.

The teams managed to communicate during the project and experienced different challenges. When 44 out of 56 students seemed to agree that there was enough communication in their teams, as shown in Fig. 1, more than half of the students still would have preferred more face-to-face communication, as shown in Fig. 2.

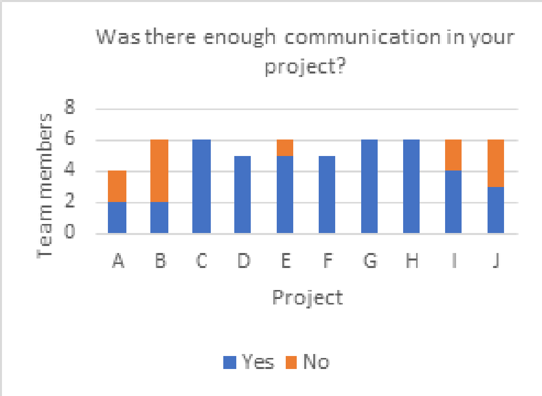

Fig. 1. Sufficiency of communication during the project.

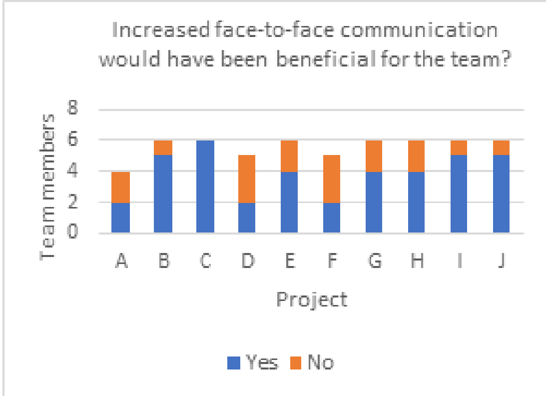

Fig. 2. Would face-to-face communication has been beneficial for the team?

All teams found appropriate communication tools according to their needs and prior experience. The most used communication tool was Slack (used by four teams). Discord and Telegram were used by three teams, and WhatsApp by two teams. The online meetings were held on Zoom (used by four teams), Google Meet (by three teams), Microsoft Teams (by two teams), or Discord (by two teams). Most teams used more than one tool. Some teams used different tools for team meetings and client meetings. For instance, Team C used Zoom for client meetings and Discord for team meetings, while Team J used Zoom for team meetings and Google Meet for client meetings. In the report, it is unclear which tool Team A used for organizing meetings. This may be a signal of insufficient communication within Team A, as reflected in Fig. 1. In addition, some teams used an instant messager, e.g. WhatsApp or Telegram as a reliable way of reaching their team member before they got used to the use of Slack, their primary communication tool.

4.1 Challenges in students' virtual team projects

There were 91 challenges reported in the 56 personal reports. Fig. 3 illustrates the challenges and their distribution in projects.

The most identified challenges are related to team members' skills, reported by 25 students in 9 project teams. They were related to the team's familiarity with the tools or technologies used in the project. Some students also reported skill differences between team members and a steep learning curve of knowledge or skills, especially at the beginning of a project. In addition, 13 members from three teams reported technical problems in project implementation; however, these are related to a particular domain and implementation technologies of the given project.

Time management and scheduling form the next common challenge, reported by 14 students in 8 teams. They were described as procrastination issues such as leaving too much work to the end of a project, inadequate time to finish all features, etc. Many projects had a slow start which led to an unbalanced workload at the later stage. In addition, challenges for team members in different time zones were reported by Project I, and members in Projects D, G, I, and J faced challenges in balancing their studies or full-time work with the project schedule.

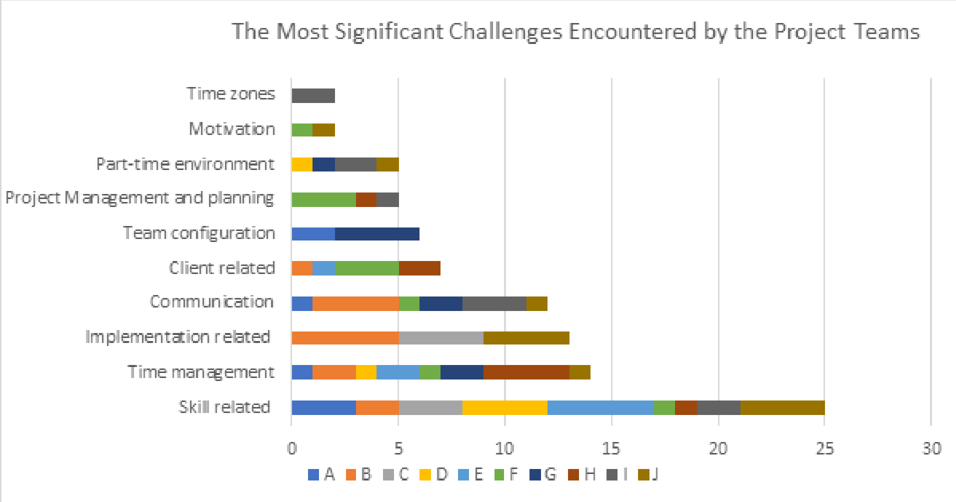

Fig. 3. Challenges identified in personal reports. The chart shows the challenges on the Y-axis and the no. of answers on the X-axis. The color represents the respective team, as indicated in the chart's legend.

Communication challenges were reported by 12 students in 6 teams, among which two teams (B and I) had significant communication challenges, as they were reported by most of the team members. The other four teams have only one or two members reporting such challenges. On the other hand, students in Projects A and G reported team configuration challenges, such as members quitting the project, teams being merged, and the project manager missing at the beginning of a project. These may partly cause communication difficulties. Also, some students reported the issue of misunderstanding project requirements, which implies the challenge of communicating with the clients and understanding their needs.

Besides, three teams have difficulties with project planning, scope management, and project management. These are related to the project managers' competence and skills and are also affected by how smoothly the team communicated with the client above the project objectives and requirements.

4.2 Tackling the challenges

Communication challenges were identified by synthesizing findings in the project team's final reports, personal reports, and interviews with project managers. We adopted the communication challenges and categories presented by Alzoubi and other [7] to summarize the identified challenges, their causes, recognized consequences, and the project teams' solutions in Table 1. The findings show that remote work decreased the feelings of social connection and team cohesion. Even though every team reported they had regular meetings, there are questions regarding the quality and ease of communications. Herein, differences in schedules and differences in skills were the most common challenges.

The difference in team members' schedules was reported in eight teams. It was one typical distance factor causing challenges like delays in communication and difficulties in arranging meetings, as one team mentioned in the final report, "*the main problem was: agile projects need frequent communication. Meanwhile, students do not like to be bothered frequently*". Even though the temporal distance was a common challenge, the teams managed to handle it in various ways, e.g. introducing the 24-hour rule of reading and responding to the posted messages, suggesting members turn on the new message notification in communication tools, being aware of team members' availability to schedule regular meetings in advance, sharing meeting notes, etc.

Table 1. Communication challenges reported by project teams and their solutions. The parentheses include teams that recognized the challenges but did not mention solutions.
(env. – environment, comm. – communication, TM – team member, PJM – project manager)

Category	Cause	Consequence	Solutions	Teams Affected
Geographical distance	Lack face-to-face meetings	Eliminates spontaneous interaction in demo or development env. setting	screen sharing and other tools in online meetings	E, (A)
	Lack of informal comm.	Lack of team cohesion	Improved over time	B, C
	Limited access to project-specific tools	Lack of shared knowledge	Tool demo using videos or shared screen	C
Temporal distance	Different schedules	Delays in communication	24-hour rule, message notification	A, B, E, G, J
		Difficulties in scheduling meetings	scheduling regular meetings in advance	B, C, D, E, F
		TMs absent in meetings	Meeting notes	B
	Different time zones	Difficulties in scheduling meetings	-	I
Comm. tools	Unfamiliarity with tools	Passive/inefficient use of tools	Using alternatives	B, C, E, J
	No use of webcams	Less social cues	-	B, H, J
	Prefer text over voice comm.	More difficult to comm.	-	H, J
	Inefficient use of task boards	Reduced comm. and awareness	Increasing TM's involvement with task board	E, F, (B, H)
	Using multiple tools	Difficult to keep track of all comm. channels	-	F
Customer comm.	Insufficient/miscomm. with the client	Assumptions about requirements or goals	Regular meetings with clients	B, F, (A, H)
Team comm.	TMs were unfamiliar with each other	Early comm. problems	Improved over time, PJM as a role model of active communication	B, C, E
	TMs quit & teams merge	Early comm. problems	Addressing problems in meetings	G, (A)
	Lack of task-related communication	Lack of task awareness, assumptions have to be made	Task boards (e.g. Trello), task dependency model, more meetings for project progress	C, F, A
	Lack of meeting agenda	Inefficient meetings	Adding agenda	C
Human factors	Different learning goals	Not following comm. protocol	-	B, J
	Different skills	Poor understanding or explaining technical concepts	Giving TMs tasks matching their skills	B, C, E, (F)
		Dominated/passive TMs	Involving less active TMs by asking their opinions	C, J, A
	Different language skills	Misunderstandings, passive comm.	-	(H, I A)

Besides, human factors related challenges were identified almost in all projects and were caused by factors such as language differences, the passiveness of team members, skill differences, and the members' motivations or goals. Among which skill differences were the most common ones leading to problems such as difficulties in explaining or understanding technical concepts, experienced team members dominating communication, and misunderstandings. Encouraging communication was the common strategy used by the teams. Specifically, two teams mentioned their strategies such as assigning tasks that match the member's skills and always asking for everyone's opinions during the meeting. However, most teams did not mention any specific solutions to the problems related to skill differences, implying the difficulties and low motivation for the teams to overcome such challenges.

It is remarkable how the virtual teams have adapted so quickly to remote working on the project and that the virtual team setting and limited face-to-face communication did not cause significant communication challenges for most teams. The availability of face-to-face interaction would have made communication smooth and mitigated the difficulties brought at the beginning of a project when team members were not familiar with each other and the team-building efforts had to take place virtually. Face-to-face interaction would have eased the demonstration of code and tools and avoided some technical problems brought by the communication tools. However, most of the communication challenges would have likely remained even if face-to-face interaction was possible. Some teams even seemed to prefer the remote setting due to its benefits, such as, saving time commuting to face-to-face meetings.

The teams solved the encountered challenges reactively. Also, the agile practices adopted by every team, like review meetings, regular team meetings, task boards, etc. helped to communicate and manage project tasks. Typically, the recognized problems were addressed in meetings and the team would decide how to deal with them; while some others were only recognized retrospectively and mentioned in the reports, like those presented in the parentheses in Table 1. The teams were able to handle the most crucial challenges to complete their project. However, the less significant communication problems were often ignored, if they did not see them as a threat to the project's success. For instance, none of the teams used webcams actively, although visual cues can help team members better read each other's emotions in a meeting. The decision of no use of webcam may be related to the team members' personal preferences or technical problems like the webcam not working, poor internet connection, etc. but the teams did not initiate any actions to improve the social cues in communication.

5 CONCLUSIONS

Software development projects are often complex, and they require sufficient communication which is not always easy to achieve. Communication becomes even more difficult in virtual teams in which face-to-face interaction is limited. This study identified communication challenges and their solutions based on software projects worked by university students. Our findings show that remote work negatively affects the social aspects of project teams, especially early communication difficulties in the project. The teams were able to handle most of the recognized challenges in one way or another. The common agile practices like review meetings, regular team meetings, task boards, etc. helped communicate tasks within the team and between the team and the customer. For these teams, communication was mostly a minor challenge, and challenges related to individual's knowledge and skills, project time management, implementation techniques, etc. impacted more on project conducting. The unsolved communication problems were mainly related to human factors. Considering that students might have different motivations to take the project course, we see that the project teams have less interest in tackling challenges that they did see as a risk to project completion. This might have been sufficient for a student project, but in real-world settings, their practices would have potentially caused more significant problems.

In virtual student projects, although most teams found ways to meet regularly, the quality and ease of communication remain challenging. Effective communication helps build trust and enhance understanding. When designing a student project course, it is importance to emphasize the learning objectives and provide sufficient guidance to help project managers and their teams organize meetings at the beginning of the project and discuss with team members not only the tasks and roles of team members but also the recommended practices and tools in communication, and expectations such as use of cameras by remote participants, trust, prompt responses, regular meeting hours, etc.

This study identified many communication challenges that are relevant to university student projects. However, not all the possible challenges could be identified. Students with limited experience may not be aware of all the problems that affect their projects. Our next step is to further investigate the challenges with data collected using different methods from similar projects. This will certainly enrich the understanding of the communication challenges and provide effective guidance for designing student project courses in the context of virtual teams.

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EFFECT OF A PRACTICE-INTENSIVE COURSE ON DOCTORAL TEACHING ASSISTANTS' TEACHING SELF-EFFICACY AND PRIORITIES (RESEARCH)

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ABSTRACT

Doctoral teaching assistants (TAs) provide key support for learning in STEM fields because they are present during exercises, labs and projects when students are actively engaging with course material. While some institutions provide training for TAs, their effect on teaching activities is rarely assessed. We use the lens of Social Cognitive Theory (SCT) to analyse data on the pre and post course teaching priorities of 20 doctoral TAs who followed a 5 day practice-intensive course on STEM HE. Course time was split between instructors modelling interactive teaching strategies to engage TAs in a data-driven reevaluation of their beliefs about teaching and having each TA teach a lesson everyday using a structured feedback loop to promote

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reflection. TAs reported self efficacy gains for designing instruction, addressing disruptive behaviour and managing student attention spans after the course. Their priorities also appear to shift away from 'teaching' and towards 'learning'. TAs' affective reactions and utility judgements after the course indicated that they thought the course was useful and they intended to use the strategies that they had learnt. This practice and reflection intensive course model, able to accommodate up to 40 TAs, is relevant for institutions seeking to improve the quality of undergraduate education or doctoral candidates' preparation for academic roles.

1 INTRODUCTION

Doctoral programs primarily prepare doctoral students for research, and may not sufficiently prepare them for other aspects of academic life including teaching [1, 2]. Additionally, doctoral candidates often play a key role as teaching assistants (TAs) in undergraduate courses and can contribute significantly to the quality of the learning. In engineering, TAs are present during exercises, labs and projects - i.e. when students are actively engaging with course material [3] and developing key disciplinary thinking skills. The importance of ongoing training is underlined by the high turn-over rate, with approximately half the TAs being new to teaching every year [3]. Investing in TA training is therefore not only relevant to prepare them for their future academic careers (presumably at a different institution) but also for maintaining excellence of the education offered to undergraduates at their current institution.

1.1 Theoretical framework

We use the framework of Social Cognitive Theory (SCT) to explore the effect of a practice-intensive course on the evolution of TAs' teaching priorities. The SCT [4] has been used in multiple fields, including education, to describe how behaviours can be learnt and maintained. One of the key features of the theory is the social dimension of learning, i.e. behaviours are learnt and/or reinforced by observing and interacting with the environment. A very important dimension of the SCT is the importance it places on the role of self-efficacy. Bandura [4] describes self efficacy as "*people's judgement of their capabilities to organize and execute courses of action required to attain designated types of performances*" (p.395). High self-efficacy is a good predictor for higher performance on tasks. However, self-efficacy can be influenced by other social dimensions such as ethnicity and culture [5].

1.2 SCT and self-efficacy in teaching

Prior research has shown that the social dimension of learning is very important for developing teaching behaviours. Teachers draw from the way they were taught and as well as their experiences in research and non-academic roles [6]. Connolly et al. [1] and DeChenne et al. [7] summarise prior work showing a correlation between high self-efficacy and teachers' characteristics of good teaching (learning focus, classroom management skills, willingness to experiment with teaching methods), as well as in TAs (persistence, student achievement). Since self- efficacy develops with experience on task, less experienced teachers tend to focus on their own behaviour (teaching v learning) and worry about student misbehaviour, potentially decreasing implementation of evidence-informed teaching strategies [8]. Bitting et al. [2] collate a series of studies that further link novice faculty's reluctance to implement evidence-informed teaching strategies to low self efficacy and concerns about the effect of negative student feedback on tenure decisions. Therefore, providing opportunities that allow TAs to practice their instructional skills and to develop self-efficacy in lower stakes environments are important dimensions for the pedagogical development of doctoral students.

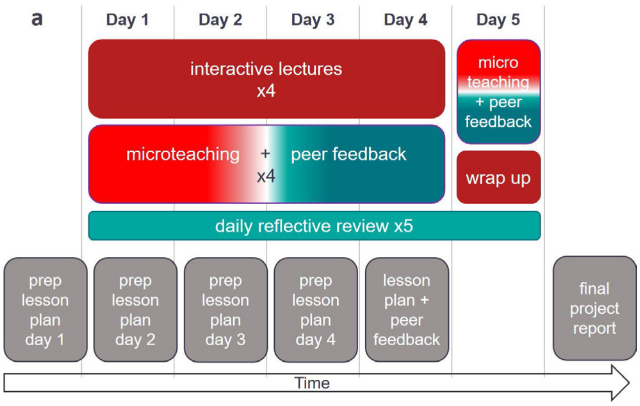
Despite broad agreement about what constitutes good teaching in higher education, (see [8] Ch. 8 for a review), traditional teaching methods persist in STEM labs, exercises and projects. Bitting et al.'s review [2] identifies TAs' tendency to reproduce their own educational experiences (which rarely include interactive courses or inquiry labs) and low self-efficacy for 'novel' pedagogical strategies as barriers to the adoption of evidence-informed approaches. Their review also highlights that "*changes in practice without supporting changes in beliefs are often short lived, inconsistent, or ineffective*" (p.520).

Tormey et al. [9] argue that STEM TAs need "*training which is informed by evidence, which addresses the needs of engineering disciplines and which is short enough so that doctoral assistants will not be discouraged from participation*" (p.379). While rigorous evaluations of STEM TA training programs are scarce [2, 7], three Canadian studies particularly interested us. White et al. [10] found that participants in a two day workshop for STEM TAs did not hold different ideas about teaching than non-participants, however attendees reported they would allocate more class time for student-to-student discussions and lecture less than non-attendees. They conclude that their workshop assisted TAs to identify effective pedagogical strategies. Meadows et al. [11] report that their training with aspects of intercultural communication designed to assist a diverse TA cohort to understand the local teaching and learning culture had better outcomes on teaching self-efficacy, observed teaching effectiveness, and adoption of student-centred approaches to teaching compared to their standard training. Hughes and Ellefson [12] report that biology students whose TAs trained them to ask good questions (*vs.* trained to provide good answers) performed better on the exam.

Our approach has been significantly informed by Tormey et. al.'s nine recommendations for TA training [9, p.383] resulting from their review of teacher education and STEM literature. For example, opportunities to confront their own ideas about good teaching, practising and getting feedback on teaching skills, and addressing the concerns of novice teachers, such as classroom management.

1.3 Description of the course

The format of this course, offered to doctoral TAs at a research-intensive public engineering school, is shown in Figure 1a. The course content focuses on strategies for inteactive teaching informed research evidence from higher education in general with a specific focus on the disciplinary skills and epistemologies of STEM.[2] The key pedagogical innovations are the course activities designed to leverage the principles for developing expertise identified by Tormey and Isaac (2022, p.257). Course time was split between instructors modelling interactive teaching strategies to engage TAs in a data-driven reevaluation of their beliefs about teaching and having each TA teach a lesson everyday. This peer microteaching occured in stable 4-5 person groups and employed a structured feedback loop (Fig. 1b) [13]. The five days of the course spanned 4 weeks to allow participants time to develop their next lesson plan and to complete additional readings. The first two days were entirely on campus and the final three days were hybrid. Daily reflective reviews, where TAs write about what they had learnt, their experience in the microteaching and the implications for their practice, are an integral part of the course. These daily reviews enable instructors to follow TAs' evolving thinking about STEM pedagogy and to provide feedback. Asssessment takes the form of a project report where TAs summarise their teaching evolution through three of Brookfield's lenses: self-reflection, peer-feedback and the literature [14]. TAs' teaching skills did not contribute to course grades.



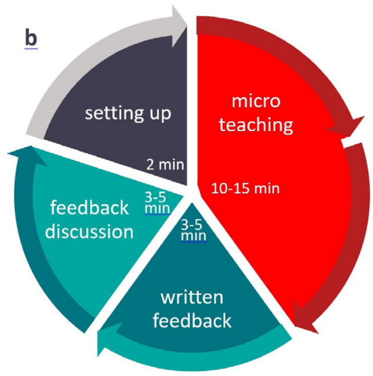


Fig 1. Schematic of (a) the course plan and (b) the microteaching cycle. *The course included daily interactive sessions with the instructors (deep red) as well as an opportunity for each student to teach and get peer feedback (red + teal). Students submit several deliverables (grey + deep teal) before, during, and after the course for teacher feedback.*

The four key components of increasing self-efficacy [15] have been addressed by various aspects of this course:

1. Mastery experience: TAs taught five lessons to their peers during the course. They were advised to use the feedback to design every subsequent lesson.
2. Social modelling: TAs observed their peers teaching and were able to analyse and learn from the strategies they chose to use.
3. Improving physical and emotional states: Since they were teaching their peers TAs were able to gain mastery in a low stress environment. Additionally, they were able

[2] More details available in the course description: https://edu.epfl.ch/coursebook/en/lecturing-and-presenting-in-engineering-ENG-629

to deal with the positive and negative emotions that come from receiving feedback in a supportive environment.

4. Verbal persuasion: TAs got a lot of feedback from their peers as well as from the instructors.

1.4 Research question

While many universities offer some TA training, the impacts are rarely assessed because it is resource intensive. This is unfortunate given the important role TAs play for STEM undergraduate programmes. In our study, we were interested in assessing the impact of a practice-intensive course on the self-efficacy and teaching priorities of doctoral teaching assistants. Specifically, does this course have a measurable impact on TAs' intention and self efficacy to teach in evidence-informed ways?

2 METHODOLOGY

2.1 Participants

2022 represents the 6th edition of this course and its first hybrid iteration. The 20 doctoral TAs came from 12 programmes including Robotics, Photonics, Electrical Engineering, Chemical engineering, and Computational biology. Roughly ¼ of the TAs were in their first 18 months of their PhD and ¼ were in the final phases of completing their doctoral work. All TAs reported that they had some prior teaching experience; 85% reported being a TA for a university level course and 50% had done private academic tutoring. Before starting the course, ⅓ of TAs had read advice about teaching well (n = 7), ⅕ had read at least one educational research paper (n = 4), and ¼ had previously attended one of the various half day pedagogical development workshop offered by our teaching support centre (n = 5).

2.2 Data collection and treatment

To generate relevant observations for our research question, we identified a series of behaviours and strategies that we anticipated course participants would use during their TA duties, such as organising group work or managing disruptions. Course participants' teaching self-efficacy assessments for teaching strategies (4 level agreement Likert scale) and teaching behaviour intentions (temporal scale, ie 5-10 minutes per hour) were collected at two time points: on the first day of the course and on the final day of the course. The final questionnaire had items oriented towards evaluating the course, including utility judgements. Both questionnaires concluded with a free text question. A set of anonymous unique identifying codes was circulated among the students to allow the pre and post data sets to be linked, ensuring that the instructors were unable to link responses to individual students. Given the nature of the study design, it was exempt from a full review of the institutional ethics review board for research involving human participants and was conducted in accordance with our institution guidelines.

This approach generated 21 responses to the pre survey and 19 responses to the post survey. Qualitative analysis and descriptive statistics used the entire data set; however only the 16 data sets which could be paired were used for statistical tests. While the non-normality of our data suggested that a Wilcoxian signed-rank test would be most appropriate to assess pre and post treatment effects, we ultimately employed a paired t-test due to constraints of the Wilcoxian signed-rank test that make it an inapporiate statistical test when ⅓ of participants report only small changes. Pre and post treatment differences for items on the ordinal temporal data scale were determined via a mixed effects ordinal logistic regression (with unique identifier as random intercept).

3 ANALYSIS AND RESULTS

We evaluated TAs' self efficacy assessments for teaching behaviours (Fig. 2). While their responses before the course show that they were already relatively confident about their teaching skills before the course, TAs' reported statistically significant improvements (paired t-test; $p < 0.05$) for 3 behaviours: Directly address students' disruptive behaviour in the moment to allow other students to work efficiently, Manage students' limits in working memory and attention span, and Design instruction using complementary modes of communication and representation. There was no increase in participants' self-assessment of their ability to 'proactively minimise disruptive behaviour'; this is useful feedback for us as instructors. While we did employ some of the proactive strategies for fostering a constructive class climate and avoiding disruptions in the current course, we did not step outside our immediate teaching role to reveal our behind-the-scenes thinking that informed our instructional choices. Nor, given the brevity of their microteaching slots, were TAs able to employ such practices in their own microteaching.

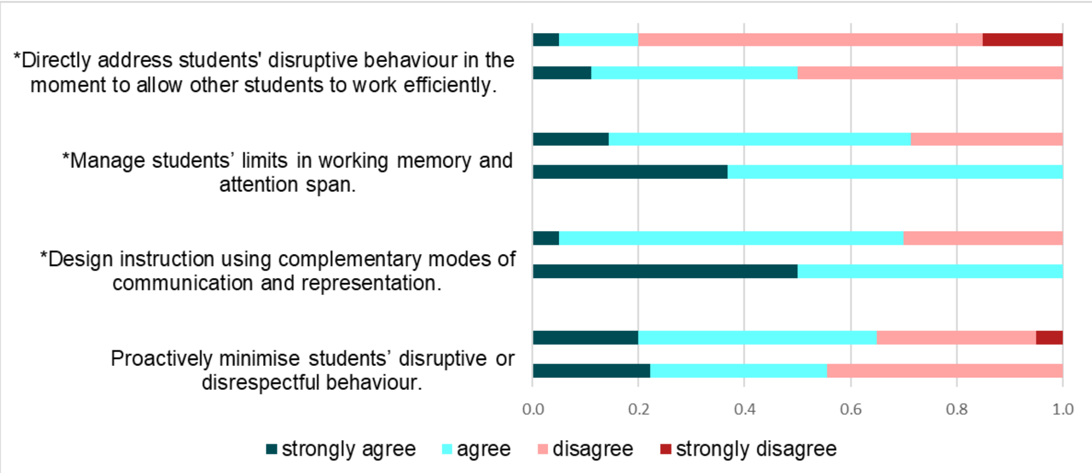


Fig 2. Comparison of TAs' self efficacy assessments for teaching behaviours. *For each item, responses on the first day appear on the upper line and post data on the lower line. Total n= 20 for the chart; missing values are excluded. Paired t-test performed only on the 16 matched questionnaires; * designates items with statistically significant differences at $p < 0.05$.*

TAs' intentions in terms of the number of minutes they would anticipate using various teaching behaviours are shown in Fig. 3. TAs' pre survey responses indicate that when teaching, they devote most of their time to presenting material and modelling their thinking for students. TAs' responses in terms of the time they would spend asking questions to their students, providing students with feedback on their learning or using small group activities spanned the entire spectrum (never to as much as possible). ⅔ of respondents stated that they would spend less than 5 minutes being silent to allow students to think during class.

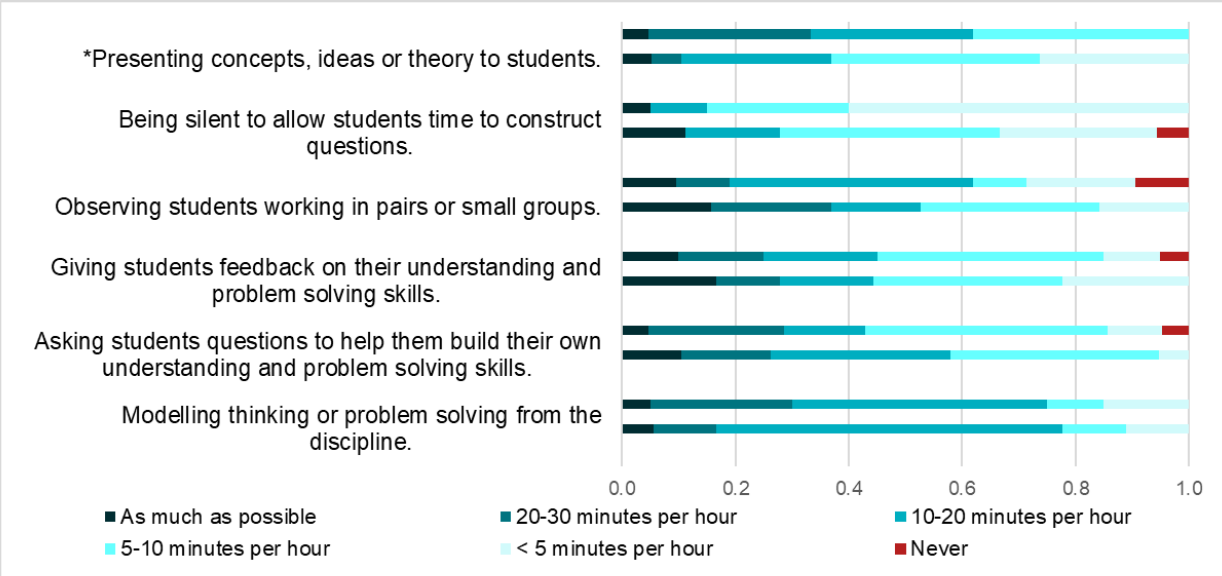


Fig 3. Comparison of TAs' intentions for teaching behaviour *. For each item, responses on the first day appear on the upper line and post data on the lower line. *designates items with statistically significant differences at $p < 0.05$ using a mixed effects ordinal logistic regression (with student code as random intercept) to analyse the data.*

Comparing the pre and post course data from a descriptive approach, TAs report small increases in the time they intend to spend on learning-focused behaviours such as 'Asking students questions to help them build their own understanding and problem solving skills' and 'Observing students working in pairs or small groups'. However these observations were (unsurprisingly given the small sample size) not statistically significant. The one item that had a statistically significant increase was a decrease in the time that TAs intended to spend 'Presenting concepts, ideas or theory to students.' There was not an appreciable difference in the time TAs intended to spend giving students feedback, making the material relevant, being silent and modelling thinking or problem solving. It is interesting to note that, after the course, TAs intended to spend less time presenting to students but to maintain their modelling of thinking or problem solving. This seems to be a pedagogically sound priority.

We also evaluated the TAs' affective reactions and utility judgements [16] following the course (Fig. 4). This allowed us to go beyond simply quantifying their satisfaction and to assessing the utility of the course as well as intentions to put learnt skills into

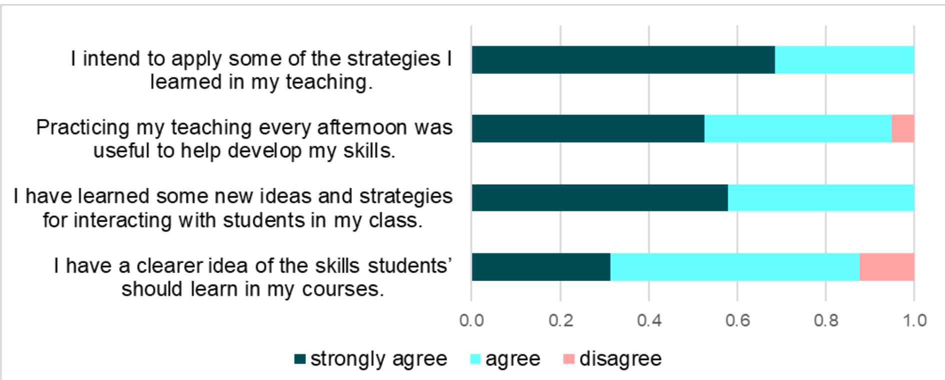


Fig 4. TAs' affective reactions and utility judgements of their experience in the course.

practice. In addition to the TAs thinking that this course was good, and useful in terms of learning and developing new teaching skills, all of them indicated that they intend to apply some of the strategies they learnt in their teaching.

We analysed the free response questions, using qualitative content analysis, to determine the key concepts that emerged. Similar concepts were then grouped together into main themes wherever possible.

Before the course, TAs' responses to the question "What are the three things you would like to improve to be a better teacher?" prioritised the 'teaching' aspect of the teaching and learning process (Fig. 5a).TAs focused on what they, as teachers, would be doing. This included structuring presentations/classes (n = 13), explaining concepts (n = 6), and attracting student attention (n = 4). Some TAs did mention wanting to learn about ways to enhance student engagement (n = 6), pedagogical research that underpins teaching methodologies (n = 4), and how to tailor the material to suit the audience (n = 3).

After the course, TAs' responses to the question "What are the three strategies you found most useful and will be using in your teaching?" indicated a shift in their priorities towards the 'learning' aspect of the teaching and learning process (Fig. 5b). While they still included teacher actions such as lesson planning (n = 16), the main focus was on enhancing student learning by using active learning (n = 16) and various active learning strategies (n = 18). Additionally they spoke about the importance of creating a classroom culture (n = 5) and giving/getting feedback (n = 5) in order to enhance learning.

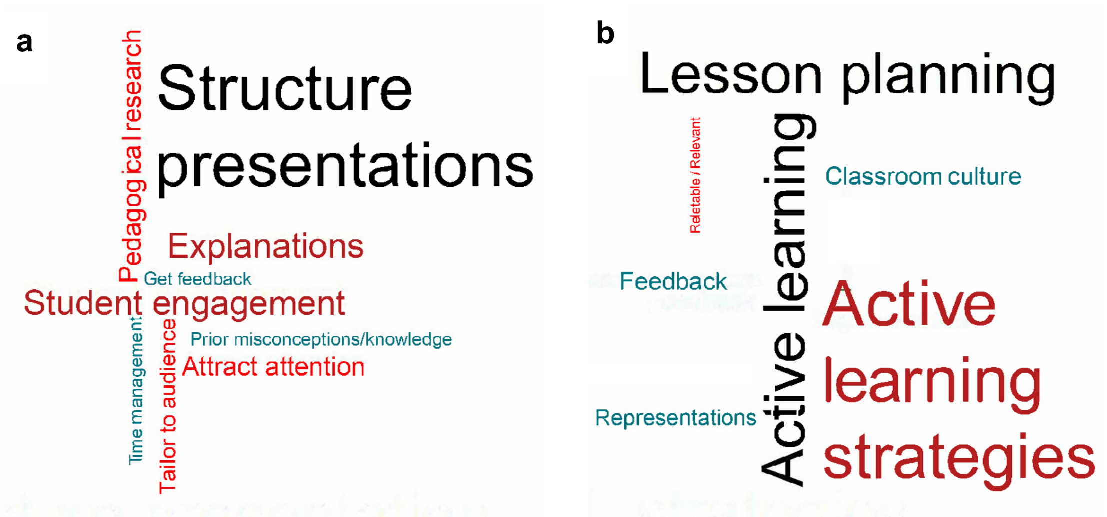


Fig. 5. Main themes from TAs' comments on (a) pre-course and (b) post-course questionnaires. *Size and colour of the font corresponds to the frequency with which these concepts appeared in student responses.*

4 CONCLUSION

This study investigated what TAs thought that they should prioritise in their teaching (a pragmatic approach to teaching philosophy) and how well prepared they feel to realise their prioroties in their teaching (self-efficacy). Our study showed that the course was effective in shifting TAs’ priorities and focus away from teaching and towards learning, including using pedagogical strategies with higher cognitive engagement. TAs also reported increased teaching self-efficacy for the skills which they practiced during the course. Similar effects of TA training programs have been documented in other studies [1, 7, 10, 11]. As Connolly et al. [1] postulated, it is possible that courses such as ours increase TAs' self-efficacy by providing students opportunities to engage in the four key activities for increasing self-efficacy.

At the end of the course, TAs reported positive affective reactions (they liked the course) and utility judgements (they intend to use concepts and strategies from the course). A meta analysis by Alliger et al. [16] identified that intention to use material from a training was more strongly correlated with implementation than direct measures of learning. So while we did not directly observe the impact of the course on TAs’ actual in class teaching behaviours, the shift in their priorities and increased self efficacy is expected to increase their use of evidence-informed teaching strategies. While we are planning a more robust evaluation of this course, the current findings support our practice and reflection intensive model. Further, the course format can accommodate up to 40 TAs without requiring significantly more resources while maintaining all the microteaching and reflection opportunities. This is relevant both within our institution, and potentially for colleagues, in light of institutional priorities around the quality of undergraduate education and doctoral candidates' preparation for academic roles.

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WHEEL OF COMPETENCIES: INDUSTRY DEMANDS OF COMPETENCIES FOR RESEARCH AND INNOVATION

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ABSTRACT

On the basis of the current state of research, this study identifies and validates future-oriented competencies. Using quantitative social research methods, it then investigates demands in industry. This involved, first, an evaluation of literature and the identification of competencies for research and innovation (R&I) activities. Next, from clusters of the identified competencies I derived 14 different types. On this basis, I generated a competency profile that informs the development of a tool for R&I, the *Wheel of Competencies*. With this newly developed tool specific competency profiles can be generated and analysed.

Second, I operationalized and implemented the competence components in a questionnaire. On this basis, 200 CEOs and heads of research and development (R&D) departments of medium-sized and large enterprises in Germany were surveyed in November and December 2021 using computer-assisted telephone interviews (CATI). All enterprises have at least 50 employees and an in-house R&D department. In addition, enterprises have to belong to one of the following industry sectors: automotive, chemical, electrical or mechanical engineering.

The results show that certain competencies are in very high demand across all industries, while others are more specific to an industry sector. Overall, the results indicate that the competencies in demand address the dynamic complexity in collaborative R&I processes. The results presented here make an important evidence-based contribution to curriculum development in engineering education based on future-oriented competencies and illustrates which transfer activities and collaborative formats are increasingly relevant.

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1 INTRODUCTION

To conceptualize Research and Innovation (R&I) activities, the quadruple-helix model is the state of the art to understand the generation and impact of academic knowledge [1]. It explains how collaborations between the sectors academia, industry, politics and society enable sustainable innovations that can drive socio-technical transformations [2].

A means to this end is Knowledge and Technology Transfer (KTT). Here, KTT is not understood as transfer in the sense of its Latin origin from *transferre*, but as exchange and joint generation of knowledge, i.e. a broader understanding.

This generation of knowledge is described as inter- and transdisciplinary as well as application-oriented, so-called mode 2, and is characterized by being "socially accountable and reflexive" [3]. Such knowledge provides answers to grand societal challenges and ‘wicked problems’, because it takes into account their complexity and systemic nature, and also because solutions are developed jointly by actors from different sectors. Currently, this is being discussed under the term ‘new mission-orientation’, in which politically negotiated missions divide complex challenges into manageable problems [4]. An example of this are the Sustainable Development Goals (SDGs) that in turn inform research policies such as EU's Horizon Europe framework program.

However, to collaboratively generate new knowledge and find future-oriented solutions to pressing challenges is no easy task. It makes certain demands of those involved. In particular, activities in innovation ecosystems, i.e. collaborating stakeholders from academia, industry, politics, and society, require competencies and skills that go beyond domain-specific knowledge and abilities. Such competencies are complementary to disciplinary hard skills and socio-communicative soft skills. Which competencies and skills will become more important in the future is the subject of various debates that are conducted under the labels ‘professional skills’, ‘future skills’, ‘transversal or general skills’, ‘transfer skills’, ‘future-oriented competencies’ and ‘emerging skills’.

This study pursues two goals:

> First, it explores the question which (professional) competencies should be developed by actors in R&I collaborations, and,
>
> second, it seeks to validate a profile of such competencies by industry.

To this end, I first reviewed the state of research to identify relevant competencies for R&I activities and KTT in the literature. In a second step, the results were analysed, typologysed, and transferred into a tool. These results were then, in a third step, validated in a quantitative survey of 200 medium-sized and large enterprises. The results complement our understanding of practice-oriented competencies and is relevant for curriculum development in engineering education.

2 METHODOLOGY

2.1 State of Research, Typology and Tool Development

Which competencies will become (more) relevant for collaborative R&I activities in the future (within the German innovation landscape) is the subject of various specialized discourses. My work is based on a broad concept of transfer, i.e. the concept of KTT referring to a dynamic process of generating knowledge in mission-oriented research collaborations [5]. I claim that pertaining to this understanding, works from the fields of transformative sciences, transdisciplinarity, education for sustainable development, key competencies, (future-, professional-, emerging-, 21st century-) skills are relevant. For each of these fields, I surveyed contemporary literature, and evaluated the state of research with a special focus on key literature and mission statements by national academies and advisory bodies, such as German Academy of Science and Engineering, German Advisory Council on Global Change, and Donors' Association for the Promotion of Humanities and Sciences in Germany. To this end, I identified professional skills and competencies for innovation activities.[2]

I build on Weinert's conception of competency [6]. Thus, competencies are more than knowledge and its application. It is a knowledge-based disposition to meet complex demands by drawing on and mobilizing psycho-social resources in varying contexts to solve a given problem [7,8].[3] On this basis, I created a pool of all competencies relevant to R&I and KTT that are not strictly disciplinary, e.g. engineering mathematics like applied analysis. Next, as illustrated by α in Figure 2, I clustered the surveyed competencies and, following Kluge, developed fourteen types that are characterised by internal homogeneity and external heterogeneity [10]. For each type a definition was derived based on concepts in literature:

Table 1 - Competencies for R&I and KTT

1	*Agility* characterizes individuals who can adapt their behaviour and expectations as well as processes and structures flexibly and promptly to new framework conditions. They can react proactively, anticipatively, and proactively to changes by utilizing distributed knowledge and by continuously adapting to varying (social) situations [11,12].
2	*Agency in systems* refers to the ability to plan and realize actions and processes within complex personal, social and technical systems. The necessary prerequisites for this are the recognition and understanding of interdependencies between elements or parts of the system as well its boundaries. Specifically, this describes the ability to consider one's own actions

[2] I describe my methodology in more detail in 'Innovation Emloyability" (forthcoming).

[3] In Chomsky's sense, I understand dispositions as the components of a competence that are expressed in observable actions [9]. Unlike Chomsky, however, I do not assume that these dispositions are essentially fixed but rather that they may be developed.

	in a larger context in order to identify necessities and assess potential consequences [13].
3	*Handling complexity* describes the ability to recognize and understand relevant relationships and patterns in situations with an unknown multitude of factors that interact dynamically. On that basis one's own actions and behaviour can then be adjusted accordingly [14–16].
4	*Process analysis and design* describes the ability to recognize opportunities and obstacles to achieving personal or professional objectives. It includes identifying limits of the scope of action, deriving steps for an effective and purposeful intervention, and managing processes [13,17,18].
5	*Teamwork* is the ability to work with others from different backgrounds, organizations, and disciplines. Working in teams requires building trust and communicating effectively face to face as well as using media services [13,19].
6	*Attitude towards challenges* describes the mindset that individuals exhibit towards cognitively demanding tasks and situations with no apparent strategy for dealing with them. Specifically, this refers to whether situations and tasks that are perceived as challenging tend to be avoided or whether they are seen as an opportunity to learn or try something new [20].
7	*Acting according to ethical principles* refers to knowledge and understanding of ethical positions including the ability to identify relevant ethical questions. It, then, refers to the ability to act in accordance with such ethical principles in order to realize an individual or societal value by considering ethical dimensions of conditions of application, norms, interests, and consequences. Specifically, this competency describes the ability to recognize and evaluate values and norms and to direct one's own actions toward values and norms, taking into account the respective context, and to be able to justify a chosen course of action [21–23].
8	*Agency despite uncertainties and contradictions* refers to the ability to recognize and understand ambiguity and heterogeneity, as well as to be able to set priorities independently in situations in which feelings of uncertainty or excessive demands arise, and to align one's own actions accordingly. Specifically, such agency describes the ability to assess situations with contradictory or unclear information and to prioritize information in order to direct personal or professional actions towards a given objective [13,14].
9	*Motivation to learn* describes the individual attitude toward acquiring new or deepening existing knowledge, skills or attitudes. The focus is on the willingness to control one's own learning process and to activate the necessary resources and social processes. Specifically, motivation to learn refers to the individual willingness to intentionally acquire new knowledge or skills and to develop one's existing portfolio which can also mean that an initiative is undertaken to create the prerequisites for doing so [13,24,25].

10	*Critical thinking* describes the ability to (reasonably) assess facts on the basis of their essential components against the background of given sources and possible alternatives by applying general standards of rationality. Critical thinking involves questioning and evaluating what is supposedly self-evident [26].
11	*Recognizing emotions and taking other perspectives* is the ability to perceive and assess emotions both in oneself and in others. Within a professional context it refers to management and control of emotions on the basis of different behaviours and incentives. This also includes the ability to place oneself in the shoes of other people or organizations. In practical terms, this involves assessing emotional states or attitudes of others and considering them when addressing these others [27–29].
12	*Reflection of own actions* describes the willingness and ability to critically analyse oneself along with personal actions. It includes the ability to manage the utilization of personal resources. In addition, it includes the ability to recognize and relate to underlying systems of behaviour, thinking and values. By extension, the ability to reflect also includes actions of other people. Practically, this describes the ability to contextualize actions by recognizing and evaluating the relevant influencing parameters. The opposite is routine action or acting according to instructions [30,31].
13	*Handling diversity* refers to an appreciative approach to diversity and the ability to recognize commonalities in professional, cultural, or personal diversity (e.g., goals or values) that form the basis for joint action in a communicative-social process. This involves the ability to direct diverse impulses towards a common objective by fostering commonality in a sensitive process of exchange and communication [19,32,33].
14	*Creativity* is the ability to generate, shape, and implement ideas in order to find unconventional, novel, and appropriate solutions to a given challenge. Creativity allows to generate original solutions to emerging, complex, and unconventional challenges. Finding such solutions requires an open-mindedness toward unconventional methods and approaches as well as the ability to develop ideas exploratorily [11,25].

Illustrated by β in Figure 2, I then developed the *Wheel of Competencies* from these fourteen competencies. It is a tool to illustrate competency profile for collaborative R&I activities and KTT formats in the context of the new mission orientation:

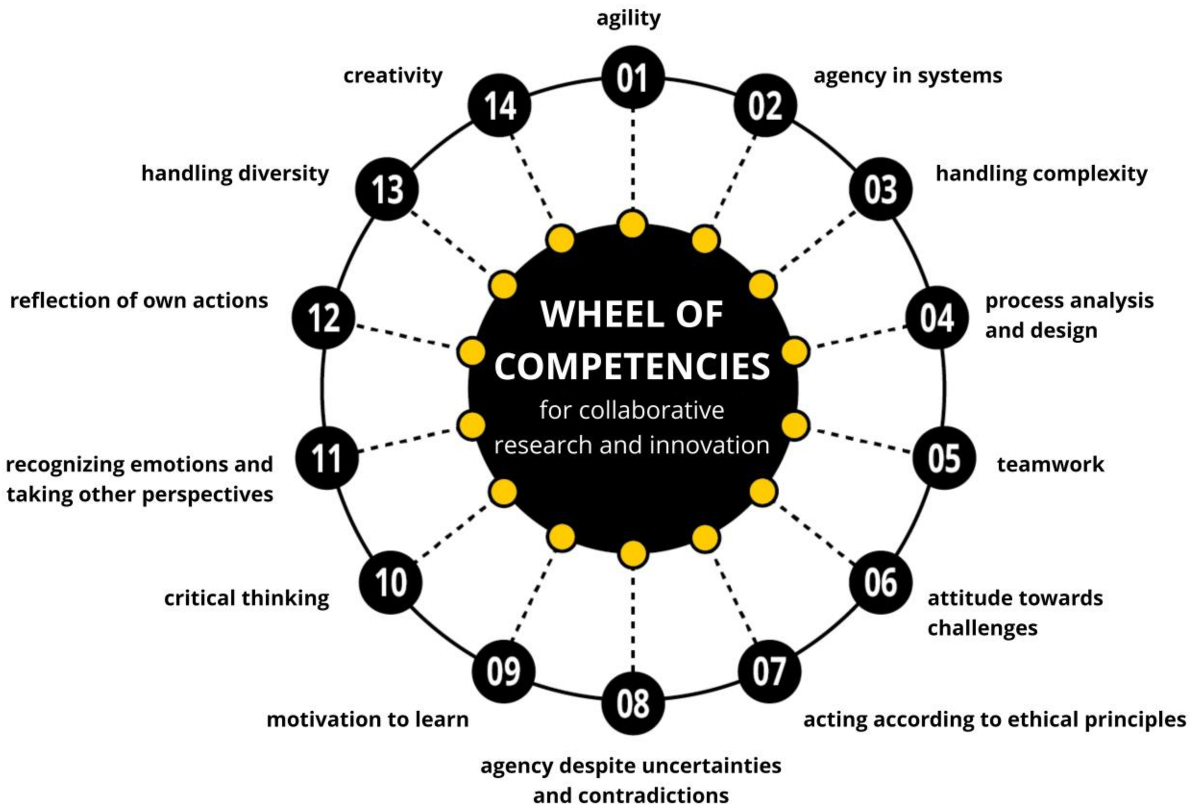

Fig. 1: Wheel of Competencies for Collaborative Research and Innovation

As a tool, the *Wheel of Competencies* may be used to compare different profiles, to identify potentials and to develop tailor-made training offers and teaching formats. Thus, it provides support for educators in engineering education to come to an understanding about desired results and outcomes of curriculum development processes. In order to validate the results and to survey such profiles, I subsequently conducted a quantitative study.

2.2 Survey

The study was designed as a quantitative survey of industry needs. Its intended to, first, validate the competencies and, second, to substantiate profiles that are needed by industry to collaborate in R&I. The survey was conducted in the form of structured computer-assisted telephone interviews [34]. In the fourth quarter of 2021, 200 managing directors or heads of R&D departments of medium-sized and large enterprises from the four largest industry sectors automotive engineering, electrical engineering, chemical engineering and mechanical engineering sectors were surveyed [35]. For each industry sector, I calculated the weighted values according to the relative size of the industry sector and size of the company in order to create a representative and accurate set of data to include in the analysis. In total, I was able to realize the following cases:

Table 2. Sample by industry sector and size of the compony

Industry sector	Staff headcount 50-249	Staff headcount ≥250
Automotive engineering	31	16
Chemical engineering	31	16
Electrical engineering	34	22
Mechanical engineering	30	20

For the purpose of the present study, I operationalized the 14 competencies and converted these into questionnaire items with a 5-point Likert scale (γ). Each item inquired: "How relevant are the following factors for your company among your R&D employees: very relevant (=1), relevant (=2), neither relevant nor irrelevant (=3), rather irrelevant (=4) or not relevant at all (=5)?" Incomplete answers were excluded. For research pragmatic reasons, the questionnaire was limited to two items for each competency. Every item covers an essential part of each definition given in Table 1. I used validated items from empirical research and, if necessary, adjusted the wording of individual items [36]. Before the start of the study, I conducted a pretest, then conducted the semi-structured interviews (δ). In order to analyse and interpret the data gathered, I used the software PSPP for analysis of statistical data. For the visualization I utilized Microsoft Excel (ε).

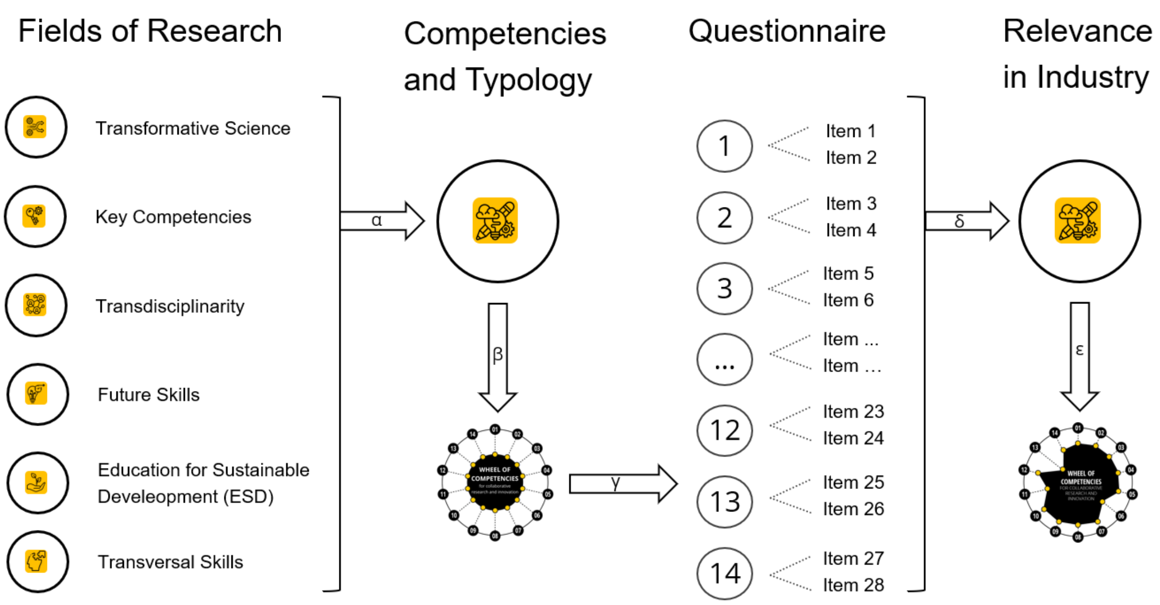

Figure 2 - Research Process

For the analysis, all data were considered that were coherent with regard to a competency. To achieve coherence, those items were excluded that varied on a 5-point Likert scale with a value larger than 1 in regard to a single competency, i.e.

Δ (item a; item b)>1 . For example, the answer to Item 1 is “very relevant” (=1) and the answer to Item 2 is “rather irrelevant” (=4) on a 5-point Likert scale. Thus, a delta follows that is 4-1=3>1. Because it is larger than 1, the answers were disregarded on the assumption that here “very relevant” and “rather irrelevant” are not coherent in respect to the competency in question. Applying this rule, the average number of cases considered per competency is 170 with a standard deviation of 19.28 among all fourteen competencies. The maximum is n=194 for *handling complexity* and the minimum is n=122 for *teamwork*.

While the *Wheel of Competency* as illustrated in Figure 3 is descriptive in regard to the relevance of the fourteen competencies, an ANOVA was conducted for the internal differentiation by competency and industry sectors.

3 RESULTS

3.1 Competencies for Research and Innovation

The results of the survey of R&D enterprises in engineering professions confirm in principle the competencies derived from literature. Figure 1 illustrates these findings. As this is a typologised summary of the latest research and debates, the data can essentially be interpreted as validation. However, the results also show that the relevance of individual competencies for collaborative R&D varies among competencies as well as among industry sectors.

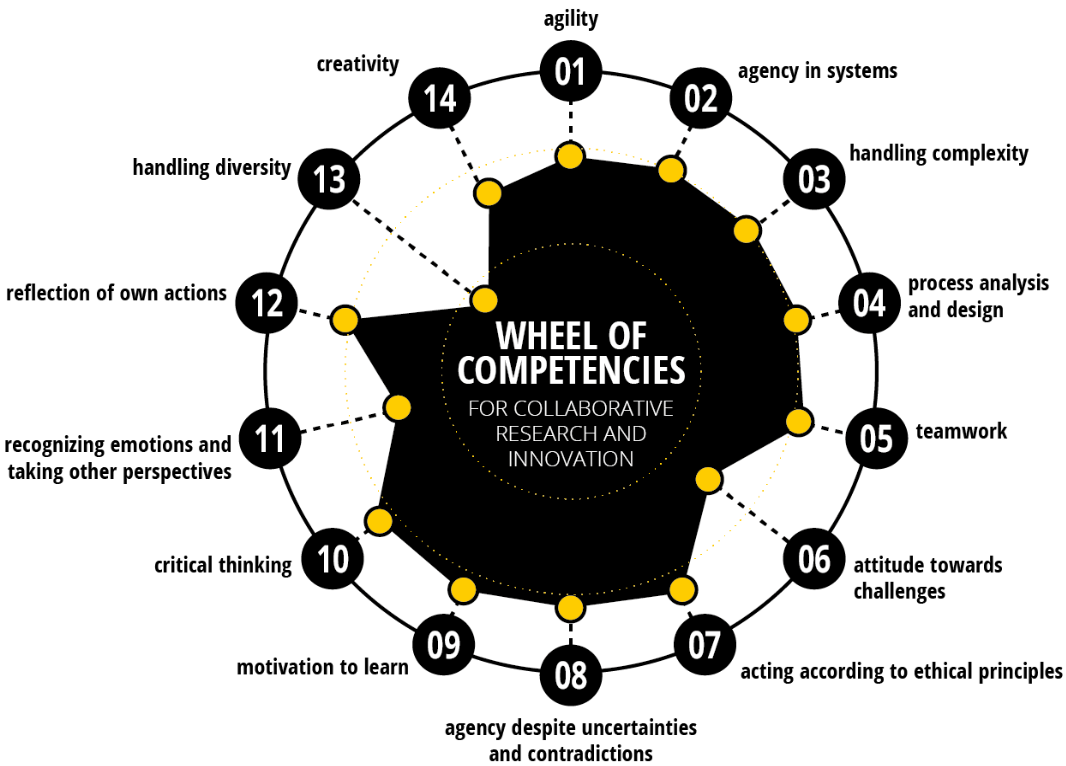

Fig. 3. Wheel of Competencies with adjusted values for all competencies (scale 1-3)

Initially, when evaluating the data collected for all industry sectors, it shows that the enterprises rank the importance of the competencies surveyed as at least "rather important" on average. With one exception, they have a mean value of <2 which translates into something between "rather important" and "very important". It is noticeable that *dealing with diversity*, *emotional competence* and, to a lesser extent, *creativity* rank behind the other competencies. Notably, *dealing with diversity* is the only competency with a value >2. The interviewed managers find it less important that their employees have these competencies. It is also striking that *agility* is less in demand than its presence in the discourse on forward-looking and innovative forms of work - particularly in the area of R&I - would lead one to expect [37].

Table 3. Competencies listed by mean value (possible max. = 1, min. = 5)

Competency	**Mean value**
motivation to learn	1,32
handling complexity	1,36
teamwork	1,41
process analysis and design	1,42
reflection of own actions	1,44
critical thinking	1,48
agency despite uncertainties and contradictions	1,49
acting according to ethical principles	1,52
agency in systems	1,53
agility	1,62
attitude towards challenges	1,63
creativity	1,77
recognizing emotions and taking other perspectives	1,85
handling diversity	2,10

Although the data cannot be interpreted unambiguously, the results nevertheless point to a scalable relevance of competencies for R&I collaborations in engineering industries. The fact that *learning* of new content and the ability to *handle complexity* stand out can be understood against this background as confirmation of the hypothesis that professional profiles are becoming increasingly dynamic - as summarized by the term employability in the interplay between person, organization and policy [38]. It is noticeable that *diversity* and *dealing with emotions*, which can also be described as *empathy*, together with *creativity* play a significantly less important role for R&I processes if the self-assessment of industry is to be believed.

3.2 Competencies by Sectors Industry

Looking at industry sectors individually, it becomes apparent that *creativity* is in conspicuously low demand in mechanical engineering. The same applies to *dealing with diversity* in chemical engineering, while *teamwork* on the other hand seems to be particularly important here. There are hardly any differences between the sectors with regard to the importance of *dealing with complexity* and only minor differences in the importance of *teamwork* and *motivation to learn*. Hence, a cross-sector consensus with regard to the three most relevant competencies exists.

Table 4 - Competencies listed by industry sector (possible max. =1, min. = 5)

Competency	Automotive engineering	Chemical engineering	Electrical engineering	Mechanical engineering
agility	1,68	1,62	1,57	1,63
agency in systems	1,61	1,40	1,48	1,63
handling complexity	1,38	1,34	1,36	1,38
process analysis and design	1,45	1,43	1,31	1,52
teamwork	1,46	1,29	1,40	1,48
attitude towards challenges	1,57	1,67	1,52	1,79
acting according to ethical principles	1,58	1,27	1,56	1,65
agency despite uncertainties and contradictions	1,53	1,39	1,47	1,55
motivation to learn	1,35	1,28	1,28	1,37
critical thinking	1,51	1,35	1,48	1,55
recognizing emotions and taking other perspectives	1,83	1,83	1,82	1,91
reflection of own actions	1,51	1,48	1,34	1,44
handling diversity	1,94	2,37	2,05	2,11
creativity	1,64	1,76	1,70	1,95

The interviewed managers reported that most of the competencies have similar relevance in all considered industry sectors. Analyses of variance (ANOVA) show that the differences in competency values in individual industries are not significant. With *acting according to ethical principles*, there is, however, a single exception.[4] Considering the descriptive level of mean values, there are notable results of the

[4] The relevance of the competency *acting according to ethical principles* differs with statistical significance for the four industry sectors: $F(3,174)=4.02$, $p<.01$.

survey. Among these is that *attitude toward challenges* in mechanical engineering is rated by interviewees as comparatively low in relevance, and represents a negative deviation from the mean value. The same applies to *handling diversity* in chemical engineering and *creativity* in mechanical engineering. The latter is particularly noteworthy because the design process, as part of mechanical engineering, would lead one to expect a different level of importance. In addition, there are also positive deviations. For example, mangers from chemical engineering state that *acting according to ethical principles* is of particular importance with the best sector-specific value of all, while the other industrial sectors only achieve a medium value.

4 DISCUSSION

4.1 Results

The results of the survey support the typology of important competencies for collaborative R&I derived from literature and show that these competencies are in demand in research-oriented industries. However, it was found that R&I managers regard these competencies to be relevant to varying degrees.

Of particular relevance are *motivation to learn* and *handling complexity*. *Motivation to learn* addresses the individual attitude towards acquiring new or deepening existing knowledge, capabilities, or attitudes. The emphasis lies on the willingness to control one's own learning process and to activate necessary resources and engage in adequate social interactions [13,24,25]. *Handling complexity* refers to the ability to recognize and understand relevant interrelations and patterns in situations with an unknown number of different variables and dynamic interactions between these variables, in order to align one's own actions in an impact-oriented manner [14,39].

With the competencies *teamwork* and *process analysis and design*, which are also considered highly relevant, the results support the observation that cross-organizational and cross-sector innovation activities are becoming increasingly important and require new competencies from those involved in order to successfully shape highly dynamic and complex collaboration processes.

The *Wheel of Competencies* can be used to generate distinct competency profiles based on context-specific parameters and individual needs. Thus, the *Wheel of Competencies* can be used to identify and depict the requirements for individual sectors or transfer activities and collaboration formats. By illustrating the requirements in this way, needed qualifications can be addressed in a second step with customized training programs or curricula respectively. This provides opportunities for professional education programs, further and executive education, but likewise for academic higher education.

4.2 Implications

In engineering education, these results help to identify not only subject-specific and disciplinary educational content, but also those competencies that are becoming increasingly important in professional careers and that enable inter- and transdisciplinary collaboration in R&I networks. In this context, competency profiles can be identified that derive specifically from the perspective of an academic discipline. For example, the relevance of the *ethical dimension* is particularly evident in chemical engineering. This should be reflected in appropriate courses of study and continuing education programs.

On this basis, firstly, curricula can be revised and supplemented with respective content. More importantly, however, this emphasizes the need to focus engineering education on competencies by implementing appropriate teaching and learning methods and didactic concepts that address these competencies. This will not have to come at the expense of the disciplinary content, but can be accomplished as an integrated approach, as I demonstrate elsewhere [40]. However, it requires a mindset change with respect to teaching and learning formats, which are too often designed traditionally in a frontal way and thus forfeit considerable potential. Which teaching and learning methods are suitable cannot be answered in general terms and must be explored in the context of the respective study programs and courses. Generally speaking, however, the focus on competency development can be a means to prepare for both changing job descriptions as well as those jobs that are currently emerging or will emerge in the near future [41]. The competencies studied here refer to underlying dispositions and, hence, are most likely to be understood as transversal competencies, but at the same time they form a foundation for acquiring new and developing existing professional competencies. The results can then also inform professional (further) education. The *Wheel of Competencies* may serve as a tool for the development of tailor-made training programs, enabling providers and recipients of trainings to identify specific focal points and to agree on desired outcomes. The typology of competencies illustrated in the *Wheel of Competencies* does not claim to be complete or exhaustive and can therefore be individually adapted to the requirements in the respective application.

4.3 Limits

The results of the study should be interpreted considering its limitations. First, the competencies considered in the study cannot claim to be exhaustive because collaborations in specific research fields or innovation ecosystems may require different competency profiles. Second, only four industry sectors were surveyed. While the comparison of results across sectors suggests generalizability, it cannot demonstrate it conclusively. Third, despite the sample size of 200 enterprises, it cannot be ruled out that there is a common method bias [42].

5 ACKNOWLEDGMENTS

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WHAT IS THE ROLE OF ETHICS IN ACCREDITATION DOCUMENTATION FROM A GLOBAL VIEW?

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ABSTRACT

Ethics in engineering has long been an important element in engineering programmes, however these subjects are often taught at a basic learning level with little attempt to connect to demonstrative learning outcomes. In recent years there has been a step change in the importance of ethics as an integral part of engineering programmes and is reflected in the text of accreditation documents. In this paper we expand our analysis from an earlier study, which focused on four European countries, to understand the role of ethics on a more global scale. We conducted a multi-country analysis on how and where ethics features in accreditation documents in twelve countries across five continents (Belgium, Canada, Colombia, France/Switzerland, Ireland, Japan, Romania, South Africa, Sweden, UK and USA). We identified explicit or implicit references to ethics education, extracted verbs relating to learning outcomes, and compared definitions of key terms. A comparison to Bloom's taxonomy showed considerably higher frequency of verbs linked to ethics teaching associated to lower levels of cognitive learning. Definitions of terms relating to the process of accreditation were often lacking in documents, highlighting a need for setting terms of reference. This study highlights differences in how ethics is described in accreditation documents. However, more needs to be done to explicitly highlight ethics as an integral part of engineering education. Relying on implicit links to ethics leaves the role of ethics open to interpretation, resulting in uneven emphasis in the translation of ethics within programme designs.

1 INTRODUCTION

1.1 Background

Globally, engineering accreditation programmes identify specific areas of knowledge and skills that need to be addressed in order for students to qualify as engineering graduates. Historically, the main focus has been on specific areas of scientific, mathematics and engineering knowledge with little detail with regards to ethics. In recent years there has been a step change in highlighting the importance of ethics as an integral part of engineering programmes, which often is reflected in accreditation documents. Examples of this renewed focus include the significant change in UK Engineering accredition by the Engineering Council launched in 2020 [1], as well as shifts in the Australian accreditation documents[2]. While this is a positive step, our previous research[3] indicates that more work is needed at the policy level to explicitly integrate ethics across engineering programmes, particularly in the way learning outcomes are written and demonstrated.

1.2 Study Aim and Research Questions

The aim of this study is to explore how engineering ethics is portrayed in engineering accreditation documents and observe trends or differences in a multi-country global analysis. We address three research questions:

1) What key terms are defined and how do they compare across documents?
2) What learning outcomes are specified implicitly and explicitly that refer to ethics?
3) What verbs are used in learning outcomes that refer to ethics and which levels of cognitive learning do they represent according to Bloom's taxonomy?

2 METHODOLOGY

A multi-country analysis was carried out on the accreditation documents of twelve countries: Belgium, Canada[4], Colombia[5], France/Switzerland[6,7], Ireland[8], Japan[9], Romania[10], South Africa[11], Sweden[12], UK [1] and USA[13]. For Switzerland, only the French Swiss region was reviewed, where the same accreditation document is used as in France, thus covering both countries. Belgium does not have national, discipline-specific engineering accreditation therefore the engineering programmes can be accredited via the procedure in other countries, such as the French speaking region aligning with the CTI French accredication document. Therefore, ten accreditation documents were analysed for the study. The competencies, learning outcomes and program outcomes where appropriate were reviewed and the analysis was divided into 3 sub-sections that align to the 3 research questions outlined below.

2.1 Classification of key terms

We identified and extracted all definitions of key terms in the accreditation documents that are related to programme content or content delivery, such as "learning outcomes", "higher education" and "accreditation". Where terms were defined in two documents or more, we performed a qualitative comparison of the different definitions. This analysis was done to help identify any contextual or interpretive differences in definitions, which may influence how ethics is viewed, taught and evaluated from the learning outcomes that were evaluated in this study.

2.2 Explicit and implicit references to ethics education

Although the general method was consistent, due to the large variety in scope and structure between different accreditation documents, the method applied was adapted on a case by case basis to accommodate different documentation formats as outlined in the appendix. To analyze *explicit references to ethics education*, we first counted how many times the terms "ethics" and "ethical" were used in the respective documents. We then extracted all the learning outcomes in relation to these terms for verb analysis (next section). To analyze *implicit references to ethics education*, we first developed a set of reference terms that are used in engineering ethics education. For this purpose, we extracted key words and topics related to ethics from the table of contents of 5 textbooks (Fig. 1) as described in the previous study[3]. A quantitative word analysis was carried out in order to identify the use of these common terms in the accreditation documents.

2.3 Analysis of verbs used in ethics-related learning outcomes

Verb usage was analysed in three steps: First, we identified all verbs in learning outcomes that are related to the terms "ethics" or "ethical". For example, in the phrase "demonstrate awareness of ethical aspects", we identified "demonstrate awareness" as a verb related to ethics learning. Second, we categorized all identified verbs as either *action verbs* (doing), *cognitive verbs* (thinking) or both. Third, a comparison was carried out on the use of these verbs according to the hierarchical learning levels from Bloom's taxonomy of learning.

3 RESULTS

3.1 Classification of key terms

A total of 22 terms were defined across 10 documents. Only five terms were found defined in three or more documents: "Accreditation" and "Learning Outcomes" (both terms in 6 documents), "Graduate Attributes", "Knowledge" and "Understanding" (each term in 3 documents). The remaining terms occurred only once or twice as shown in Table 1.

What is not clear from the frequency of the use of specific terms across documents is how the use of terms can vary across contexts. For example, the term "accreditation" can refer to processes of quality assurance for engineering programmes that include formal assessment of compliance to existing standards, peer review by stakeholders regarding program quality, or both. Similarly, "learning outcomes" are defined in relation to different contexts, such as the programme of study (Colombia/UK AHEP4) or the process (France/Bel CTi/Switzerland). Furthermore, “learning outcomes” can include “knowledge” and “skills” (UK, USA, Colombia), “competence” (France), “values” (UK), and “approach” (Sweden) or they can be used to specify “graduate attributes” (South Africa).

Table 1. Word list highlighting most common terms of reference in 10 documents from 12 countries showing the most commonly defined in red.

Terms Defined	No. of documents	Terms Defined	No. of documents
Accreditation	6	Learning outcomes	6
Assessment	1	Module	1
Competence	1	Pathway	1
Delivery	1	Programme educational objectives/ Programme Outcomes	1
Engineering design	2	Programme/Program	1
Evaluation	1	Responsibilities of engineering practice	2
Graduate attributes	3	Skill	2
Higher Education	2	Societal context	2
Higher Education Institution	1	Student	1
Know-how	1	Transferable skills/ Complimentary skills	2
Knowledge	3	Understanding	3

3.2 Explicit and implicit references to ethics education

The terms “ethics” or “ethical” were only *explicitly* mentioned in learning outcomes or programme outcomes between 2 and 10 times across documents (average 4.5 $\pm$ 2.2 SD). In contrast the *implicit* terms were found between 6 and 187 times (average 77.5 $\pm$ 62.1 SD). The explicit terms will be expanded in section 3.3 on verb-usage.

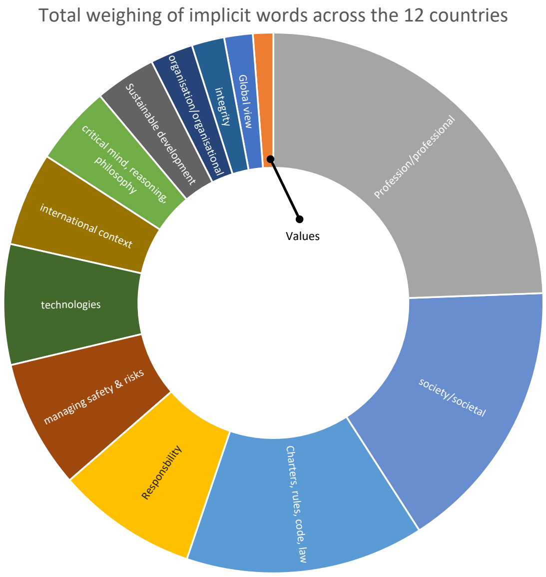

Fig. 1. Weighted frequency with which implicit reference terms are used, showing high representation of terms such as “professional” and low represention of terms such as “integrity” and “values”.

Our analysis of terms associated with *implicit* references to ethics showed that the frequency with which the top five terms were used corresponds to more than 70 % of all implicit terms were used (Fig. 1), these were: “Profession”, “Society”, “Codes/Laws”, “Technologies” and “Responsibility”. Conversely, four of the five least used terms constitute less than 6 % of all occasions of term usage: “Global views”, “Organisation”, “Integrity” and “Values”. Finally, “Justice” was not used in any of the analyzed documents.

3.3 Verbs used in ethics-related learning outcomes

Among verbs *explicitly* related to ethics learning, we found a strong emphasis on *cognition* and less on *action* verbs (Fig. 2).

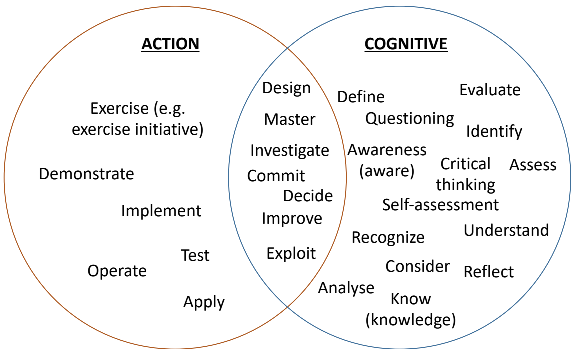

Fig. 2. Verbs related to explicit references to ethics learning that are used in the included accreditation documents.

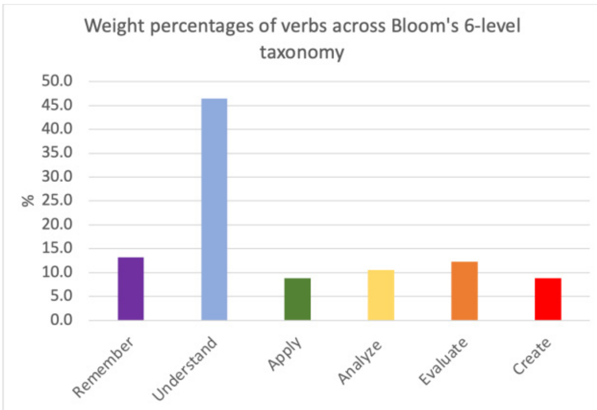

Fig. 3. Weighted percentage of verbs in learning outcomes relating explicitly to ethics shows high representation in the lower levels of learning according to the Bloom’s taxonomy model.

Comparing the verbs (including both action and cognition) to Bloom’s six levels of cognitive learning, we found that verbs relating to learning outcomes at all levels are included, however, verbs related to the second level (“understand”) clearly dominate in all documents (Fig. 3). While a peak is expected at the lower levels of learning, there was no trend showing a gradual transition to higher levels of cognition from “Understand” to “Create” (Fig. 3).

4 DISCUSSION

The aim of this study was to explore how engineering ethics is portrayed in engineering accreditation documents and observe trends or differences in a multi-country global analysis. The definition of terms provides context to the terms used in the documents. Currently the lack of common definitions potentially leaves room for ethics to be differently defined, perceived and actualised in the engineering programmes of the different participating countries. The most common terms that were found across 6 documents were “Accreditation” and “Learning Outcomes” allowing some comparative analysis. However, the remaining terms were either found once, twice or thrice across all 10 documents reviewed. This made a comparison of terms not always possible for terms such as “assessment” (USA and South Africa) and “competence” (France, UK, Ireland, Colombia). Furthermore, in the case of South Africa, there was an emphasis on definitions for technical, rather than educational terms. For Canada, the definition of terms were removed in 2021 and made accessible elsewhere. In this instance, they were not relevant to programme development but rather to the accountability of roles in the accreditation process. The implications of differences in the definitions of terms is that some national accreditation documents have international reach and have been used as a benchmark for other countries, such as ABET (US), which accredits programmes in 41 countries, using an identical process for all. This wider reach makes these terms open to varied, and perhaps unintended, interpretations and affects how the terms are applied in programme development. With this in mind, accreditation bodies could bring into focus the terms they use and what they mean as part of their ethical due diligence in the construction of engineering programmes across a range of countries where the context or intended meaning of the learning outcomes as stated might otherwise be missed.

The explicit and implicit analysis of terms reflects that ethics is still marginal to the curriculum compared to other subjects. A more common language in other technical areas of the curriculum where terms and context are well-defined and understood. This is in contrast to the varied vocabulary found in the implicit terms identified in this analysis. Making this transnational comparison is important as student are mobile when they graduate and may be required to undergo legal processes for their degrees to be formally recognised. The implicit terms identified demonstrated a lack of pattern between countries or even between regions, other than the observation that the better represented ethical topics are ones that directly impact technical instruction such as “technology”, “profession” and “responsibility”. This lack of commonality is of interest and perhaps suggests no rigorous discussion on ethics from a regional level as compared to the technical subjects in engineering. This raises the question as to whether there should be a transition to a more common agreed language for ethics education in engineering.

The low profile of non-demonstrable aspects of ethics education is shown by the low emphasis on terms such as “Values”, “Integrity” and “Justice”. A focus on these terms may require a specific framework as a benchmark for the analysis of ethics education, such as that provided by the Rest Model[13], which identifies the four areas of ethical decision-making as Moral Awareness, Moral Reasoning/Judgment, Moral Intent and Moral Behaviour/Action. The Rest Model can be used to capture the non-actionable aspects that are a pre-requisite to demonstratable skills and behaviours. For example, ethical motivation and ethical character links to integrity and values, which are largely missing from accreditation requirements. This suggests that ethical competence and a stepwise progression through ethical development may be missing and perhaps could be included at a policy level. This will be explored in the next phase of the study.

There are several limitations to the study. For practical reasons, we had to rely on a convenience sample, including countries based on the nationalities and associations of the participating authors. We focused primarily on differences in the linguistic formulation of policy across the included countries. As we do not aim to *explain* these differences, we did not engage in in-depth analysis of the different social, cultural, political and technological challenges across borders. Therefore, our analysis may indicate differences in how the responsibilities of the engineering professionals are represented in the accreditation documents, but these differences are not the focus of the analysis. We further assume that the inclusion of definitions of certain key terms in accreditation documents to some degree reflects what is considered relevant by the respective accreditation agencies.

Another limitation is the nuanced differences between methodological approaches, which was captured in the appendix. With such an overview the next stage is for quality control measures such as cross-checking the methodologies with a second reviewer to assess the true variation in approaches. The second limitation is the representation of regions. Europe is well represented (6 countries), whereas the remaining regions have very limited representation with only one document analysied in Africa (South Africa), Asia (Japan) and South America (Colombia). However, this is a preliminary study where our observations will feed into further inclusion of countries to be expected for the next stage in this study.

Further work will look to ensure a wider coverage of ethical topics in common use is considered, which may have been excluded from the list derived from text references, where a further exploration of alternative terms of association is planned. The authors also take this opportunity to invite researchers to join this study, particularly from countries in less represented regions (South America, Africa and Asia or Australasia) and encourage any interested parties to contact the corresponding author.

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Appendix

The analysis process adopted for each of to the documents; the range of approaches mirrors the high level of diversity in how documents are structured.

Country	Methodology for quantitative assessment of words	Language
Beligum	See France	n/a
Canada	Engineers Canada – Criteria and Procedures (complete document) **Excluded: references & appendices.**	English & French
Colombia	Agreement 02 of 2020 – The National Council of higher Education – CESU	Spanish
France	CTI 2022 table of contents – Sections D-G **Excluded: remaining sections and references.** CTI 2018 Definition of Terms. **Excluded: remaining sections and references.**	French (2022) English (2018)
Ireland	Engineers Ireland Accreditation Criteria (complete document in English): Section 2 Definitions; Section 3.4 Programme Outcomes for Charetred Engineers https://www.engineersireland.ie/LinkClick.aspx?fileticket=Mz3SCCk_uRg%3d&portalid=0&resourceView=1 **Excluded: remaining sections and references.**	English
Japan	JABEE Common Criteria for Accreditation of Professional Education Programs applicable in the year 2019 and later. JABEE Category- and Discipline-specific Criteria for Accreditation of Professional Education Programs applicable in the year 2019 and later https://jabee.org/en/accreditation/basis	English translation
Romania	Specific standards for external evaluation of academic quality in undergraduate and master's degree programs – Engineering Sciences; Decision no. 915 of 14 December 2017 on amending the annex to Government Decision no. 1418/2006 for the approval of the Methodology for external evaluation, of the standards, of the reference standards and of the list of performance indicators of the Romanian Agency for Quality Assurance in Higher Education (original language for both documents: Romanian)	Romanian
South Africa	ECSA P-02-PE version 6 (full document)	English
Sweden	In the Swedish Higher Education Act, section 5 was analysed as it outlines general requirements for all higher education. In addition, in the Swedish Higher Education Ordinance, Annex 2, two sections referring to Engineering Bachelor and Master degrees, respectively, were analysed. **Excluded: remaining document and other documents that may contain additional definitions of key terms.**	English translation
Switzerland	See France	French
UK (AHEP-4)	The Accreditation of Higher Education Programmes (AHEP) 4th Edition: Learning outcomes & definitions analysed. **Excluded: remaining document and references.**	English
USA	Criteria for Accrediting Engineering Programs, 2021 – 2022 Sections analysed limited to "Definitions" and "I. General Criteria for Baccalaureate Level Programs." **Excluded: remaining document and references.**	English

INTERNATIONAL PRACTICE OF CAPACITY BUILDING IN ENGINEERING EDUCATION: A COMPARATIVE CASE STUDY

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Conference Key Areas: *Niche & Novel*
Keywords: *capacity building, teaching staff's professional development, comparative study*

ABSTRACT

Capacity building is a corner stone for having well prepared and effective teaching staff in engineering education. Despite the importance of capacity building in engineering education, there is relatively little research on this topic. In this paper, we address this gap by reporting on an international comparative study on capacity building practices in university-level engineering education. We examine how capacity building is organised in seven European institutions (in Belgium, Finland, France, Germany, Hungary, Sweden, UK) and Australia, based on institutional education policies and practices. We compare the preparation of teaching staff, their initial training, and continuing capacity building activities throughout their careers. To do this, we applied a qualitative approach, collecting data through (1) a structured questionnaire answered by the members of the SEFI SIG on Capacity building and (2) written notes produced during an international workshop on capacity building at the 2021 SEFI conference. We then conducted a comparative case study, exploring similarities and differences between incentives for permanent academic staff to engage in capacity building, how capacity building is organised, and at what point in their careers staff engage in it. Our findings indicate very diverse approaches, rules and practices as well as different obstacles and challenges for engineering education. The outcomes of our study can be used by policy makers to inform capacity building practices and engineering education in HEIs (Higher Education Institutions), and our questionnaire provides a tool for monitoring and reporting practices throughout the sector.

1 INTRODUCTION

Accelerated technological development, population growth and environmental change lead to constant changes in the sociotechnical landscapes in which engineers operate. These changes necessitate responsiveness in engineering education to prepare students for the shifting realities of the workforce and society at large. As the purveyors of technical content and professional socialization, engineering educators play a key role. Changing expectations for engineering graduates and developments in cognitive science have emphasized the need for educators and institutions to engage in capacity building [1]. Capacity building, also known as pedagogical training or professional development, is an important mechanism for improving engineering education [2]. Academic staff who participate in capacity building are more likely to use active learning pedagogies and student-centered approaches [3], and the adoption of such evidence-based practices improves learning and student outcomes [4].

In this study, we collected and analysed data regarding the ways in which capacity building (pedagogical training) is organised for permanent academic staff at nine institutions that offer engineering programs. Employing an exploratory, comparative approach, we address the following research questions (RQs):

RQ1 What are the incentives for permanent academic staff to engage in pedagogical training?

RQ2 How is this pedagogical training organised (who designs and delivers the provision, and how tailored to a specific discipline is the training)?

RQ3 At what point in their careers, and how frequently, do permanent academic staff engage in pedagogical training?

2 LITERATURE REVIEW

The notion of *capacity building* has been defined as ‘the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time’ [5:5].

Even though capacity building has been shown to benefit staff development and student learning, research in the United States has shown that participation is generally low and that most engineering educators continue to learn by trial and error [6]. Further, most capacity building opportunities in the United States are organised by social scientists (having no, or little, engineering background and teaching expertise) for a campus-wide audience and without discipline-specific examples and practices [7]. Consequently, ‘there is generally neither a meaningful incentive for engineering faculty members to participate in instructional development nor meaningful reward for any improvements in teaching that may result from their participation’ [7:90-91]. Perceptions of incentives and barriers can vary depending on the different roles academic staff have in their institutions; According to Sabagh and Saroyan’s [8] comparative study, there are significant differences between permanent and non-permanent (tenured and non-tenured) academic staff’s continuous engagement in capacity building for pedagogical improvement. In particular, non-permanent academic staff are more influenced by institutional cultures, which are often perceived as unsupportive of teaching excellence compared to research due to, for example, perceptions of a lack of appreciation, professional rewards and support for teaching activities and development. Permanent academic staff identified high workload and lack of time as the main barriers to engage in capacity building. However, in their study, Felder et al. [7:90] identified several incentives for engaging in capacity development, including institutions placing high value on teaching, teaching improvement activities, self-motivation, efficiencies of time, and teaching evaluation [see also 12].

Another challenge in capacity building is the lack of time and incentives for sharing results and effective practices, unlike in research where there are clear and relevant incentives for sharing results [9]. Furthermore, even when staff have an individual interest in teaching improvement activities, high requirements for research productivity can prevent academic staff from dedicating effort and time for it.

The challenges for academic staff to engage in capacity building are different during early-, mid- and late-career stages [7]. Therefore capacity building programmes need to ensure relevance throughout academics' entire careers. Provision of capacity-building opportunities for early-career academic staff is crucial for an institution's education performance as these educators often provide the majority of undergraduate and practical courses, thus playing a significant role in students' education [10]. Contrarily, if there is no required initial training (e.g., teaching certificates) for new academic staff – or only limited opportunities for participating in adequate professional development programmes –, early-career staff are forced to resort to developing their teaching skills through trial and error, based on their personal experience and with limited efficiency.

3 METHODOLOGY

To explore similarities and differences in capacity building practices across institutions, we developed and distributed a survey among the members of the Special Interest Group of SEFI focusing on Capacity Building (https://www.sefi.be/activities/special-interest-groups/capacity-building/). The following 9 institutions are considered in this study: (1) Budapest University of Technology and Economics (Hungary), (2) ENSTA Bretagne (France), (3) Hamburg University of Technology (Germany), (4) KU Leuven (Belgium), (5) LAB University of Applied Sciences (Finland), (6) University College London (UK), (7) University of Technology Sydney (Australia), (8) Umeå University (Sweden) and (9) Vrije Universiteit Brussel (Belgium).

The survey was designed based around qualitative data and arising themes from a preliminary discussion in the SIG meeting at the 2021 SEFI conference covering capacity building approaches at 7 of the included institutions. We developed four multiple-choice questions with response alternatives that covered all scenarios we identified during the preliminary discussion. For each question, we also included two open-ended alternatives (“other”, “comments”) to allow participants to enter responses that had not previously emerged. Finally, we added an additional open-ended question (“comments”) at the end of the survey. Participants were required to respond to all multiple-choice questions, but open-ended questions were optional. For each question, it was possible to select multiple answers. The survey (See Appendix) was administered through a web survey tool.

4 RESULTS

The findings of the study are presented in the following three sub-sections, directly related to the three research questions (see above).

4.1 Incentives

To gather information regarding the reasons why staff engage in pedagogical training, we asked: “What incentives do permanent academic staff at your institution have to engage in pedagogical training?” Response items are related to three types of incentives: (1) formal requirements (mandatory for all/part of the permanent academic staff or required for promotion), (2) formal incentives (wage setting or non-economic incentives, such as diploma or awards) and (3) informal incentives (valued by colleagues, students or others outside of the institution). The exact wording of the response items can be found in the Appendix.

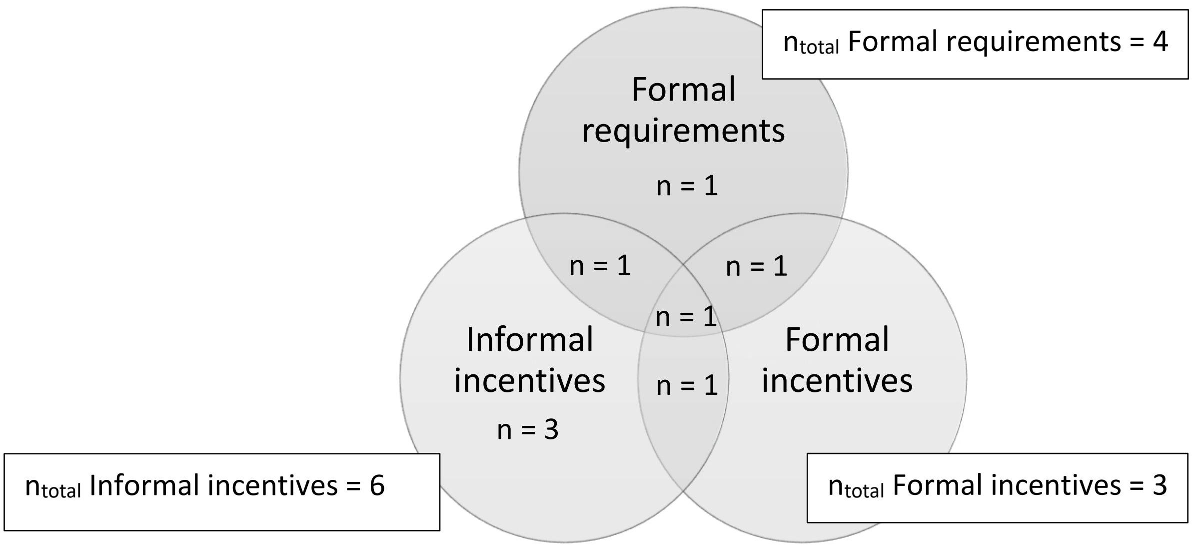

Figure 1. Overview of responses concerning incentives

The responses to this question indicate that all three types of incentives are used at the included institutions, but that informal incentives may occur slightly more often than formal requirements or formal incentives (Figure 1). For only one institution, no incentives or requirements were reported. More specifically, the results indicate that *formal* requirements are in place at only 4 of the included institutions. *Formal incentives* were identified for 3 institutions, two of which also have formal requirements. Examples of formal incentives are: (1) including criteria related to pedagogical training for wage setting or promotion, or (2) pedagogical awards and diploma. In total, formal requirements and/or formal incentives were identified for five institutions.

Six institutions provide *informal* incentives, such as (1) opportunities for teachers to meet for stimulating pedagogical discussions, supportive networks, opportunities to meet pedagogical experts, (2) support for dealing with teaching challenges and saving time, (3) recognition by colleagues and university leadership, and (4) intrinsic motivation. 3 institutions provide only informal incentives and only one respondent indicated that their institution has both formal requirements, formal incentives, and informal incentives.

4.2 Organisation

Participants were asked about the ways in which pedagogical training is organised at their institutions. We asked two separate questions to explore this aspect of pedagogical training. The first aimed to explore the level within the institution where pedagogical training is designed and delivered. Response items for this question included organisation at the national/regional, institutional, faculty, or departmental level (see Appendix). 7 of the 9 participants indicated that pedagogical training at their institutions is organised in a top-down manner, by a pedagogical development centre or other entity at their institution (Figure 2). 3 of these participants also indicated that faculties organise additional training for their teachers. Free text answers related to this item further indicate that training at the faculty level tends to be organised in a bottom-up manner – as a response to pedagogical challenges experienced by the faculties' staff. One participant indicated that pedagogical training at their institution is organised at a national level. Thus, 3 of the included institutions appear to combine top-down and bottom-up approaches to pedagogical development, while 5 institutions only employ top-down approaches. One participant indicated that no pedagogical training is offered at their institution at any level.

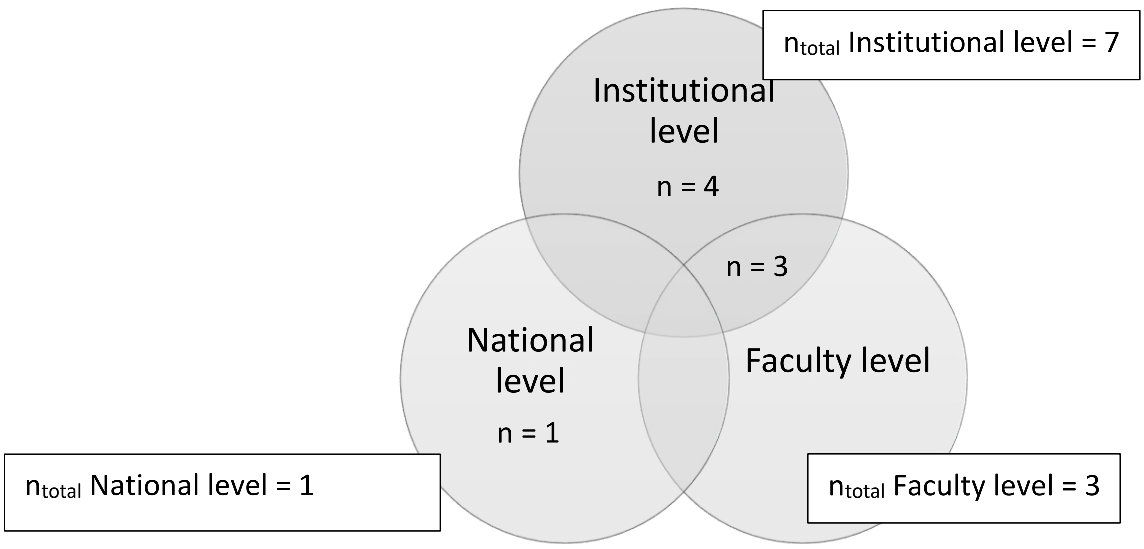

Figure 2. Overview of responses concerning organizational levels

The second question focused on the level of discipline specificity with which pedagogical training is organised: "How is pedagogical training organised across different faculties/disciplines at your institution?". Response items for this question included options indicating (1) multidisciplinary (open to staff from all faculties/disciplines), (2) disciplinary (tailored to staff from a specific faculty/discipline), and (3) generic monodisciplinary (offered to staff from one faculty/discipline, but not tailored to their disciplines) approaches.

Participants' responses indicate that the majority of the included institutions (n=8) employ multidisciplinary approaches, often combined with monodisciplinary or generic monodisciplinary approaches. One institution was categorized as not offering any pedagogical training.

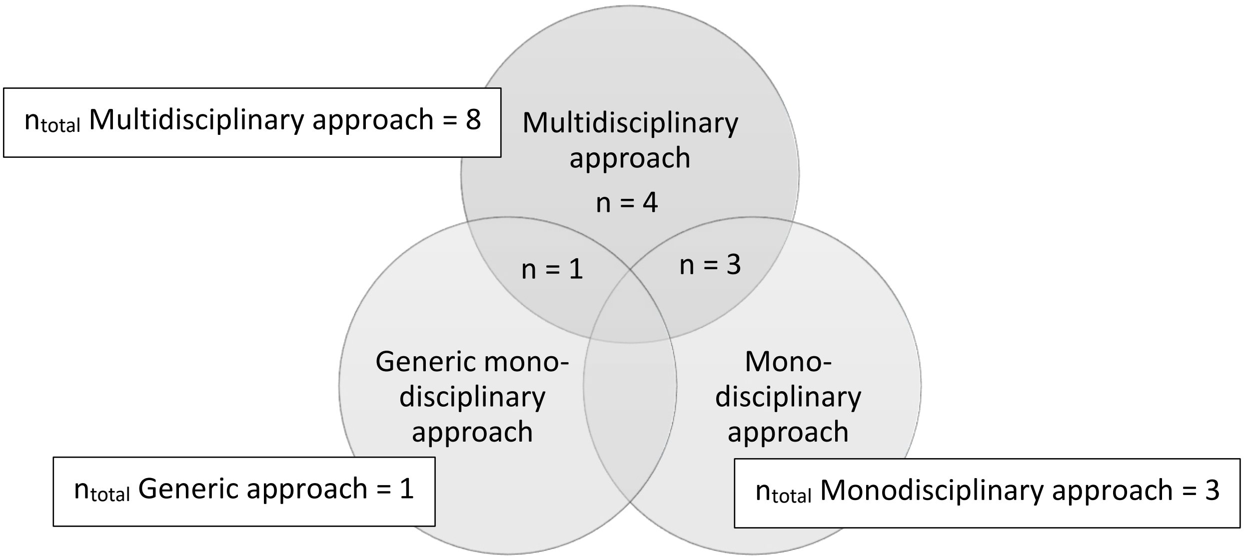

Figure 3. Overview of responses concerning organizational approaches

4.3 Participation

To gather information about participation in pedagogical training, we asked: "At what point(s) in their careers (after obtaining a permanent academic position) do staff at your institution engage in pedagogical training?". Response items for this question included options indicating whether staff primarily participate in pedagogical training early (first five years after obtaining a permanent position) or later (after more than five years after obtaining a permanent position) in their careers. Most of the responses (n=7) indicated that training typically occurs early in academics' careers. Just one institution indicated that pedagogical training is more common during later career stages and one institution was, again, categorized as not offering any pedagogical training.

Finally, we asked about the frequency with which staff members engage in pedagogical training. Only three of the participants indicated that staff members at their institution), on average, engage in pedagogical training at least once a year.

5 DISCUSSION

Our results indicate a diversity of approaches, rules, policies and practices related to capacity building. This is in line with findings from other studies: even research focusing on just research-intensive institutions within a single country (UK) have found that “job titles, expectations, development opportunities, reward systems and careers structures of educators vary widely across institutions” [11]. It would be valuable to explore possible reasons for, and effects of, this diversity, as it may indicate both strengths (e.g., that many capacity building programmes are developed in context-sensitive approaches) and weaknesses (e.g., that many capacity building programmes are developed ad hoc and without clear aims and strategies).

Our analysis of *incentives for engaging in capacity building activities* shows that no institution in our study solely offers formal incentives; these are always coupled with either formal requirements, which may indicate commitment from senior leadership, or with informal incentives such as peer esteem and networks, which may indicate an environment where good practice and engagement with pedagogical development is valued locally. We have also observed a relatively low overlap between formal requirements and informal incentives, which raises questions about whether and how they are related. Are there any systematic differences in how formal requirements and informal incentives are organised across contexts? Could formal requirements decrease rather than strengthen a culture in which pedagogical training is valued by students and colleagues? Or do institutions that lack a strong tradition of valuing pedagogical training resort to formal requirements to increase participation and the perceived value of training activities?

In our analysis of *how pedagogical training is organised*, we noted that some institutions combine top-down and bottom-up approaches, while others only seem to employ top-down approaches. It would be interesting to explore opportunities and challenges that may arise when institutions in different contexts employ either or both of these approaches and the reasons for their decisions to do so. This may be related to Felder et al.’s [7] conclusion that there is no meaningful perceived incentive for engineering educators to participate in capacity building organised at institutional level where there is a lack of discipline-specific examples.

Further, our results indicate that permanent academic staff, on average, *engage in pedagogical training less than once a year.* We also found that staff at most of the included institutions primarily engage in pedagogical training during their first five years of employment. These findings suggest that continuous pedagogical development may not be adequately valued or prioritised at some of the included institutions. More specifically, it appears that pedagogical training is often deemed necessary/desirable for junior academics, but that senior staff do not need to continue developing their pedagogical skills.

Finally, we observed the following *potential relationships between dimensions* explored in this study*:* (1) If pedagogical training is not valued throughout the organisation and as part of permanent academic staff members' careers, informal incentives will likely be weaker. It may also be that the relationship with the incentives on offer may change over an individual's career or that the opportunities for engagement with relevant capacity building decrease as careers progress. (2) In our sample, we noticed that institutions with monodisciplinary approaches have 'formal' requirements and institutions with frequent engagement in pedagogical training have 'formal' incentives or requirements. We therefore suggest that future research should explore any potential relationships between the ways in which pedagogical training is enforced or valued through different forms of incentives, how pedagogical training is organised in terms of disciplinary approaches and levels of organisation, the frequency with which permanent academic staff engage in it, and at what stages in their careers they do so. We expect that both large-scale, quantitative analyses and in-depth qualitative studies will be needed to better understand the role of capacity building for improving engineering education practice.

Limitations

Due to the complexity and large variety in institutional organisation of capacity building, interpreting the results has been challenging. More in-depth research will be needed to explore nuances, for example regarding different groups of academic staff. It should also be noted that all participating institutions are active members of SEFI, with staff who engage in the Capacity Building SIG, which may have influenced their experiences of and knowledge about how capacity building is organised at their institutions.

Also, in a written comment, one participant added an option we had not included in our survey: pedagogical training is also regularly organised in a *decentralized* manner, for example by the institution's digital learning team. This is likely the case in other institutions as well and should be taken into account in future studies.

Finally, participants may have relied on different interpretations of "permanent academic staff". For example, "permanent" can be interpreted more narrowly – as staff who have obtained tenure, or more broadly – as staff with other types of long-term contracts. There are also distinctions to be made around academic staff on research and teaching tracks and those on teaching and scholarship tracks.

6 CONCLUSION

In conclusion, our study has taken a snapshot of capacity building for engineering educators at nine institutions across seven European countries and Australia. It offers preliminary data and a framework for studying and monitoring capacity building across institutions which can be used to inform policy makers and create a common understanding of activity across the sector. This is particularly important at this time, since the expectations of staff at all levels in organisations related to their own and colleagues' future engagement with education are changing. The international Teaching Cultures Survey [12], for example, indicates an expectation from university staff at all levels that reward and recognition for quality teaching will increase.

We intend to follow up on this study with a larger, explanatory mixed methods study, including more institutions and an in-depth investigation of incentives and motivation related to participation in capacity building. We welcome other engineering education scholars to join our group and projects.

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APPENDIX

Question: What incentives do permanent academic staff at your institution have to engage in pedagogical training?
Response items for incentives

A. Pedagogical training is mandatory for all permanent academic staff.
B. Pedagogical training is mandatory for part of the permanent academic staff.
C. Pedagogical training is required for promotion.
D. Pedagogical training automatically leads to salary increase.
E. Pedagogical training is one of several aspects considered in salary setting.
F. Pedagogical training is rewarded through non-economic incentives
G. Pedagogical training is valued by colleagues.
H. Pedagogical training is valued by students.
I. Pedagogical training is not acknowledged or valued at the institution, but at a national/regional level.
J. Pedagogical training is not acknowledged or valued at the institution, nor at a national/regional level.
K. No pedagogical training programs are offered for permanent academic staff.
L. Other

Question: What type(s) of entity/ies organize pedagogical training for permanent academic staff at your institution?
Response items for organizational levels

A. Pedagogical training is organised by national/regional entities.
B. Pedagogical training is organised by a pedagogical development center/entity at the institution.
C. Pedagogical training is organised separately by each of the institution's faculties.
D. Pedagogical training is organised separately by each of the institution's departments.
E. No pedagogical training is organised for permanent academic staff at the institution, but staff are encouraged to engage in pedagogical training on their own.
F. No pedagogical training is organised for permanent academic staff.
G. Other

Question: How is pedagogical training organized across different faculties/disciplines at your institution?
Response items for organizational approaches

A. Pedagogical training programs are tailored to each faculty's/discipline's specific needs.
B. Pedagogical training programs are offered separately for each faculty/discipline, but they are generic and not tailored for each faculty's/discipline's specific needs.
C. Pedagogical training programs are open for staff from all faculties/disciplines, but they are often dominated by participants from one or a few faculties/disciplines.
D. Pedagogical training programs are open for staff from all faculties/disciplines and participants typically come from various faculties/disciplines.
E. Pedagogical training programs are organised to guarantee that participants come from various faculties/disciplines.
F. No pedagogical training programs are offered for permanent academic staff.
G. Other

Question: At what point(s) in their careers (after obtaining a permanent academic position) do staff at your institution engage in pedagogical training?
Response items for participation

A. Permanent academic staff engage in pedagogical training primarily during the first five years after obtaining a permanent position.
B. Permanent academic staff engage in pedagogical training throughout their careers, but they engage more often during the first five years after obtaining a permanent position.
C. Permanent academic staff engage in pedagogical training throughout their careers, but they engage more often during later stages in their careers (more than five years after obtaining a permanent academic position).
D. Permanent academic staff engage in pedagogical training primarily during later stages in their careers (more than five years after obtaining a permanent academic position).
E. On average, permanent academic staff engage in pedagogical training at least once a month.
F. On average, permanent academic staff engage in pedagogical training at least once a year.
G. Permanent academic staff typically do not engage in pedagogical training.
H. Other

STUDENTS' UNDERSTANDING OF DOUBLE INTEGRALS – IMPLICATIONS FOR THE ENGINEERING CURRICULUM

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Conference Key Areas: *Mathematics at the heart of Engineering,*
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ABSTRACT

Mathematics plays a significant role in engineering students' education. To undergraduate engineering students, calculus concepts are foundational to their engineering courses. One such concept is the double integral. It is thus important to ensure that students not only learn this concept but also engage to understand it and are able to apply this knowledge in relevant engineering courses. This research paper focuses on the following two components: Firstly, the relevance of double integrals to the engineering curriculum. And secondly, students' understanding of the double integral concept.

We present the relevance of double integrals in the engineering curriculum by looking at the use of this concept in different engineering fields. We explored students' understanding of double integrals and administered a test to 35 second year engineering students enrolled in an undergraduate Calculus III course. In a qualitative study, the performance of students was used to analyse the type of misconceptions they have in double integration. The findings reveal that the students encounter difficulties with graphical representation of surfaces and region of integration. In addition, students struggle with changing the order of integration and performing the integration process. While some of these errors are conceptual, others are really due to carelessness in the procedure.

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Further analysis indicate that some misconceptions are a result of misunderstandings in prerequisite courses. The results will be useful to Mathematics educators who are keen in finding sources of misconceptions. The research may be used in designing functional teaching and learning instruments to rectify misconceptions in double integrals.

1 INTRODUCTION

1.1 Background

Undergraduate engineering students taking mathematics courses in the first and second years of their programmes are introduced to calculus concepts as a foundation for other engineering courses. Thus, for their success in professional engineering programmes and their future practice, the understanding of such mathematical concepts and the ability to interpret and apply them in future courses is essential for engineering students.

In South Africa, engineering students enrolled in a four-year programme encounter mathematics courses, of which calculus is a large part, in their first two years of study. Students are introduced to differential and integral calculus and their related applications during their first-year calculus courses [1] and this concept is further expanded on in the second-year vector calculus course. At the University of Cape Town, it is mandatory for engineering students to complete three semesters of calculus.

Integral calculus consists of the study of fundamental concepts useful in engineering. It also has various applications in fields such as physics and engineering [2] and is used widely in courses such as thermodynamics, mechanics, and hydraulics. For example, in thermodynamics, energy is a function of pressure, temperature, volume, and entropy; in engineering, density may be a function of $x, y,$ and z [3].The significance of calculus in engineering is highlighted in a study [4] where the correlation between students' understanding of derivative and integral calculus with thermodynamics is researched. The aforementioned study reports that results of the thermodynamics subject were affected by students' comprehension of derivatives and integrals and makes a convincing argument to improve calculus learning in order to increase the quality of achievements in thermodynamics and moreover other topics that involve integrals. It stresses the importance of monitoring engineering students' understanding and experience of calculus concepts.

The body of research on calculus topics show that students have difficulties in limits, derivatives, and integrals. Their difficulties are a result of various errors and certain misconceptions in the calculus concepts [5]. Common errors, persistent misconceptions and misunderstandings should be identified to inform and improve the teaching and learning of mathematics to facilitate student success. While researchers have documented students' understanding of various concepts in single variable calculus such as on difficulties and errors made by students in the topic of limits and integration [5,6], fewer studies exist about their understanding of multivariable calculus concepts making a case for this research study[3].

Double integration is a fundamental concept in many engineering applications and widely used in courses across the engineering disciplines. Integral calculus is a prerequisite for further coursework as it consists of important concepts such as the fundamental theorem of calculus and integral-area relationships. The focus of this research is to investigate the misconceptions in double integration in vector calculus among undergraduate engineering students.

1.2 Relevance of double integrals to Engineering

In the Mechanical engineering curriculum, vector calculus is a prerequisite course for the two third year courses namely control systems, and stress analysis and materials. In the latter, the course content covers topics such as theories of failure due to different loading conditions and material processes.

In theories of failure, finding beam deflections by double integration is one of the basic calculations students should know. They have to use boundary conditions and integrate twice; firstly, to find the slope and secondly the deflection. At this point, students apply double integration knowledge from their vector calculus course to calculate beam deflections.

For a cantilever beam in Figure 1 subjected to a combination of loading, the method of double integration is used to determine the deflection at the free end by integrating this deflection equation $EI\frac{d^2y}{dx^2} = 5 - \frac{20x^2}{2}$ twice.

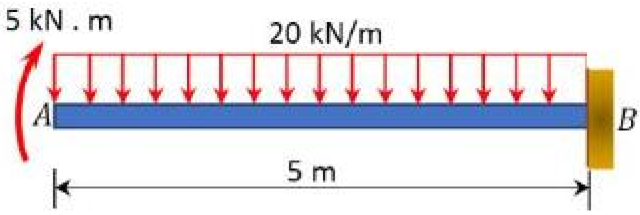


Fig. 1. Beam deflection calculation

With this example, it is clear that students have to understand the concept of double integration to minimise carrying misconceptions to future courses like the stress analysis and materials. Civil engineering students also apply the same concept in calculating beam and column deflections.

2 METHODOLOGY

2.1 Introduction

A mixed method approach was used drawing on quantitative and qualitative research data. Statistical data analysis was used to describe students' performance in the test on double integrals. The qualitative data was in the form of document analysis of the test, including their reflective notes and conducting interviews with students.

2.2 Participants

The research participants were second-year undergraduate engineering students at the University of Cape Town taking vector calculus. All participants had completed two first year calculus courses. Students in the class were invited to participate in the study, with all students agreeing that their class test could be used. Seven students agreed to be interviewed. They had given written consent and allowed the researcher to use their responses in the study.

2.3 Research method

The researcher designed the double integrals test to investigate students' understanding of and their reflections on the concept. Five questions were prepared for the test, discussed with the second researcher, and refined thereafter. The test included a reflection question at the end of each of the five questions, added to allow students to make sense of the material or experiences and the conditions that shaped those experiences. In the research study, the reflection questions help identify how the student perceived their response to the question.

Students wrote the test in 75 minutes. After the test marking was completed, an interview schedule was developed to learn about students' perspectives, experiences, and mathematics knowledge that shaped their understanding of double integrals. Amidst the circumstances presented by the pandemic, and students' unavailability for a physical meeting, the interviews were conducted and recorded using video conferencing technology. The qualitative data collected were thematically analysed through comparing and contrasting students' responses and interview results. These themes were students' misconceptions.

3 RESULTS

3.1 Performance statistics

The quantitative data analysis is presented as performance statistics of the test. This is followed by the analysis of the test responses, students' reflections and interviews culminating in the identification of the double integral misconceptions students displayed.

Overall statistical analysis on the test is presented below. Figure 2 shows the distribution of marks. The minimum mark obtained in the test was 2 and the maximum marks obtained were 28. The mean and the standard deviation were 16.06 ± 6.86 marks. Eighteen students (51%) achieved a passing grade in the test. In as much as a fair performance is observed, the overall test performance, looking at misconceptions students have and the errors they made, was not satisfactory.

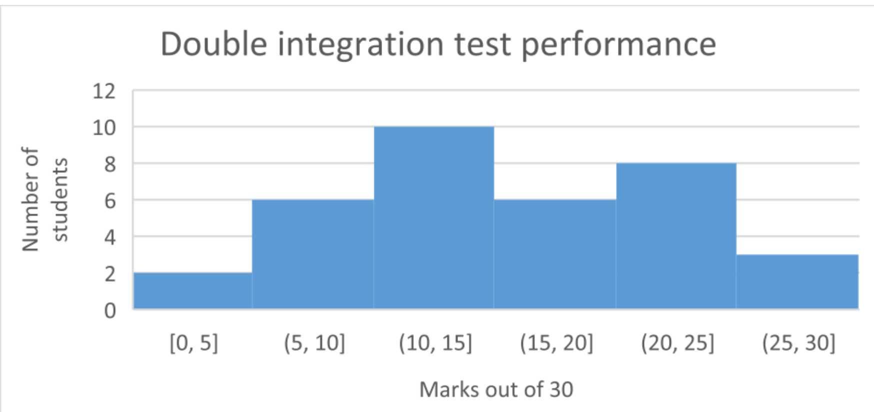


Fig. 2. Test performance

3.2 Misconceptions

Misconceptions are recognised as conceptual difficulties that students have. These may delay the learning process and hinder mathematical conceptual understanding. In this research, the following seven misconceptions were identified: Graphical representation of surfaces and the region of integration, difficulty with changing the order of integration, difficulty in setting up the integral, algebraic difficulties, treating a double integral as a triple integral, and changing the coordinate system from cartesian to polar coordinates. The first two prominent misconceptions will be discussed in the following sections.

3.2.1 Misconception 1: Graphical representation of surfaces and the region of integration

Graphical representation of the region of integration and of the three-dimensional surfaces was the primary misconception identified from the test analysis. This misconception is prevalent in all test questions. Sketching the region of integration is fundamental to setting up an integral to be evaluated. Despite students' knowledge of integration and integration techniques, incorrect double integrals setups will result in incorrect results. To this end, students' prior knowledge of curve sketching is necessary.

Curve sketching is a large focus in first-year calculus and with students sketching planes and intersecting planes. This prior knowledge would have been extended to include an introduction to 3D surfaces in second year vector calculus where students are required to recognise the equations and names of the typical surfaces (cylinders and quadric surfaces) and be able to sketch them. Sketching the region of integration requires the students' ability to draw curves and lines.

As an example, in question 1, students were required to sketch a plane $z = 5$ above the rectangle R = {x, y: 0 ≤ x ≤ 2, 1 ≤ y ≤ 4}. It is common practice to sketch the region of integration before setting up the Integral. Figure 3 shows Mary's correct response

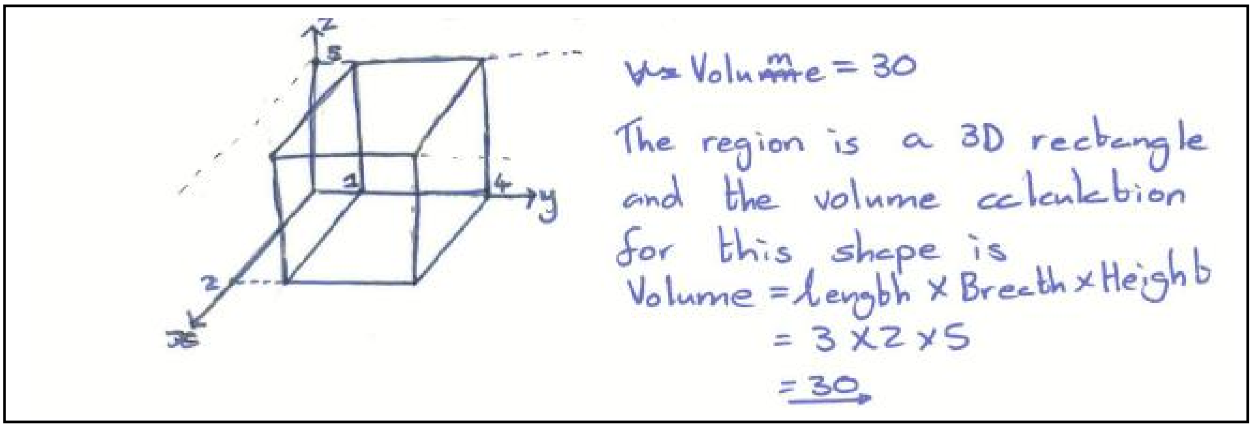


Fig. 3. Mary's correct response to sketching z=5 above the given region

In figure 3, part of the plane $z = 5$ above the region of integration is drawn. The region of integration lies in the xy plane and is defined by the rectangle. Five students were not able to draw the plane and the region of integration at all. When interviewed, some students mentioned that they knew that they had to draw a plane but were not able to draw it in three dimensions. Jessica drew a line to represent a plane in three dimensions and later during an interview said that although she knew that $z = 5$ represented a plane ,it was difficult to represent a plane in three dimensions on paper.

Figure 4a shows Jessica's region of integration. The region shows that the limits in the x and y axes were swapped and emphasises a further issue of plotting intervals incorrectly. When interviewed, the student demonstrated that they understood the required region. Figure 4b shows the plane $z = 5$. The student could tell that this particular plane lies flat at a value of $z = 5$ but could not represent it in three dimensions. Instead of a plane, a line was drawn above an unknown region of integration. Since this misconception is fundamental, it is important to ensure that first year calculus equips students with necessary curve sketching skills and revision of this should be done at the beginning of vector calculus.

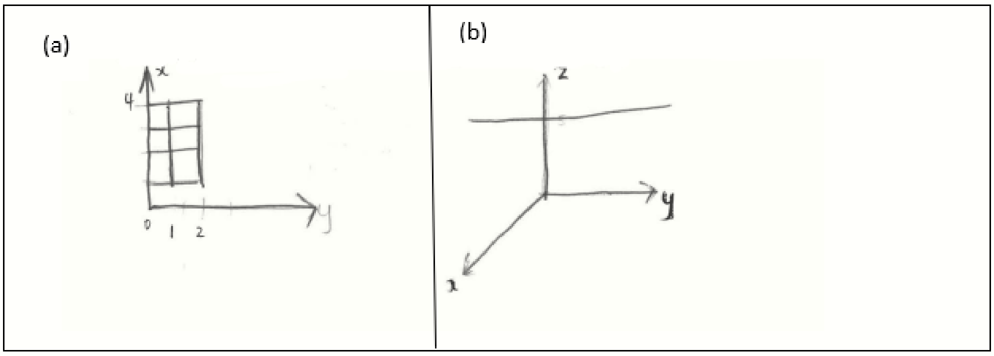


Fig. 4. Jessica's region of integration and plane sketches

Some students could not interpret the plane $z = 5$ as a function $f(x, y)$ with a value of 5 for all values of x and y. They were used to the plane with the following equation $ax + by + cz = k$, yet they could not tell in the case of $z = 5$ that $a, b \;=\; 0, c = 1$ and $k = 5$. The understanding of what a double integral represents was also crucial in interpreting the sketch. Students with ability to interpret a double integral as being used to calculate volume under a surface could have drawn the cuboid in figure 3.

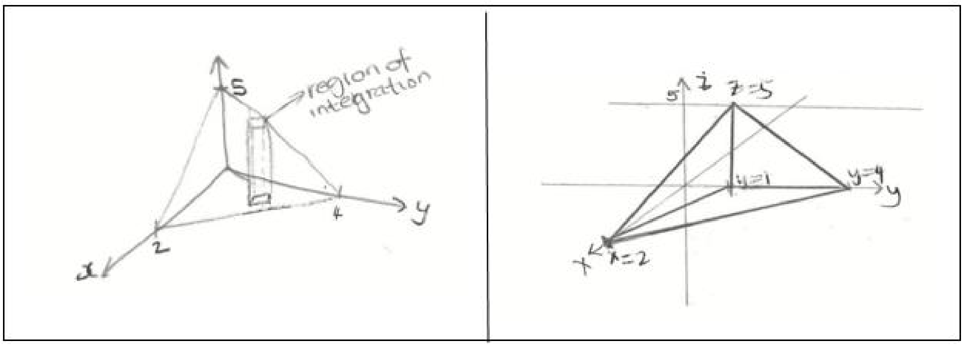
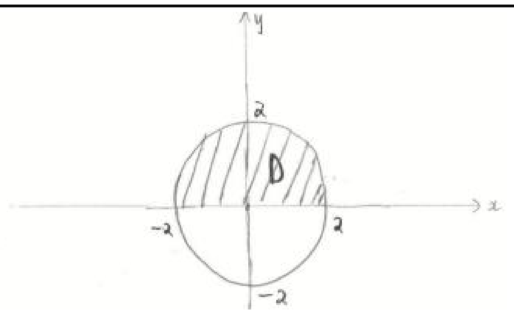


Fig. 5. Incorrect sketches from two students

One way of understanding double integrals is by relating them to the Riemann sum. Thus, students can set up the integral $\iint_R 5dA$ by thinking about $\sum\sum f(x_i y_j)\Delta A$ as an area (determined by the region of integration in the xy plane) multiplied by the height function z=5. Interpreting double integrals this way can be helpful in sketching the three-dimensional surfaces.

In some cases, students' interpretation and understanding of the limits of integration can be a determining factor in sketching the region of integration. In question 1 for example, students were given that $0 \leq x \leq 2$ *and* $1 \leq y \leq 4$. To draw the rectangular region in the xy plane, the limits can be interpreted as the area enclosed by the following straight lines $x = 0, x = 2, y = 1\ and\ y = 4$. This rectangle can be extended upwards to have a cuboid representative of the plane $z = 5$ above the region of integration. Figure 5 reveals, that the two students could not interpret the limits of integration and hence their sketches were not representative of a rectangular region of integration even though this was indicated in the question.

In addition, it is important for students to distinguish a rectangular region from non-rectangular regions. Students with non-rectangular regions ended up with limits of integration representative of a rectangular region. John's region of integration shown in the double integral in figure 6 represents a rectangle not a circle as in the picture on the left. When interviewed, students expressed that they often struggle identifying the upper and lower limits of integration even with the correct sketch. This, they say it is because they want simpler limits to work with when integrating. Students should understand that the limits of integration describe an area and they should express bounds of this area. Taken in the x direction first the bounds are $f_1(y) \leq x \leq f_2(y)$ and the limits in the y direction will range from $a \leq y \leq b$, a,b are elements of real numbers.



$$\iint_D (x^2+y^2)\,dx\,dy$$
$$\int_0^2 \int_{-2}^2 (x^2+y^2)\,dx\,dy$$

Fig. 6. John's limits of integration representative of a rectangle

3.2.2 Misconception 2 : Difficulty in Changing the Order of Integration

The change of the order of integration is important in cases where the given integrand is complicated and results in the integration being difficult or not possible to compute.

The integral $\int_c^d \int_a^b dx\,dy$ is written in a way that the integration with respect to x is carried out before the integration with respect to y. Assuming that the limits of integration were constants, changing the order of integration will result in simply $\int_a^b \int_c^d dy\,dx$. The difficulty is experienced when the region of integration is not rectangular. To achieve changing the order of integration in this context, students are required to sketch the region of integration before determining new limits of integration.

This misconception arose in response to question 4 of the test. Students were required to change the order of integration of the following double integral $\int_0^2 \int_{y^2}^4 ye^{x^2}\,dx\,dy$. They were to begin by drawing the region of integration with the resultant expected integral of this form ; $\int_0^4 \int_0^{\sqrt{x}} ye^{x^2}\,dy\,dx$. When asked if they were able to evaluate this integral, twenty-six students responded with "No", mostly citing that the integrand ye^{x^2} is too complex to integrate with respect to x. Nine students however commented that it was possible to evaluate the integral since the limits of integration were given. Two of the nine students highlighted incorrectly that knowledge of integration by parts could be employed to solve the question.

Confirming misconception 1, 30% of the class presented incorrect sketches and therefore were not successful in changing the order of integration. Even though this cohort of students had difficulties with sketching the region of integration, they acknowledged its importance in identifying limits of integration. Some students' responses revealed that they did not understand the limits of integration and what these represented. With the given integral $\int_0^2 \int_{y^2}^4 ye^{x^2}\,dx\,dy$, it is expected that students interpret the inner integral limits as $y^2 \leq x \leq 4$. The outer limits will therefore be $0 \leq y \leq 2$. The four inequalities culminate to produce the region of integration on the xy-plane. Jeffry's region of integration and the integral setup revealed this misconception. In figure 7, Jeffry represented the parabola $x = y^2$ as a straight line. Furthermore, the student did not understand that, when setting up the integral, changing the order of integration requires the limits to also change to first in the y direction and followed by the x direction. With the current limits, Jeffry suggests that the boundaries are $4 \leq y \leq y^2$ and $0 \leq x \leq 4$. The equation $y = y^2$ is the case for the two points $y = 0$ and $y = 1$.

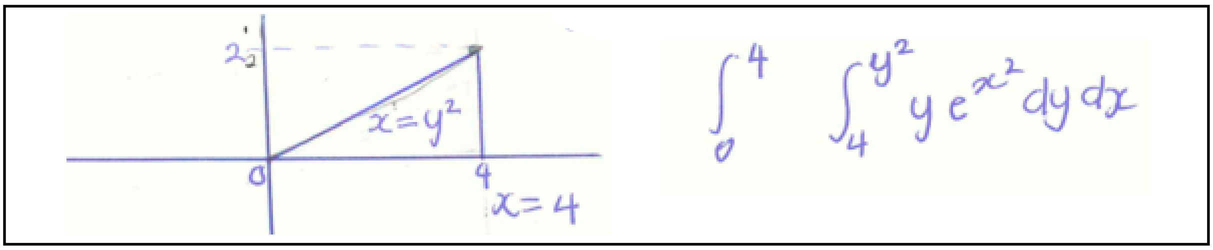


Fig. 7. Jeffry's change of order of integration

A few students did not understand that changing the order of integration involves changing the limits of integration accordingly. They simply changed the $dxdy$ to $dydx$ without altering the corresponding limits of integration. This is a serious misconception and, it was impossible for such students to succeed in effectively changing the order of integration.

In the question, three students not only denoted the incorrect region of integration but also an incorrect integrand. This is demonstrated through Jordan's response in figure 8. The integrand in question is the function $f(x, y) = ye^{x^2}$. In changing the integrand to $yln(x^2)$, Jordan effectively changed the question. It is not clear how the student arrived at this integrand. Because Jordan did not change the order and the limits, it is concluded that the student did not understand what it entailed to perform the change of order of integration.

$$\int_0^2 \int_{y^2}^4 y \ln x^2 \, dx \, dy$$

Fig. 8. Jordan's change of order of integration

4 SUMMARY

This study highlights the relevance of double integrals to the engineering curriculum. Therefore, students' understanding of the double integral concept is non-negotiable if they are to avoid difficulties in engineering courses. To identify and address misconception in double integration, difficulties experienced by vector calculus students in double integrals were studied. The prominent misconceptions included difficulty with graphical representation of surfaces and regions of integration, setting up of the double integral and changing the order of integration. It is recommended that the software application for the visualization of multivariate functions should be explored further in the teaching of this course to better students' achievements in determining the domain of integration and the integration bounds in order to solve double integrals.

Misconceptions in double integration also affect students' performance in other sections in vector calculus such as line integrals, surface integrals and Stokes' Theorem, making it equally important for teaching to focus on these misconceptions to improve performance in vector calculus

Researching students' difficulties help educators design appropriate teaching and learning activities. It is suggested that vector calculus educators liaise with first year calculus educators to discuss misconceptions resulting from prerequisite knowledge.

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SOFTWARE ENGINEERING TEACHER NETWORKS - WHAT MOTIVATES TEACHERS TO COLLABORATE?

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Conference Key Areas: Building Communities and Coordination, Fostering Engineering Education Research

Keywords: Teaching collaboration, networking activities, software engineering teachers, motivation to collaborate.

ABSTRACT

Teaching collaboration between universities is becoming increasingly important. Student intakes are increasing, and students are including MOOC courses from other universities to their studies. In Finland, there has been a long tradition in national teaching collaboration in computing education field. Our main research question is what motivates software engineering teachers to collaborate among universities. In this paper, we first give a short overview of national teaching collaboration from 1990's to the present day. Then, we present findings from a questionnaire that had respondents from active network participants. Main factors and practices that motivated teachers to participate in networking activities were existing project funding, active leaders and enough participants, interesting topics such as new innovations in learning technology, regular meetings and remote participation.

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1 INTRODUCTION

Finland has long traditions in national teaching and research collaboration in the fields of computing education (CE) and computing education research (CER). Typically, active Computer Science (CS) teachers have also done controlled experiments related to their courses to study different teaching methods, developing new tools and software, and doing learning analytics, just to mention a couple of research activities. These early adopters have also collaborated among teachers from other universities to share the new innovations and practices with other pioneering stakeholders.

Currently, Computer Science is taught in almost every Finnish university. Most of the university level teachers in Finland have a PhD degree. First year basic programming courses are large and typically each course has hundreds of students. This is one of the motivations to develop novel learning tools and methods, but also to share the best practices with colleagues. It is not surprising that the teachers giving these first bachelor's level courses are the most active in the Finnish teacher networks as well.

As our theoretical lens, we use Lave and Wenger's communities of practice [1], as reviewed by Li et al. [2]. The communities of practice are a type of learning community that are characterised by "the support for formal and informal interaction between novices and experts, the emphasis on learning and sharing knowledge, and the investment to foster the sense of belonging among members" [2, 7]. These communities of practice are often informal networks, where learning occurs in social interactions between professionals rather than in a formal classroom settings. Experts mentor novices and eventually a professional identity forms for these communities. The informal interactions between the professionals are eventually systematized as means for professionals to improve practice and generate new ways to address recurrent problems [2]. In an previous study, Ryoo et al. [3] found that learning communities helped computer science teachers at high school level to transition to an inquiry-based classroom culture and break professional isolation.

In this paper, we study the history of established networks to recognise the enablers and blockers of the collaboration in Finnish context. We describe three past *network projects*, which institute the current collaboration among Finnish university teachers giving software engineering education (see Table 1). By a network project, we refer to a granted project that has a principal investigator, and limited time frame after which it is reported to the funding agency. In addition, we analyse four latest thematic *teacher networks* (Data Structures and Algorithms, Databases, B.Sc level programming, and Web Software Development), which might be project spin-offs, but attract enough participants to make the collaboration continue also after the original project has ended. In these networks, there is some fluctuation in the collaboration intensity throughout the years. In addition, the latest undertakings to run teacher networks seem to have different levels of activity, thus we do not dare to call them Special Interest Groups (SIGs), which we consider to be more established organizations possibly under some legal entity such as an association.

Our main research question is what motivates software engineering teachers to collaborate among universities. We present findings from a literature study as well as from a questionnaire that had respondents from active network participants. The results show that the main cohesive factor is project funding. However, having an active leader and participants is what keeps the network running. Moreover, shared interesting topics, regular meetings and remote participation seem to be important factors as well.

The rest of the paper is structured as follows. In Chapter 2, we first give a short overview of national teaching collaboration from 1990's to the present day. Chapter 3 gives an overview of the current situation. In Chapter 4, we report the results from a survey we conducted between

Table 1: List of former and current Finnish universities, which field of study is engineering or information and communication technologies including their participation in three different Teacher Networks between 2001-2020. The year for founding universities are boldfaced and underlined. Some of the universities have merged during the years, e.g., TUT and UTA are nowadays known as TUNI.

Members of Finnish University Networks in Software Engineering			
University Name (Acronym)	OSCU	NBEP	ÄlyOppi
Aalto University (AALTO) / Helsinki University of Technology (HUT)	2007*	**2006**	**2018**
LUT University (LUT)	2009		**2018**
Tampere University (TUNI) / Tampere University of Technology (TUT) / University of Tampere (UTA)	**2001** / **2001**	**2006**	**2018**
University of Eastern Finland (UEF) / University of Joensuu (UJ) / University of Kuopio (UKU)	2007*	2007*	**2018**
University of Helsinki (UH)	2007*	2007	**2018**
University of Jyväskylä (JYU)	2009	2006	**2018**
University of Oulu (UO)	**2001**		2020
University of Turku (UTU)	2007*	**2006**	**2018**
University of Vaasa (UWA)	2007*		2020
Åbo Akademi University (ABO)			2020

December 2021 and January 2022. Finally, in Chapter 5 we make some conclusions.

2 TEACHER NETWORKS IN FINLAND

Table 1 gives an overview of the network projects conducted between 2001 and 2020. The table indicates the year each university has attended the network.[1] The year is boldfaced and underlined in case of founding universities.

2.1 OSCu Network – Open Source Courseware Network

In 2001, three universities (UTA, TUT, UO) founded the Open Source Courseware (OSCu) network [4]. The philosophy behind OSCu was to be able to share courses and improve cooperation between universities. Courses given through the OSCu network were expected exceptionally high quality documentation following common guidelines and practices, and teachers were given training on how to give online lectures for remotely participating universities. The network grew quickly and in 2007 it already involved eight universities (TUT, UTA, UTU, UWA, UH, UO, HUT, UKU), with two more universities joining in 2009 (JYU, LUT). The network activities were at their peak in year 2007, when 8 course implementations were offered across universities, after which the offering started to diminish, as only 2-4 courses were arranged each year 2008-2010, and from 2011 onwards only one course was offered. OSCu's way of providing the courses was such that a course lectured on one of the participating universities was streamed to all other participating universities via a video bridge and Virtual Network Computing (VNC). In other shared sessions Adobe Connect Pro was used for communication. Each university had local arrangements for handling the stream, organizing exercise sessions, and so on. The most popular course was "Software Architectures", lectured at TUT, which

[1]Records from OSCu are incomplete between years 2001-2007. While universities have joined the network at different stages between 2001-2007, we only have access to data on who were part of the network at the end of 2007.

was given yearly while other offered courses varied every year. The course became such a staple that other universities in the network began to rely on receiving lectures from TUT, even after the OSCu network itself was discontinued. Software Architectures was shared to other universities until 2015, while other OSCu activities quietly faded away in the turn of 2010-2011, due to little enthusiasm to share other courses, critical changes in university representatives in the network (mainly, the surprising death of the founding member), and ending of ministry funding for virtual teaching networks.

2.2 NBEP – The Network for Basic Education in Programming

The Network for Teaching Basic Programming (NTBP) (Ohjelmoinnin perusopetuksen verkosto) was funded by Ministry of Education, and founded by three universities (HUT, UTU, TUT) in 2006 [5]. It was operating in the fields of engineering and computer science to coordinate national and international activities. These activities included seminars, which were organized in the participating universities and had also international keynote speakers from Europe, Australia, and USA. Many participating teachers were also active researchers in the field of Computing Education Research. The goal was to research, develop, disseminate, and maintain tools and systems for teaching basic computer science courses. The tools included software for automatic grading and feedback [6–9], style checkers [10], visualizations and animations [11], as well as learning management systems [7, 8]. Many researchers and research groups in the network still collaborate and attend many international conferences such as those organized by ACM/SIGCSE (Association for Computing Machinery / Special Interest Group on Computer Science Education). The SIGCSE provides an international discussion forum for teachers and researchers in the field to exchange ideas on software and training development, courses, training programs, and other elements related to the teaching and pedagogy of computer science.

The network worked in close co-operation with the Computer Science Teaching SIG, a thematic group still active within the Finnish Society for Computer Science. The aim of the theme group is to bring together teachers in the field of computing education and researchers interested in teaching technology. The purpose is to promote e.g. cooperation between teachers, the exchange of teaching and learning materials, the introduction of novel tools to support teaching, and taking a stand on current societal issues in the field of teaching programming.

3 CURRENT NETWORKS

Universities that were active in OSCU and NBEP projects started to prepare a funding application together with Arcada University of Applied Sciences, Metropolia University of Applied Sciences and Tampere University of Applied Sciences in early 2018. Aalto University coordinated the application preparation. The Ministry of Education and Culture gave funding for this project called Intelligent Systems and Content Creation project (Älykkäät oppimisympäristöt ja niiden sisällöntuotanto in Finnish, shortly ÄlyOppi) for years 2018-2021 [ÄlyOppi, 2022]. In addition of funding the development of smart learning environments, part of the funding was targeted to establish teacher networks where teachers can demonstrate new developed systems, give support to take systems in use in other universities, create course materials together and then to share teaching and learning materials.

First teacher network meeting was held in December 2019. There were about 40 participants coming from eight Finnish universities. Initially it was planned to divide participants into five groups: i) Bachelor level programming, ii) Data structures and algorithms, iii) Databases, iv) Web-programming, and v) other special areas, like machine learning and data security. First three of the groups got most of the pre-registrations, last two groups only a few. The three most popular groups began their networking activities, and last two are still waiting for active leader and participants. These three groups also relate to topics lectured in all universities in the fields of engineering or information and communication technologies. Data structures and algorithms also has very active international teacher networks.

3.1 Data Structures and Algorithms

ÄlyOppi established The Teacher Network for Data Structures and Algorithms (TN-DSA) to enable call for participation for Finnish stakeholders that are interested in developing such courses in collaboration with instructors, teachers, researchers, and developers from other institutions. The different implementations of these courses range from pure lecture courses to realisations that heavily rely on automatically assessed assignments (AAA). The assignments can include simple multiple choice questions, but also smart content such as automatically assessed programming exercies [6, 9, 12] and algorithm simulation exercises [11, 13]. TN-DSA offers a forum to exchange ideas and materials among the teachers and other stakeholders. Due to COVID-19, TN-DSA has convened in Zoom. The meetings took place about every other month in 2020 (6 times), and almost every month in 2021 (11 times). Several interesting themes have emerged from the discussions, which are discussed in the following paragraphs.

Textbooks. The current trend in higher education is towards open courses and free learning materials including textbooks. This is also the case in DSA courses. There are several freely available textbooks that have gained a lot of interest in the DSA community. For example, Shaffer's OpenDSA [14] is a textbook developed further in collaboration with many researchers and instructors worldwide to include also interactive exercises and smart content [15]. Another example of freely downloadable material is the textbook written in Finnish by Laaksonen [16]. Both of these textbooks are examples of freely available materials to be shared among teachers and students, and which have introduced and discussed in the TN-DSA meetings.

Course arrangements. Many DSA courses were well prepared to COVID-19 as they already had a lot of automation and many students were already able to pass the courses almost without attending the campus teaching at all. For instance, the first automated assignments were introduced in Aalto University as early as 1991 [17]. In the corresponding DSA course, the development of novel automated exercises have continued ever since. For example, visual algorithm simulation exercises (VAS) [7, 13] were developed during the millennium changeover period. Nowadays, the course consists of multiple choice exercises, VAS exercises, and programming assignments that are all assessed automatically and the students can get immediate feedback on their submissions. This kind of assignments and learning management systems capable of hosting automatically assessed exercises are examples of demonstrations in the TN-DSA meetings. However, the idea is not only to exchange software, but also to learn from each other to maintain and develop courses further and discuss, for example, how to produce online learning materials or how to create innovative lecture videos.

New assignments. One of the issues with assignments is that they need to be varied once in awhile to prevent the students passing and sharing the solutions. Finding good new assignment topics can be laborious process. Thus, even though the assignments do not have any kind of automatic assessment, sharing the topics could be a valuable aid for teachers. Especially topics that have been tested with students and maybe elaborated based on the feedback can be very beneficial. This is also one of the frequent discussion points in the meetings.

Term Bank. New terms in computer science appear typically first in English. However, many universities in Finland teach DSA also in Finnish and Swedish. This has the consequence that different universities might have translated the terminology a little bit differently. It is a constant debate how to translate and try to harmonise the terminology. The developed

Term Bank includes definitions of the terms, links to external material (such as Wikipedia, Wiktionary or The Helsinki Term Bank for the Arts and Sciences [18]), and the local and most common translations among different universities in Finland. This is an ongoing project, which aims at expanding to other teacher networks than TN-DSA as well.

3.2 Databases

As a part of the ÄlyOppi project efforts to establish teacher networks, databases was identified as one of the networks due to SQL databases being an established concept with fundamentals changing only slowly. For this reason, it was thought that database fundamentals courses would have a potential to share.

The full establishment of the databases network (TN-DB) was slowed down due to COVID-19 and has convened few times per year over Zoom. During these introductory meetings, shared network interests were identified. Initially, these were: Sharing and listing open educational resources such as textbooks or query practise tools, showcasing course structures that use these resources, and comparing degree programs' course structures, to see how they implement the curriculum.

Although it has not been under the network umbrella, there has been some deeper one-to-one collaboration among TN-DB partners. For example, LUT has previously used JYU's openly available web-based coursebook for databases with embedded exercise tasks. Currently the databases network is in the process of mapping course units and has plans to reconvene to review the outcomes in 2022.

3.3 Bachelor level programming

Bachelor level programming lays the basis of computing curricula through higher education (HE). The teacher network for bachelor level programming (TN-BLP) was established in Äly-Oppi to support collaboration and information sharing. TN-BLP can be seen as a direct successor of NBEP.

Bachelor level programming is such a staple of computing curricula that it is a natural as well as a challenging topic for the network. Each HE provider offers teaching that covers the same learning outcomes while each have organized the teaching to meet the learning expectations of their specific degree programme. This means that the courses under the umbrella of TN-BLP vary in size, organization and programming language used.

TN-BLP included all universities participating in ÄlyOppi. The network initially met face to face but due to the COVID-19 pandemic, the meetings were held over Zoom. The network met based on availability and need. The topics discussed:

Courses included. At start the network collected the names and learning outcomes of courses that make the bachelor level programming in each participating university. This work covered also the programming languages used by each university. It is worth to note that while most commonly, all universities use Python, Java or Scala or C++ for learning, there are several different approaches to the order of the languages and the frequency of moving to a new language.

Course arrangements. The teaching of bachelor level programming has relied on automated grading and the use of flexible learning allowing for off-campus participation even before the COVID-19 pandemic hit. Still, how to organize teaching and especially assessment in remote teaching was a much discussed topic at the beginning of the pandemic. Experiences on the learning management systems and ways to automatically grade assignments and exam answers have also been shared.

Bridge Courses. As the student intake in computing has increased the backgrounds of students on the courses has become more heterogeneous. Furthermore, students' mobility between HE providers has increased. Hence one goal set by TN-BLP was to create a collection of small course modules coineed bridge courses to make collecting the necessary learning from several HE providers even though the programming languages are not compatible from the learning point of view directly. The pandemic brought this work to a halt.

Shared Courses. The idea of sharing course material and programming tasks has been discussed. There has also been sharing of full courses between two network participants. However, a wider sharing of course content has not been established. As a topic, this has increased interest to participate in the network among the Universities of Applied Sciences.

4 SURVEY ON WHAT MOTIVATES TEACHERS TO COLLABORATE?

Teacher communities are claimed to contribute to the improvement of teaching and schooling practices [19], where learning occurs in a social system through a dual process of meaning making. In addition to building and sharing profession-related artefacts (courses), these communities learn through activities and store the outcomes of learning as a body of knowledge in the form of words, tools, concepts, methods, stories, documents, and links to resources [20]. The participation and sharing has been reported to motivate newcomers [19].

This section describes the data collection and analysis in the context of Finnish teacher networks, a type of teacher community. In addition, findings on what themes the communities worked on and what factors supported participation in the communities are presented.

4.1 Data gathering

Data was collected during December 2021 and January 2022 using a web form. The form link with a brief description of the research was first sent to all teacher network participants, and later further distributed via the Finnish Society for Computer Science. The form had three background questions. First question asked consent (yes / no) to use respondent's answers in this research. Second question asked respondent's university, and third question asked respondent's teaching experience (0-4 years, 5-9 years, 10-14 years, 15-19 years, and 20 or more). Second and third questions were voluntary.

After the background questions, the fourth question was on which teacher network the respondent was involved in or whether they were answering to teacher network activities in general and not related to any specific network. The fifth question asked what themes the network has dealt with so far, and the sixth question asked what themes should be considered in future. The seventh question asked factors that support participation in networking activities. The last question was for free comments and future development ideas.

4.2 Findings

The questionnaire was answered by 13 respondents from 7 universities, all of which gave permission to use the data in the research. All the respondents were experienced teachers: nine had 20 years or more teaching experience, one 15-19 years, and three 10-14 years. The answers were spread over the teacher networks so that 5 were for TN-DSA, 2 for TN-DB, 1 for TN-BLP, 1 for Web Programming and 4 for network activities in general. Responses to question on themes covered in meetings match with the actual content of the network meetings according to the network leaders as described in Sub-chapters 3.1-3.3.

The following themes for future network meetings were mentioned in answers to the question six: common transition courses (between programming languages), more teachers should be involved in networking activities, electronic exams and evaluation in general, what kind of advanced level database courses are in universities, tools and methods related to distance learning, university level collaboration, developing open access course materials and exercise banks, and developing and sharing knowledge on learning management systems. Some themes that require new networks were also mentioned: data security, platform economy, information systems, operating systems, and programming larger scale applications.

Answers of questions 7 and 8 were classified by keywords into different topics. The seventh question surveyed the factors that supported participation in the networking activities. Most of the answers were related to meeting arrangements. Possibility to participate remotely was mentioned by 9 respondents. A few respondents mentioned that occasional face to face meetings would also be good. Many of the respondents mentioned factors that were related to the meeting practices: regular and enough meetings to keep connected (mentioned by 2 respondents), one hour per meeting (1) and two hours is maximum (2), usually one main topic per meeting (1), champion who leads and organises the meetings (1) and updates shared memo (1), and meeting recordings (1). Another theme that clearly raised from the answers was content of the meetings. Possibility to discuss with colleagues, give or follow tool demos and share ideas that can be used in teaching were seen important (2). General level goal setting was also mentioned by a respondent. Teacher networks should agree common tasks or goals with responsible persons. Required effort of the tasks should be realistic especially when there is no funding. One of the respondents also mentioned concrete outcomes as a motivating factor.

5 DISCUSSION

From the questionnaire data, several collaboration enablers were detected. Our data is collected from Finnish University teachers and instructors. Most of the answers mentioned importance of the meeting practices and arrangements: regular meetings to keep teachers connected, remote participation possibility, length of the meeting from one hour to two hours, as well as, active champion who leads and organises the meetings. In addition, content of the meetings was seen important. A meeting should provide a place to discuss with the colleagues, see tool demos and share ideas, and ideate teaching collaboration and material creation. However, the same factors can be the blockers as well. The end of a project is a critical moment. The network might also lose the champion that brings the participants together if the continuation of the networking is not planned during the project.

Although information about the network and network activities was disseminated successfully and a significant portion of the relevant field of education was reached, it was found that uptake and reuse of the materials remains an open question despite project funding. Some successes have been found due to good relationships between individuals and build of trust, but no new widely applicable approaches have been found. To summarize the dichotomy, awareness about the materials has been increased, but increased uptake of shared resources requires ongoing work. Traditional textbooks are still the most popular way of disseminating content, but disseminating interactive smart content remains hard to achieve.

Fortunately, from the learner point of view, utilization of resources has taken other forms during the last 10–15 years. MOOCs (Massive Open Online Courses) seems to be the contemporary way of sharing educational content. In addition, open education movement is currently actively trying to broaden access to the learning traditionally offered through formal education systems. Automatic assessment is one of the enablers that makes it easy to allow participation in online learning even though the number of participants is very large. MOOC seems to be the new book.

Although our data is only from Finland, the ebb and flow in network activity is a common aspect of all networks. Depending on the current topics discussed in the network and on the very human aspect of how busy the core network participants are in their daily work, the networks go through active phases followed by a quieter or even inactive phase. COVID-19 pandemic can be seen as one outside factor both driving network activity seen in TN-DSA, but driving network activity down due to the needed major shift in how education is provided seen in TN-BLP. There is also an overlap in the themes of the networks; when one network is active the participants may be less active in the other networks they participate in. The size of the network is important here. For the networks to thrive both shared interests or future directions and a leader or core group of people is needed to keep the networks going.

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AN INTRODUCTIONAL LECTURE ON CHAOTIC SYSTEMS THROUGH LORENZ ATTRACTOR AND FORCED LOTKA VOLTERRA EQUATION FOR INTERDISCIPLINARY EDUCATION

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ABSTRACT

Is it possible to predict the future? How accurate is the prediction for the future? These questions are fascinating and intriguing ones in particular for young generations who look at their future with curiosity. For a long time, many have tried to quantitatively predict future behavior of systems more accurately with techniques such as time series analysis and derived dynamical models based on observed data. The paper proposes a lecture structure in which elements of chaos, which greatly impacts the predictive capabilities of dynamical models, are introduced through two classical examples of nonlinear dynamical systems, namely Lorenz attractor and Lotka-Volterra equations. In a possible lecture, these two structures are introduced in a basic and intuitive way, followed by equilibria analyses and Lyapunov control approaches. The paper intends to give a possible structure of an interdisciplinary lecture in chaotic systems, for all students in general and non-engineering students in particular, to kindle students' interest in challenging ideas and models. By presenting an intuitive learning-based approach and the results of the implementation, the paper contributes to the discourse on interdisciplinary education. The lecture is a part of a course within a Complementary Study at Leuphana Unversity of Lüneburg. The material which inspired the proposed lecture structure is taken from the scripts of the Master Complementary Course titled Modelling and Control of Dynamical Systems using Linear and Nonlinear Differential Equations held at Leuphana University of Lüneburg.

1 INTRODUCTION

The presented lecture can be used in different contexts: in Bachelors courses for engineers as well as for Masters courses dedicated to non-engineers (non-engineering minor programs,

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complementary study). In this way, the paper provides important insights into how to teach the first and only control course in non-control engineering programs. In fact, an important point of the complementary study at Leuphana University in Lüneburg, Germany, is a holistic vision of the culture in which also non-engineers can profit from knowledge which typically is just for engineers. Therefore, such liberal education demands and encourages the intellectual and personal development of each and every specific student profile, in which new ideas to teach and to connect naturally or technically with human sciences represent a prerequisite.

In this paper, a modified Lotka-Volterra model with fixed initial condition has been employed to examine whether there is a pattern in chaos situations and where equilibrium points are that do not change over time, see [1]. It is important that the course starts recalling basic knowledge of differential equations and, before starting with a lecture dedicated to sliding mode control, the course should introduce elements of nonlinear differential equations considering the fundamental direct method of Lyapunov [2] related to the stability of a solution of a differential equation.

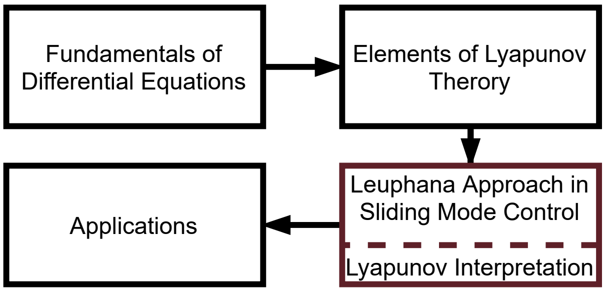

Fig. 1. Structure of the proposed course

Figure 1 shows the structure of the proposed course of this lecture in which the control of chaotic systems using Lyapunov control is proposed as an application. There are theoretical backgrounds about Lorenz's chaos theory and Lotka-Volterra model along with the explanation of forced Lotka-Volterra equations in Section 2. In Section 3, differential equations of Lorenz attractor of chaos theory as well as forced Lotka-Volterra equations in chaos scenarios with Jacobian matrix are computed manually in order to find equilibrium points and then they are followed by manual computation of Lyapunov equation for controllers. In Section 4, the simulations in Matlab/Simulink regarding Section 3 has been described. Later, conclusion and some remarks are devoted in Section 5.

2 MODELLING

Several kinds of dynamical systems from nature, and also synthetic ones, can be chaotic in their solutions. Two important ones are Lorenz attractors and forced Lotka-Volterra models.

2.1 Lorenz attractor

In the context of meteorology and fluid dynamics, Edward Lorenz came up with the simplest equation to explain the observed chaotic phenomena in the Earth atmosphere [3]. The result are three nonlinear differential equations $\dot{x}$, $\dot{y}$ and $\dot{z}$,

$$\frac{\mathrm{d}x(t)}{\mathrm{d}t} = \sigma\left(y(t) - x(t)\right), \quad (1)$$
$$\frac{\mathrm{d}y(t)}{\mathrm{d}t} = px(t) - y(t) - x(t)z(t), \quad (2)$$
$$\frac{\mathrm{d}z(t)}{\mathrm{d}t} = x(t)y(t) - \beta z(t), \quad (3)$$

where x is the rate of convective motion, for instance how fast the rolls are rotating, y is the temperature difference between the ascending and descending currents, and z is the distortion (from linearity) of the vertical temperature profile, see [3] for details on the practical interpretation of the parameters and variables of this example system. Parameters σ, p, and β depend on condition of the fluid, the heat input, etc., but they are assumed to be constant throughout experiments. So, in the simulations from Lorenz, $\sigma = 10$, $p = 28$, and $\beta = \frac{8}{3}$, see [4]. When the aspect of movement is transferred to the coordinate planes of the x, y, and z axes, a 'strange butterfly' shape can be seen. It is also called Lorenz's Butterfly Attractor because its shape resembles a butterfly. Here, the characteristic of chaos shows that it is sensitive to initial conditions but at the same time it is still possible to find the underlying pattern. Another, structurally simpler class of dynamical systems that can exhibit chaotic behavior under certain conditions is the dynamics of predator and prey populations in nature.

2.2 Lotka-Volterra models and their control

When there are preys, there are predators. It can also be applied to the other way around. When there are predators, there are preys. From this phenomenon, one can see that there must be a pattern or trend of prey and predator population over time. This pattern has been formed into equations by Alfred J. Lotka in 1910, analyzing prey-predator interactions as known as Lotka-Volterra model and predicting the population rate of change over time, see [5]. So the original Lotka-Volterra model is described by the following pair of equations, see [1]:

$$\frac{\mathrm{d}N_1(t)}{\mathrm{d}t} = \alpha_1 N_1(t) - \beta_1 N_1(t)N_2(t), \quad (4)$$
$$\frac{\mathrm{d}N_2(t)}{\mathrm{d}t} = -\alpha_2 N_2(t) + \beta_2 N_1(t)N_2(t), \quad (5)$$

where $N_1(t)$ and $N_2(t)$ are the population of prey and predator respectively, α_1 is the growth rate of prey and α_2 is the die out rate of predator. The term - $\beta_1 N_1(t)N_2(t)$ represents the loss rate of prey due to collisions with predator and $\beta_2 N_1(t)N_2(t)$ represents the growth rate of the population of predator due to collisions with prey. The equations have periodic solutions under the assumptions that none of parameters α_1, α_2, β_1, β_2 are negative, see [1]. From the model, the population of predator seemingly follow the pattern of the population of prey putting both populations into loop of increase and decrease. In this paper, the modified Lotka-Volterra (forced Lotka-Volterra) model which has been introduced by Gause, see [6], has been employed in order to obtain chaotic behaviour

$$\frac{\mathrm{d}N_1(t)}{\mathrm{d}t} = \alpha_1 N_1(t) - \beta_1 \sqrt{N_1(t)}N_2(t) - \gamma_1 (N_1(t))^2, \quad (6)$$
$$\frac{\mathrm{d}N_2(t)}{\mathrm{d}t} = -\alpha_2 N_2(t) + \beta_2 \sqrt{N_1(t)}N_2(t), \quad (7)$$

where $\gamma_1(N_1(t))^2$ is a logistic term and also a penalty due to lack of room for prey as its number grows and the terms - $\beta_1\sqrt{N_1(t)}N_2(t)$ and $\beta_2\sqrt{N_1(t)}N_2(t)$ are now not proportional to $N_1(t)$

but to $\sqrt{N_1(t)}$. In other words, the original Lotka-Volterras collision terms are proportional to $N_1(t)$ while Gauses collision is obtained when it is proportional to $\sqrt{N_1(t)}$ of the prey community which contributes to collision and provides saturation effect for the collision. The saturation effect causes a population explosion of prey when the logistic term is disregarded, see [6]. In this paper, time-variance will be considered since recovery of grass causes a periodic oscillation of the grass-eating prey's population. Then the growth rate of prey turns out to be as following, which according to [1] yields chaotic behavior:

$$\alpha_1(t) = 2\left[a - b\cos(\omega t)\right] \tag{8}$$

where a is the positive constant and b and ω are the amplitude and angular frequency of the oscillating part of the growth rate respectively. Furthermore, these two forced Lotka-Volterra equation will be extended again using control inputs which are $\mu_1(t)$ and $\mu_2(t)$. It is possible to control the population of both species by intervening in their interaction. In other words, population dynamics can be affected by controlling amount of food provided, or controlling the population of species by introducing or withdrawing individuals from the habitat.

$$\frac{\mathrm{d}N_1(t)}{\mathrm{d}t} = \alpha_1 N_1(t) - \beta_1\sqrt{N_1(t)}N_2(t) - \gamma_1 N_1(t)^2 + \mu_1(t), \tag{9}$$

$$\frac{\mathrm{d}N_2(t)}{\mathrm{d}t} = -\alpha_2 N_2(t) + \beta_2\sqrt{N_1(t)}N_2(t) + \mu_2(t). \tag{10}$$

Here, $\mu_{1,2}(t)$ will be regarded as controlling the population of two species by introducing or withdrawing individuals since time-variance for the amount of food has been already considered in form of $\alpha_1(t)$. Even in the presence of chaotic behavior in the populations, a controller can help to stabilize the populations from the outside at an arbitrary level.

3 SYSTEM ANALYSIS AND CONTROL

3.1 Equilibrium points of Lorenz attractor

With Lorenz equations (1-3), equilibrium points fulfil the conditions $\dot{x} = 0$, $\dot{y} = 0$, $\dot{z} = 0$

$$0 = \sigma\left(y(t) - x(t)\right), \tag{11}$$

$$0 = px(t) - y(t) - x(t)z(t), \tag{12}$$

$$0 = x(t)y(t) - \beta z(t), \tag{13}$$

Since parameters σ, p, β are given as constants, the solutions are $x = 0$ or $x = \pm\sqrt{\beta(p-1)}$, $y = x$, and $z = p - 1$. Therefore, the equilibrium points of x, y, z including the origin are [4]

$$C^{\pm} = (\pm\sqrt{\beta(p-1)}, \pm\sqrt{\beta(p-1)}, p-1). \tag{14}$$

Using parameters $\sigma = 10$, $p = 28$, and $\beta = \frac{8}{3}$ as fixed by Lorenz, computing equilibrium points by hand results in $C^+ = (8.5, 8.5, 27)$, $C^- = (-8.5, -8.5, 27)$, which corresponds with Fig. 2.

3.2 Limited equilibrium of Forced Lotka Volterra using Jacobian Matrix

Using the forced Lotka-Volterra model in Section 2.2, limited equilibrium points can be reached Solving these two conditions,

$$0 = \alpha_1 N_1(t) - \beta_1\sqrt{N_1(t)}N_2(t) - \gamma_1(N_1(t))^2, \tag{15}$$

$$0 = -\alpha_2 N_2(t) + \beta_2\sqrt{N_1(t)}N_2(t), \tag{16}$$

apart from the trivial solution $N_{1,2}(t) = 0$ yields the following two equilibria:

$$N_1(t) = \frac{\alpha_1}{\gamma_1},\ N_2(t) = 0 \text{ or } N_1(t) = \frac{\alpha_2^2}{\beta_2^2},\ N_2(t) = \frac{\alpha_1\alpha_2\beta_2^2 - \alpha_2^3\gamma_1}{\beta_1\beta_2^3}. \tag{17}$$

For sake of brevity, we will consider just the first two equilibrium points in terms of local stability using the Lyaponov criterium which concerns the local stability. We can see that these two equilibrium points are locally unstable. Point 1 gives trivial solution because when there is no prey ($N_1(t) = 0$), there will be no predator as well ($N_2(t) = 0$). In other words, when one species will go extinct, the existence of the other species will also be endangered. When it comes to determining whether equilibrium points in both Point 1 and 2 are stable, the eigenvalues of the Jacobian Matrix J should be examined. Assuming that $f_1(t) = \frac{\mathrm{d}N_1(t)}{\mathrm{d}t}$ and $f_2(t) = \frac{\mathrm{d}N_2(t)}{\mathrm{d}t}$, Jacobian matrix of forced Lotka-Volterra can be described as following.

$$J = \begin{bmatrix} \frac{\partial f_1(t)}{\partial N_1(t)} & \frac{\partial f_1(t)}{\partial N_2(t)}, \\ \frac{\partial f_2(t)}{\partial N_1(t)} & \frac{\partial f_2(t)}{\partial N_2(t)} \end{bmatrix} = \begin{bmatrix} \alpha_1 - 2\gamma_1 N_1(t) - \frac{\beta_1 N_2(t)}{2\sqrt{N_1(t)}} & -\beta_1\sqrt{N_1(t)} \\ \frac{\beta_2 N_2(t)}{2\sqrt{N_1(t)}} & -\alpha_2 + \beta_2\sqrt{N_1(t)} \end{bmatrix}. \tag{18}$$

In order to analyze the equilibria stability, Lyapunov stability theory for time-variant systems states that the eigenvalues of $J_p^T + J_p$ must have a negative real part [7]. Two points are investigated. First, when point 1 is used,

$$J_{p_1} = \begin{bmatrix} \alpha_1 & 0 \\ 0 & -\alpha_2 \end{bmatrix}, \tag{19}$$

where we have two eigenvalues λ_1: $2\alpha_1$ and $-2\alpha_2$.

$$\det(\lambda_1 I - J_{p_1}^T - J_{p_1}) = 0 \Rightarrow \det \begin{bmatrix} \lambda_1 - 2\alpha_1 & 0 \\ 0 & \lambda_1 + 2\alpha_2 \end{bmatrix} = 0. \tag{20}$$

The determinant formula shows that λ_1 equals $2\alpha_1$ which has a positive value, thus making the system locally unstable around this equilibrium point. On the other hand when using point 2, the result is as follows

$$J_{p_2} = \begin{bmatrix} -\alpha_1 & -\beta_1\sqrt{\frac{\alpha_1}{\gamma_1}} \\ 0 & -\alpha_2 + \beta_2\sqrt{\frac{\alpha_1}{\gamma_1}} \end{bmatrix}, \tag{21}$$

and so

$$J_{p_2}^T + J_{p_2} = \begin{bmatrix} -2\alpha_1 & -\beta_1\sqrt{\frac{\alpha_1}{\gamma_1}} \\ -\beta_1\sqrt{\frac{\alpha_1}{\gamma_1}} & -2\alpha_2 + 2\beta_2\sqrt{\frac{\alpha_1}{\gamma_1}} \end{bmatrix}, \tag{22}$$

where we have two values for λ_2:

$$\det(\lambda_2 I - J_{p_2}^T - J_{p_2}) = 0 \Rightarrow \det \begin{bmatrix} \lambda_2 + 2\alpha_1 & \beta_1\sqrt{\frac{\alpha_1}{\gamma_1}} \\ \beta_1\sqrt{\frac{\alpha_1}{\gamma_1}} & \lambda_2 + 2\alpha_2 - 2\beta_2\sqrt{\frac{\alpha_1}{\gamma_1}} \end{bmatrix} = 0. \tag{23}$$

The two solutions for λ_2 are complicated, with the same real (and non-zero imaginary) part

$$\mathrm{Re}(\lambda_2) = -\alpha_1 - \alpha_2 + \beta_2\sqrt{\frac{\alpha_1}{\gamma_1}}, \tag{24}$$

so in order to investigate stability, it is enough to consider the real part of the two solutions of λ_2 and the stability condition (depending on the system model parameters) becomes:

$$-\alpha_1 - \alpha_2 + \beta_2\sqrt{\frac{\alpha_1}{\gamma_1}} < 0. \tag{25}$$

3.3 Controllers using Lyapunov equation

With controllers $\mu_{1,2}(t)$ which allows for convergence to an arbitrary level, a Lyapunov equation is used to make sure that the arbitrarily desired population size combination is stable. According to the Lyapunov theory, it can be described as

$$v(N_1(t), N_2(t)) = \frac{1}{2}[(N_1(t) - N_{1d}(t))^2 + (N_2(t) - N_{2d}(t))^2], \tag{26}$$

where $N_{1d}(t)$ is desired population of prey and $N_{2d}(t)$ is desired population of predator. In this paper, the desired population of prey and predator have been set for 200 and 300 respectively. Assuming that $(N_1(t) - N_{1d}(t))$ is $S_1(t)$ and $(N_2(t) - N_{2d}(t))$ is $S_2(t)$, the result of computing $\dot{v}(N_1(t), N_2(t))$ is as following.

$$\begin{aligned}\dot{v}(N_1(t), N_2(t)) &= (N_1(t) - N_{1d}(t))\frac{\mathrm{d}N_1(t)}{\mathrm{d}t} + (N_2(t) - N_{2d}(t))\frac{\mathrm{d}N_2(t)}{\mathrm{d}t} && (27)\\ &= S_1(t)\frac{\mathrm{d}N_1(t)}{\mathrm{d}t} + S_2(t)\frac{\mathrm{d}N_2(t)}{\mathrm{d}t}. && (28)\end{aligned}$$

Substituting equations $\frac{\mathrm{d}N_1(t)}{\mathrm{d}t}$ and $\frac{\mathrm{d}N_2(t)}{\mathrm{d}t}$ with forced Lotka-Volterra equations, $\dot{v}(N_1(t), N_2(t))$ can also be described as

$$\begin{aligned}\dot{v}(N_1(t), N_2(t)) = S_1(t)[\alpha_1 N_1(t) - \beta_1\sqrt{N_1(t)}N_2(t) - \gamma_1(N_1(t))^2 + \mu_1(t)]\\ + S_2(t)[-\alpha_2 N_2(t) + \beta_2\sqrt{N_1(t)}N_2(t) + \mu_2(t)]\end{aligned} \tag{29}$$

The input terms $\mu_1(t)$ and $\mu_2(t)$ which both consist of an equivalent and a corrective control term, can then be derived considering requirement $\dot{v} \leq 0$ of the sliding mode control approach

$$\begin{aligned}\mu_1(t) &= \mu_{1eq}(t) + \mu_{1corr}(t), && (30)\\ \mu_{1eq}(t) &= -\alpha_1 N_1(t) + \beta_1\sqrt{N_1(t)}N_2(t) + \gamma_1(N_1(t))^2, && (31)\\ \mu_{1corr}(t) &= -\eta_1 \tanh(S_1(t)), && (32)\\ \mu_2(t) &= \mu_{2eq}(t) + \mu_{2corr}(t), && (33)\\ \mu_{2eq}(t) &= \alpha_2 N_2(t) - \beta_2\sqrt{N_1(t)}N_2(t), && (34)\\ \mu_{2corr}(t) &= -\eta_2 \tanh(S_2(t)). && (35)\end{aligned}$$

Here, $\eta_{1,2}$ determines how strong the input term will affect the equation to which it is applied, which means in this case, how strong it controls the population of prey and predator in order to stabilize a population combination, where it naturally would not be possible. In simulation for the convergence under the control, η_1 and η_2 have been set to 1 so that the desired population of prey and predator can be reached. Furthermore, the corrective term contains the hyperbolic tangent function as a substition of sign function $\mathrm{sign}(\mathrm{S}_{1,2})$ for leading to a smoother graph with less oscillations in the simulink model.

4 SIMULINK MODEL IN MATLAB

The simulation of Lorenz attractor has been implemented in Matlab/Simulink to check whether it is possible to find pattern in chaotic situations. Instead plots of the considered Lorenz attractor have been visualized to describe the state evolutions of variables x, y, and z with Fig. 2. The Simulink implementation to see how the population dynamics of prey and predator converges using chaotic methods and controllers shows the following. Without connecting controller parts, both of the population of prey and predator show chaotic, unpredictable patterns in the respective scope blocks individually.

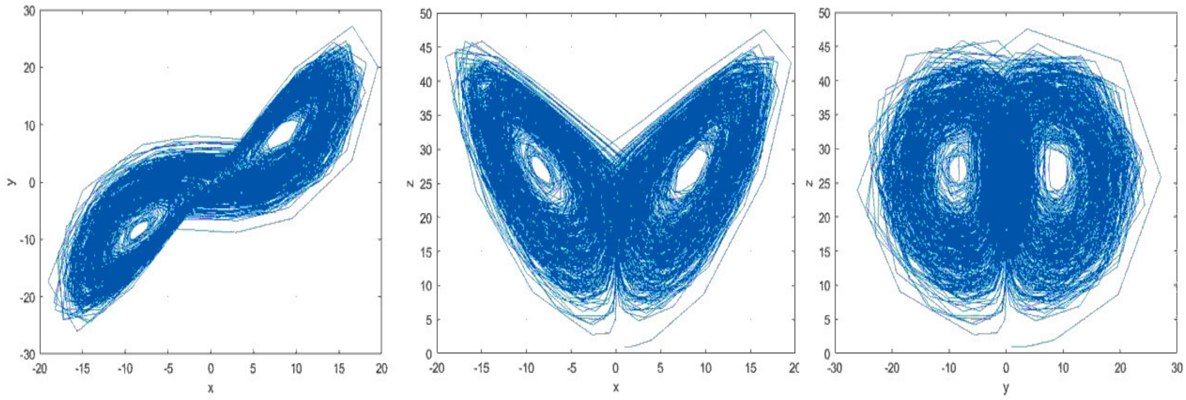

Fig. 2. 2D visualization of the three states of the Lorenz attractor

(1).png

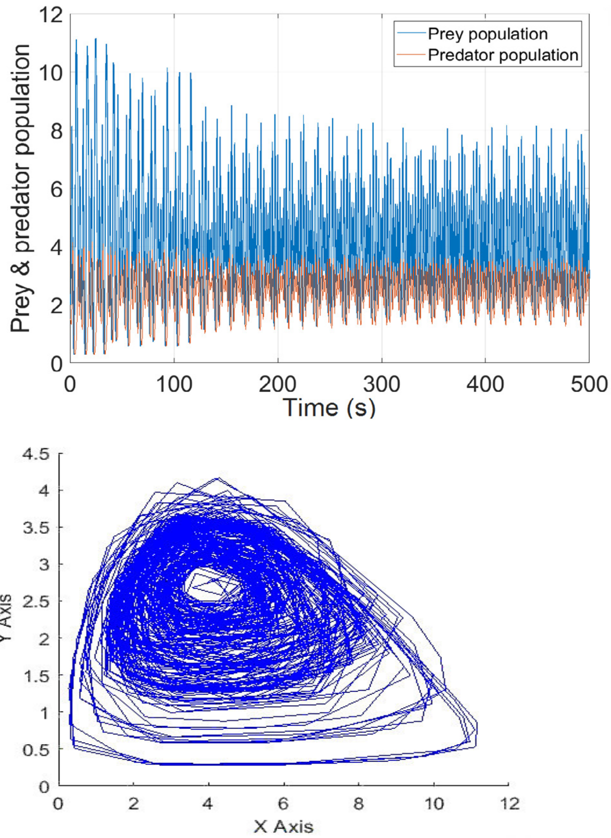

Fig. 3. Population evolution (left) of prey and predator without controllers and phase plot (right)

In Fig. 3, it can be observed that the population of prey ($N_1(t)$) fluctuates between 0 and 12 over time and the population of predator ($N_2(t)$) fluctuates between 0 and 4.5. Nevertheless, the XY graph shows that the population of prey and predator still converges into the center of the circle-like figure predicting that there will be approx. 4 preys (X axis) and 3 predators (Y axis) as time goes. With the controller part, the results show that the population of prey (X axis) and predator(Y axis) eventually reaches the desired population size which is 200 and 300, respectively, see Fig. 4.

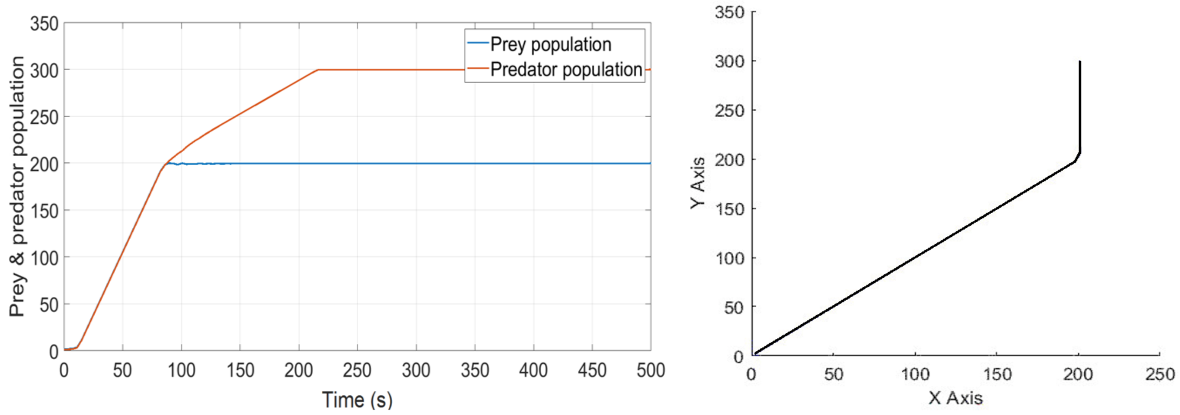

Fig. 4. Population evolution (left) of prey and predator with controllers and phase plot (right)

5 CONCLUSION

The real world is full of uncertain and chaotic phenomena. Therefore, employing simple linear prediction models with some assumptions is often not enough to enhance the accuracy of model-based predictions. Lorenz attractor from chaos theory and the forced Lotka-Volterra model are introduced as examples for systems that impede such predictions, due to extreme sensitivity w.r.t. the initial conditions. In case the initial conditions (and the model) are known with certainty, the chaotic behavior is deterministic and, hence, also predictable, with or without controller, yet more difficult. The presence of multiple equilibrium points implies that it is hard to predict real-life phenomena but thanks to simulation studies, it is still possible to make analyze convergence of the states. Furthermore, it is possible to deal with chaotic phenomena of fields other than meteorology using Lorenz attractor model and forced Lotka-Volterra equations. Promising applications can be found in economics (market shares of complementary and substitute goods), immunology of infectious diseases (populations of infected COVID-19 patients and susceptibles, etc.) or electronic devices (Chua's circuit). In execution of the course, the students' progress of learning was extensive.

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"IT'S NOT LIKE IT'S POPULAR SCIENCE WE ARE DOING"

- POPULAR SCIENCE, MOTIVATION, CALCULATIONS, AND CONCEPTUAL UNDERSTANDING AMONG PHYSICS AND ENGINEERING STUDENTS (RESEARCH)

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ABSTRACT

This paper discusses the role popular science and science dissemination texts can have in learning physics in higher education for physics students and technical physics engineering students. In a mixed-methods study, students' attitudes, experienced motivation, and learning is mapped through a quantitative survey (N=155) and two qualitative surveys with in-depth interviews, one with six master level students and one with four 1st year students. The interview data shed light on two aspects of popular science's role in learning physics. Students report that reading popular science is highly motivating, but they do not have the perception of having learned physics from it. This converges with a division between calculations and conceptual understanding among the students. The paper then questions whether this gap could be closed or made smaller with greater emphasis on conceptual understanding in physics classes.

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1 INTRODUCTION

In this study, we will examine the role of popular physics in motivation and learning in university-level physics education. We will try to answer the research question:

What contribution can popular science have as a learning tool, and how can it be employed as one in university-level physics?

Literature and experiences with popular science and physics education describe several tensions and dualities when it comes to the view of popular science from an academic perspective. We will particularly look at the literature regarding popular physics, but also use some considerations from the wider field of popular science.

1.1 The societal function of popular science

The first question we should apply is to define popular science. There is no common definition of what popular science is. A simple demarcation could be that it should be both “popular” - directed at a mass audience without strict demands on pre-knowledge, and “science” - it should be based on scientific knowledge, not fiction (or science fiction). As such it will have a large overlap with science dissemination texts, with one main difference being the latter having the stated objective of scientific dissemination.

However, one seminal text on the topic proclaims that ”If we are then to think of popular science as part of a conceptual ecosystem, we might then also have to conclude that there is no such thing as popular science.” [1] On the other hand, the author continues to argue that ”for popular science: it is not a thing, nor a category but a historical phenomenon that happens in human relationships.” In other words, do not ask what popular science *is*, but what popular science *does*.

We will firstly look at discussions on the role of popular science in society. This is not our primary objective - that is the effect on students - however, as little as physicists might like it, we too exist in society [2] and for our students, society is the primordial ooze they crawl out of on their way into the domain of physics.

In this area, the literature on popular physics mainly revolves around the role of popular science in domain conflicts, with common references to C.P. Snow’s “Two cultures” [3] and the United States’ “Science Wars” of the 1990s [4].

As an example, Felicity Mellor describes how ”The intertextuality of popular science books causes images of science which are supportive of scientists’ interests to continue to circulate in public discourse despite the alternative images thrown up by public scientific controversies reported in the news.” [5] Popular physics books are here thus seen as a tool for scientists to dominate not only science but also the public discourse on science in a process similar to a Gramscian struggle for hegemony [6].

In science, there has been a general concern about “public understanding of science“ and hence science has the responsibility to inform. “Scientists must learn to communicate to the public, be willing to do so, and indeed consider it their duty to do so” [7]. This will also to a large part be through science dissemination texts which will fall within popular science.

1.2 The effect of popular science on students

Drawing on a wide range of literature Christidou proclaims that «Popular science, communicated by the mass media, the internet, comics, films etc., pervades information sources widely used by young students -and the public in general- and is therefore considered as greatly influencing students’ conceptions, interests, and attitudes towards science.” [8].

We here, however, also find a duality, because even though it is important in forming and shaping students’ views of science, ”These information sources often promote intense, outdated, controversial, stereotypic and gender-biased images of science and its people.” [8]

This duality is about motivation and the view of science, but also of its practitioners, which popular science promotes. Similar dualities can also be found in the views on the effects popular science can have on learning physics. There does not seem to be a lot of literature on this topic, but there are a few more experience-based accounts that can give us an impression of the views on popular science from scholars in the relevant fields.

Lam [9] holds that «The use of popular science (PS) books is a long-neglected tool in teaching. [...] The idea is to help the students to broaden their scientific knowledge base as demanded by the real world out there, to foster a lifelong habit of buying and reading PS books, and become a science-informed citizen.” In such a perspective popular science can be a contribution to Bildung, in the sense of the German/North European tradition of education of popular enlightenment and connecting one’s education to one’s role as a citizen [10].

However, there are some worries about whether popular science might be more popular than it is scientific. Henry [11], e.g. observes that “However what sometimes happens is I see candidates who can regurgitate a lot of facts they have read in popular science books or New Scientist, but are then unable to relate this to the physics they have learned at school. They tell me about the Large Hadron Collider and the Higgs Boson, but get stuck when asked to draw the trajectory of a particle in an electric or magnetic field.” In this context, research on physics cultures sometimes one-sided focus on calculations should be mentioned as a possible partial explanation of the latter [12].

Leane also questions the scientific rigor of popular physics books. She e.g. points out that her “analysis of the use of metaphor in Zukav's The Dancing Wu Li Masters identifies the slippage of meaning that renders this text more of a hindrance than a help to cross-disciplinary communication.” [4]. There is thus a fear of simplifications that can hinder learning instead of strengthening it.

There thus seems to be a gap between the physics they read in popular science books and "real physics", i.e. the physics they learn in school or college, and the students cannot connect the two.

1.3 The effect of popular science on students

In reviewing the relationship between popular science and motivation we will employ self-determination theory (SDT) as described by Deci and Ryan [13]. SDT's describes three basic psychological needs, essential for motivation; autonomy, competence, and relatedness.

The first one, autonomy - the experience of being self-regulated in one's actions and experiences. Life as a student will always have the volitional aspects of being a student, feeling congruent and integrated, and not controlled by others, but at the same time, controlled by deadlines, a defined curriculum, and the final exam.

A second element is belonging - the experience of belonging and feeling socially connected. In this sense, it could be relevant to connect this to the discussions of popular science as a tool in domain struggles [4]. A university department will have a strong role in managing and controlling the professional domain of physics. In the sense that popular physics, perhaps written by a seasoned physicist, can give a student the feeling of access to this domain, it can be highly motivating. However, the skepticism towards aspects of popular science found within the same professional domain [4, 11], will also affect students' attitudes in the process of entering the domain of physics.

The third element, competence, is more contentious. How can students experience mastery and effectance from popular science if they struggle to connect it to their "school physics" [11]? One possibility is the overview popular science can give you [9]. If they do manage to connect it to the physics they learn in lecture halls, it can help the students to position it within a wider framework of knowledge.

When students enter the field of science, they are motivated to start studying and have a goal to finish, but, arrive with various knowledge about the path into the domain. Goals are representations of future scenarios that remain in memory, stored as knowledge structures. A goal can be defined as a "cognitive representation of a desired endpoint that impacts evaluations, emotions, and behaviors." [14]. Parts of this domain knowledge may be created by popular science.

2 METHODOLOGY

2.1 Section 1

The quantitative analysis is based on the Interactive Engagement and Motivation in Physics Learning (IMPEL) survey [15], which again is based on the Eccles-model within motivational theory [16]. The respondents are 157 first-year students from a physics class, composed of students where roughly one third are part of a bachelor physics program and two-thirds belong to an applied physics and mathematics 5-year engineering program. The students are asked about their motivations and perceived learning from different activities on a 5-point Likert scale.

We do a simple quantitative comparison of these IMPEL data on questions of perceived learning and motivation.

The 6 Master level physics students have gone through semi-structured individual interviews of approximately an hour length each. The data have been transcribed and are interpreted through a Phenomenological analysis looking for larger recurring meaning-units, using a process of meaning condensation from Giorgi [17-19].

We have also included elements from interviews of 4 first-year physics students. These interviews were mainly focusing on how students viewed their learning process facing the first course of mechanics but are included as there were elements from the interviews relevant to this current topic as well. The interviews were conducted by Martine Strand, a Master's student of Thorseth**.** These data were analyzed using thematic analysis as developed by Braun and Clarke [20].

We do not claim these qualitative data sets give reason to generalize to all physics students, not least as they are all from one Norwegian university, but also because it is a qualitative survey of a few students. We however believe these results may shed light on the quantitative results, and direct further research into whether and how popular science can be employed to increase student learning.

3 RESULTS

The quantitative results from this study show a huge gap between the perceived learning and motivation from popular science in physics. The qualitative data give us some suggestions for the mechanisms behind this gap and how it can be reduced.

3.1 Popular physics as motivation

The scores from the IMPEL-survey are presented in Table 1. If we first consider the responses on motivation, we see that all the popular science activities enter the top half, and 2 out of the top three most motivating activities are related to popular science. Only direct human interaction with peers tops popular science. When asked about perceived learning the popular science activities however drop dramatically. Watching popular science videos now get a medium score, while reading and lectures are placed in the bottom half. This difference between perceived learning and motivation can not be seen in any other activities. To clarify this we can look at the difference between the scores and see that apart from programming (which was not yet integrated well into physics for this student group) popular science are the only activities that motivate more than supply experienced learning, but also that the difference on a 5 point scale, between - 0,58 and - 0,82, is of a different magnitude than any other activities.

In examining the responses from the 6 master students we can confirm the motivating role of popular science. In describing their path to physics five of the six mention either popular science or fascination with the "big questions" about the universe as a key factor in their path to physics, often in connection. The same students, however, also reproduce the duality found in literature when it comes to perceived learning.

Table 1. Student responses to whether they experience learning and motivation from a range of learning activities on a 5-point Likert scale. The difference in mean score between learning and motivation is presented in the final column. The number of respondents, N, on the different questions ranged from 154-157 respondents.

	I learn physics well by…		I am motivated by…		Learn well minus motivated
	Mean	Std.dev	Mean	Std.dev	Mean
listening to the teacher talking in lectures	3,26	1,139	3,06	1,172	0,2
watching the teacher doing a demonstration	3,89	0,898	3,75	1,004	0,14
doing experiments	3,31	1,122	3,1	1,172	0,21
discussing subject matter with fellow students	4,5	0,799	4,32	0,843	0,18
solving problems with fellow students	4,46	0,83	4,23	0,944	0,23
solving problems alone	4,45	0,73	4,02	0,886	0,43
receiving help from a learning assistant	4,16	0,94	3,84	0,951	0,32
reading in textbooks	3,63	0,985	3,28	1,144	0,35
programming	2,55	1,024	2,81	1,127	-0,26
finding information I need by searching	3,61	0,918	3,4	1,033	0,21
watching podcast of lectures	3,03	0,872	3	0,95	0,03
popular science talks about physics	3,24	1,012	4,06	0,969	**-0,82**
reading popular science about physics	3,22	0,972	3,95	1,002	**-0,73**
watching popular science videos about physics	3,64	1,053	4,22	0,906	**-0,58**

Student 2 e.g., shows how she has made an autonomous choice of going to popular science to keep her motivation for physics up: "*I have in a way, parallel with my studies, to keep the spark, had to read popular science and sort of getting some* *input on that side parallel to my studies.*" We can see that this activity supplies motivation she needs for her studies. At the same time, it is considered as something separate from them. She also separates the two with the following description of her studies: "It's not like it's popular science we are doing".

Similarly, we can see from Student 3. "*I read about it, about physics on quite a popular science level, but… it was something I found quite interesting*", while at the same time describing his knowledge in one field: "*When we start talking about quantum field, because I haven't had that, it still becomes for me, like, popular science, because I don't know anything about that.*" We see here that popular science becomes a description om "not knowing anything about" something.

Student 6 brings in the same skeptical view: "*I always felt that when you read popular science, you become a little insecure - do you understand this? To understand physics, you sort of have to work intensively with it over a long period of time and the understanding comes gradually. If you read a popular science book, it's interesting, but the you think: 'Do I really understand this now?'*"

3.2 Conceptual understanding vs. calculations

Understanding how the world works is a central motivational point for physics students, most of the interviewed Master's students regard conceptual understanding as important for choosing physics. All students stress the importance of conceptual understanding in physics. Two students without being asked explicitly, point to the use of math to describe physical reality rather than just math itself, as the reason they chose physics over math.

The reality in physics education is however that many of these students believe there is too little room for the conceptual understanding within university physics. Student 2 points out that "*at times it becomes a bit like you learn what's in the books, learn to calculate and solve exercises, but you perhaps don't get to attach it to physical phenomena you can observe*". S3 continues: "*You sit there at the quantum lecture, and go through an hour of calculations, and you get something, and then - you got, the math is ok, you understood every step, but pfff - what happened here, like? What did we figure out?*"

Student 4 sums the sentiment up with "*you have to understand it up against nature. If it's just symbols on a paper and you don't even know what it means, what the result is for the world around it, then I actually don't have much interest anymore.*"

The Master level students thus share the dual view on popular science seen in literature: Motivating, yes - learning, more doubtful. At the same time, they experience a lack of conceptual discussions in calculation-dominated physics classes.

3.3 A possible connection

From one of the interviewed first-year students, we however get an example of how popular science perhaps could have a positive role in learning physics, at a university level. Here we see students having an aha moment when they link learning to previous knowledge, given by popular science:

"*At upper secondary… Yes, I had some aha-moments. They're not as big as here at university, I feel. But my aha-moments are often that I think something is very cool or that I have heard about something, and then I finally learn about it.*" He then goes on to explain how popular science can give these aha-experiences in later education: "*For example, this relativity with Einstein, not that I understand it completely, but that I have gotten to hear something about it, learn something about it, then I think it's very exciting and I get that aha-experience.*"

Being primed by popular science and then learning (more) about something can thus create motivating effects. If the perceived gap between popular and "school" physics can be overcome; this then discloses a role in learning popular science. By priming the students and giving an overview of a field of research, students can connect what they learn in classrooms to a wider map of knowledge.

4 SUMMARY

Physics students have self-driven motivation to read popular science beyond what is communicated in media and movies. Our physics students repeatedly turn to popular science for motivation, as an active way of regulating motivation. In this sense, popular science will fit well as it is usually not a part of a curriculum and will be something students autonomously choose to pursue on their own. They find popular science and popular science lectures motivating. A motivating part might be that it might reactivate the goals of becoming a physicist.

We have seen that both academics and students have a dual view of popular science. While it is highly motivating, its' learning effects are doubted. Both earlier research and students interviewed in this paper, often describes a calculation-driven university physics education. They call for increased attention to conceptual understanding, which connects the mathematical physics to the world it's meant to describe. One of the questions we thus would like to put forward based on these data is whether the gap between the mathematical and conceptual is an important reason for the perceived gap between "popular physics" and "school physics".

Conceptual understanding is an important part of physics, and in cases where this is being neglected, it should be given more room. This should diminish the gap between calculation-oriented university physics and conceptually oriented popular physics. If this is successful, could popular physics then be a tool for increased conceptual understanding and a better overview of the field in university physics?

We believe the results from these different surveys prompt the idea that this question should be taken more seriously and suggest that there is a possibility of more conscious use of popular science even at the university level. We believe there are possible paths for popular science to contribute to learning, and in addition, popular science brings forth a motivational factor sorely needed by some students when facing a perhaps solely calculation-oriented university physics education.

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A cross curricular Comparison of Professional Capabilities in Engineering Education

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Abstract
In this paper we studied the student's perception of the acquisition of professional capabilities in Challenge based learning environments with a strong reflective component. The results show students feel the relevance of personnel development from the very moment the enter their master studies. However, they only truly acquire all the relevant professional capabilities when working in interdisciplinary teams on real life problems in interaction with stakeholders.

Introduction

Current trends in education, such as embedding challenge-based education and reflective activities, presume that professional skills training in these contexts strengthens students' professional capabilities. Moreover, it should prepare them for a better professional life after their higher Engineering Education. However, the variety in curricular design, the moment of measurements, and students' profiles will likely impact the students' perceptions of their capabilities. This paper investigates three types of challenge-based education offered on critical parameters. Successively, we will assess the impact of students' reflective journey in CBE on their perceived professional capabilities. The central questions is: **"What are the professional capabilities students feel they have acquired during courses including elements of challenge based education and reflection on personal, professional, disciplinary aspects?"**

The three CBE contexts concern (1) an MSc Programme in Robotics, (2) a fundamentals course in Bio-Medical Engineering and (3) a Second-year master course focused on interdisciplinary R&D development with external stakeholders. Each of these programmes/courses includes challenge-based elements; it consists of real-life cases, multi/interdisciplinary learning, stakeholder involvement, self-directed learning of students, collaboration, (transversal) skills development and last but certainly not least reflective learning. Together with the opportunities of a challenge-based learning environment, the reflection should expose students to learning that improves their professional capabilities. Professional capabilities consist of different elements based on the concept of the "deliberate professional" of Trede; the elements are:
personal development, collaboration, critical evaluation skills and contextualisation.

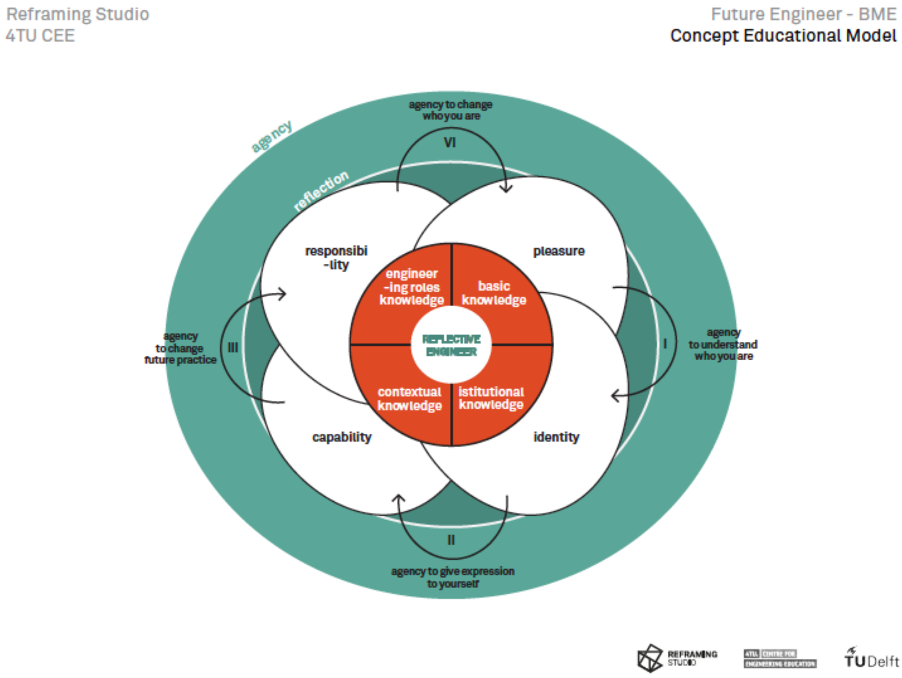
A survey has been administered to investigate the perceived professional capabilities. We will examine the curricular difference, moments of measurements, and to some extent, students' profiles related to the perceived differences. Finally, we will consider the implications for the curricular design of CBE and reflective activities.

THEORETICAL BACKGROUND

Nowadays, there is less congruence between scientific discipline and the occupational structure. New occupations and professions often emerge at the frontiers of disciplines, thus requiring a different kind of knowledge, skills and attitude (van Damme, 2022 (dies Natalis lecture wur). Biesta (2017) call this new purpose of education the task of qualification, socialisation and subjectification. The function of acquiring knowledge, skills and attitude for a job, the socialisation into a particular culture and the growing of identity as each individual are unique. Professional capabilities are representative of **the missing gap between** the more traditional disciplinary degrees towards the occupational structure, which also requires skills relating to socialisation and subjectification. According to Biesta, we need to balance these three educational functions and not over-emphasise one over the other. Trede (2016, 2022) has identified these additional capabilities, besides qualifications, as actions of the deliberate professional. She holds that reflexivity, action and dialogue will ultimately lead to purpose and values, decision making as supportive of choice and gaining change agency. The characteristics of the deliberate professional are expressed in fig. 1

Focusing on:

- Being aware of the complexity of the workplace practice, cultures and environments
- Being realistic about what can be done concerning existing and changing practices
- Positioning oneself in the field as well as making technical decisions
- Being aware of the consequences of doing and acting in relation to a particular practice.



In this" new model" (fig. 2), we have translated these principles into a cycle of Metamorphosis, wherein the kernel, the Qualifications and Socialisation are addressed at the level of basic disciplinary knowledge, the institutional knowledge of methods, tools and approaches and the accompanying skills, the contextual knowledge of authentic real-life situations of a company, institution or other stakeholder party and the finally, the individual engineering role or deliberate professional that emerges from the knowledge and skills accrued on the way, while centre-staging reflection on each of these (iterative) phases of growth. Where one first has to establish; who am I? How to express myself in a professional/academic context, have the insight and foresight to change future practices and eventually have the Agency to enact my role and change who I am. These translate into criteria that need to be met within the curriculum and are likely to be emboldened in challenging learning environments.

The three CBE contexts concern (1) an MSc Programme in Robotics, (2) a foundational course in Bio-Medical Engineering and (3) a Second-year master course focused on interdisciplinary R&D development with external stakeholders. These three courses have been chosen because they include reflection (on socialisation/subjectification) and are, to a greater or lesser extent, to offer a challenge-based environment (addressing qualification and socialisation) and in interaction and iteratively reinforce subjectification. Each of these programmes/ courses includes challenge-based elements; it consists of real-life cases, multi/interdisciplinary learning, stakeholder involvement, self-directed learning of students, Collaboration, (transversal) skills development and last but certainly not least reflective learning. These elements have been identified in scientific research from the 4TU Centre for Engineering education[1]. Together the opportunities of a challenge-based learning environment and reflection should expose students to learning that improves students' professional capabilities. Professional capabilities consist of different elements based on the concept of the "deliberate professional" of Trede.

In a recent review study by (Garcia-Alvarez et al., 2022), it is emphasised that higher education institutions are responsible for educating students to be relevant to the labour market and the need to adapt pedagogies of employability, where students learn to operate adequately across different contextual situations. They have investigated transversal skills in the literature and how oft these are mentioned by the industry as necessary skills to be learning in higher education to respond to and be aware of unpredictable environments. In contrast to this view, we would rather like to emphasise another stance, where it is not the industry that should or might determine what students need. Instead, it should be the students who have the tools and capabilities to shape and make sense of their personal lifelong learning trajectories. Despite this different viewpoint, there is a significant overlap in the knowledge and skills being addressed. However, it emphasises the individual's Agency to act with reason and decision in diverse situations. Thus, as Trede (2016) defined, professional capabilities have been operationalised in the elements; personal development, Collaboration, critical evaluation skills, and contextualisation, which are tooled to realise daily practices within a coherent model. (Higgs, figure 13.3, p……) see below fig. 3.

Fig. 13.1 Deliberate practice and deliberate education

We have further defined these elements in table 1 as;

Table 1 Constructs used to measure Professional Capabilities

Part 1 – Personal Development	
Self	Discovering who I am
Emotional Reflexivity	Dealing with emotions
Resilience	Bouncing back from set backs
Part II Agency	

Evaluating Information	Judgement against professional quality criteria/standards also known as evaluative judgement (Adawi)
Critical Stance	Critical thinking and taking a position concerning professional topics
Part III Collaboration	
Communication	Being able to collaborate with peers, within the community (team/groupwork) (Picard et. al)
Interprofessional Competence	Being able to communicate across domains/professional boundaries (Picard et. al)
Part 4 Contextual insight	
Informed Vision	Being aware of the wiser developments and one's (organisational) roles there in
Ethical Sensitivity	Ethical behaviour in complex sensitive situations. (Picard et. al)

In the table 2, we will show the elements of both the focus of reflection and the characteristic of challenge-based elements present in each course. Later on, we will reflect on these by combining them with professional capabilities.

Table 2. Characteristics of Challenge based education and the investigated courses.

Characteristics	**BME – 1st year MSc**	**1st entire year Robotics Programme, MSc level**	**Joint Interdisciplinary Course 2nd year MSc**
			Reflection (metamorphosis) Reframing/4TU- CEE based on Trede (2016)
Who am I	Personal reflection	Goalsetting	Establish personal learning goal at the beginning
Develop insight and foresight	Peer feedback from other teams	Continues feedback from staff and peers on reflection in portfolio assignment	Continuous feedback from peers, staff, stakeholders – during the course. Formalised reflection moments
How do I give expression to myself	X	Reflect on the received feedback in portfolio assignment	Reflect on feedback – write reflection doc.
Who I am and determine change	X	Feedback-cycle, setting new learning goals and making choices in that direction.	Growth feedback moments and reflection writing as a team and individual as part of the final assessment.
			CBE- based on
Learning Students work with teachers, in order to develop a deeper knowledge of the subjects they are studying. It is the challenge itself that triggers the generation of new knowledge, necessary tools and resources	Students follow lectures, workshops and at the end do a project with "real life" case. No external stakeholders are involved	Students design learning path, formulate learning goals (20 EC electives), follow multidisciplinary (5 EC) and integrated programme with focus on individual choices in the context of challenges in society. Transversal skills development /reflection portfolio (together 11 EC)	Students independently tackle and R&D project either with a societal or phenomenal problem.

Product It requires students to create a solution resulting in a concrete action	Results focus on solving the project assignment and passing the exam for their own learning	In the multi-disciplinary project students work with companies on real life cases by finding a robot integrated solution. A reflection portfolio is continuous.	Project report, including a concept design, prototype, model or research report
Focus it faces students with an open, relevant, problematic situation, which requires a real solution	It faces students with a relevant situation and pre-defined problematic for which a solution needs to be found	Students have to define the problem in teams and have to take the company's expectations into account, when generating ideas and creating solution findings for the multidisciplinary project.	it faces students with an open, relevant, problematic situation, which requires a real solution
Process students analyse, design, research and develop and execute the best solution in order to tackle the challenge in a way they and other people see and measure.	Students work with the assigned project in teams and generate products for their own learning	Students work during the whole programme on their development in skills in the (project) courses by reflecting in a portfolio and the guidance of mentors in mentor groups. As a final assignment the have to present their portfolio.	Students work in teams in collaboration with company staff and academics to come to a desired solution for a real-life problem
Students in the lead of the process, and from interdisciplinary backgrounds	Students (with narrow interdisciplinary backgrounds) coached on predefined problems space.	Students (with narrow Interdisciplinary backgrounds), work in teams, create an individual portfolio are coached by a mentor and partly define the problem space.	Interdisciplinary and intercultural students' teams are in the lead of the entire process
Teachers' role coach, co- research and designer	Instructing/ coaching students as expert.	Mentoring groups, mentors focus on student's personal development	Everyone (students, company staff/academic experts/IIP) is looking for answers.
Evaluation of the activities	Quality assurance and additional surveys + interviews	students reflect on the (technical) experiences. Instructing, coaching, guiding, advising.	Testimonials, surveys, interviews etc.

METHODOLOGY

In this mixed-method study, we have questioned whether students, through reflectional activities and course activities, felt better able to perform particular behaviour related to professional capabilities. The questionnaire has been developed to measure these professional capabilities across various contexts in two Master's programmes of an Engineering School, besides the interfaculty course referred to in this article. All of the Sample contexts include Reflective activities on personnel and skills development, some challenges – ranging in openness of the design briefs and "real" life cases, involvement of stakeholders, a level of flexibility in students' choice and a Master's level.

Professional capabilities are measured at four levels:
1st: Personal Development: Knowing oneself (Self), Emotional reflexivity and Resilience
2nd: Agency: skills to critically think about the problem at hand and take a stance; evaluate information at a professional level, such as evaluative judgements
3rd: Collaboration, consisting of interprofessional competencies and teamwork.
4th: Contextual Insight concerns contextualisation and ethical sensitivity.
.

The overall model components are derived from Trede's model on professional capabilities explained in her book the Deliberate Professionals (Trede, 2009). Such as having an informed vision, emotional reflexivity, resilience, and taking a stance. Questionnaire questions have been taken from existing and validated questionnaires or qualitative studies, amongst others from the IMPQ (Picard et al. 2021), which investigated professional teamwork skills. Furthermore, the critical thinking white paper from Davies & Stevens (2019) Pearson's talent management offers evaluative judgement and critical thinking items as a construct.

Table 3. Cronbach's alpha of each construct

	items	Cronbachs' alpha	Source
Part 1 – Personal Development		**.90**	
Self	N = 4	.75	Trede
Emotional Reflexivity	N = 6	.79	Trede
Resilience	N = 8	.79	Trede
Part II Agency		**.85**	
Evaluating Information	N = 5	.78	Critical
Critical Stance	N = 4	.77	Critical
Part III Collaboration		**.86**	
Communication	N = 5	.69	IMPQ
Interprofessional Competence	N = 5	.81	IMPQ
Part 4 Contextual insight		**.80**	
Informed Vision	N = 7	.67	Trede
Ethical Sensitivity	N = 4	.83	IMPQ

Response Rate
The sample population consisted of voluntary participants in a survey of those students who followed the course/programme. For BME, the response rate was N = 28 out of 100. For the Robotics, N= 47 out of 200, and for IiP, N = 54 out of 150, amounting to around 20 to 30% of the sample population. As the subgroups were not big enough for major comparative statistical procedures, we are reporting the aggregate average and (SD) on a construct (continuous variable) for each group. The ideal sample size with 95 confidence interval would be 177 in total. However we only have 126, which means we can interpret the data at a 85% confidence level, taking an error margin of around 5% into account, while at the same time not discarding relevant findings (Bacchetti, 2013)

As most of the Cronbachs' alphas were moderately high, we have been able to include all of the constructs. Hopefully, we'll be able to do a CFA when we have collected additional data in the next academic year. We do emphasise, however, that the question items have been taken from validated questionnaire scales, and we, therefore, assume they, together with the reliability measure, meet the quality criteria.

Focused Group Interview

After the survey, a focused group interview was held with students of the BME course N= 5, mentors of the BME- course N = 4, and Robotics N= 2 students. The JIP students have left testimonials. We have organised the group interviews around a journey map on which students could indicate their highs and lows within the course on specific key issues, such as engineering roles or organisation. After which, a conversation ensued about their likes, dislikes and recommendations for improvement. Equally, they indicated what they learned the most. No guiding comments were made apart from the engineering roles on aspects of the questionnaire. Here we will report on the Miro documented journey map and learnings. And possibly some quotes, as a systemic analysis has yet to happen on the transcripts of the group interview recordings.

RESULTS

In this part, we will 1st report on the survey results. Successively, we will proceed to the focused group interviews. In the conclusions, the results will be summarised..

Survey

We are comparing three different groups here. The constructs have been aggregated for a continuous variable. As almost all the assumptions for a One way ANOVA are met, no outliers, normal distribution (Shapiro Wilkes,05), apart from the Levine's test of homogeneity of variance, we have used the WELCH ANOVA to correct for differences in homogeneity and have used a post- hoc Games- Howell test and have found sig difference between all the groups. The following paragraphs will look at the levels and separate sub-constructs.

Table 4 Welch Anova test

Robust Tests of Equality of Means

		Statistic[a]	df1	df2	Sig.
Self	Welch	17.596	2	58.154	<.001
EmotionalReflexivity	Welch	21.694	2	62.087	<.001
Resilience	Welch	12.181	2	60.746	<.001
informedvision	Welch	11.938	2	63.925	<.001
EvaluatingInformation	Welch	19.469	2	55.782	<.001
CriticalStance	Welch	13.851	2	62.875	<.001
Communication	Welch	9.203	2	69.485	<.001
Interprofessionalcompetence	Welch	11.852	2	61.304	<.001
ethicalsensitivity	Welch	8.501	2	69.796	<.001

a. Asymptotically F distributed.

Personal development

In the personal development table one, we notice that the interfaculty interdisciplinary project (IIP) scores the highest average on personal development, closely followed by Robotics and the BME course, as shown in table 5.

Table 5. Personal Development (means /sd)

	SELF	EMOTIONAL REFLEXIVITY	RESILIENCE
IIP	M = 4.3 (SD.37),	M = 4.2 (SD. 44)	M = 4.15 (SD .40)
ROBOTICS	M= 4.1 (SD.51)	M = 3.8 (SD .48)	M= 3.9 (SD .46)
BME	M = 3.4 (SD.73)	M = 3.4 (SD .64)	M= 3.5 (SD .65)

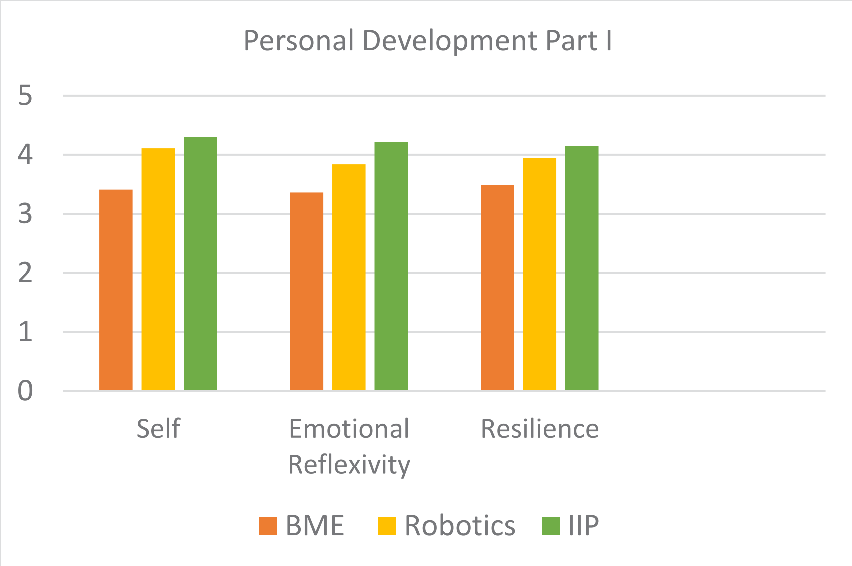
Despite the slight differences, there are significant differences for each sub-construct, Self, Emotional Reflexivity and Resilience smaller than < .001, between the IiP and BME groups. The IiP and Robotics group on the sub-construct Self do not score significantly .096. On the sub-construct Emotional Reflexivity, the Robotics/BME group scored significant (.005) differences. And on the sub-construct Resilience significance of .054 between Iip and Robotics and significance of .007 on Robotics BME. We are making the distance between IiP and Robotics more similar than the equation Robotics – BME.

The estimated medium effect sizes eta- squared are Self .30 Emotional Reflexivity .30, and Resilience .21. The numbers show a large effect size as their all higher than .14, meaning a larger proportion of the variance can be attributed to the personal development variable than what we can expect based on the standards of variance. Where Self and Emotional Reflexivity are vital aspects of knowing who one is. If we look at the course criteria, the BME course does not yet include all the reflection opportunities available, whereas the Robotics and IIP course does.
This finding suggests that going through the full circle of reflection is of importance; equally, the extent to which autonomy, interdisciplinarity and a real-life case is present may have impacted these results. Specifically, since Robotics is moving up to the fully challenge-based and interdisciplinary, autonomous shows results towards the IiP course. With items such as

- "I am aware of my engineering role."
- "I have become aware of my passions."
- "I have been able to make a choice that fits my personal value."
- "I feel more independent (in control)."
- "I am better able to make decisions."
- "I am better able to ask for help."

very close to the IiP course. Noteworthy is the item: I feel confident to share my ideas, which scores highest for Robotics average at 4.2 and an only average of 3.7 for IiP and BME. All the other items are scored close to BME.

Table 6. Visualisation average means Part I



Agency

The sub-construct Agency has the capability of giving expression to one Self. This Agency is supported through the creation of judgement and evaluation of professional standards in the survey evaluating information. Secondly, critical thinking helps to take a critical stance. Included in table x are the mean averages and SD.

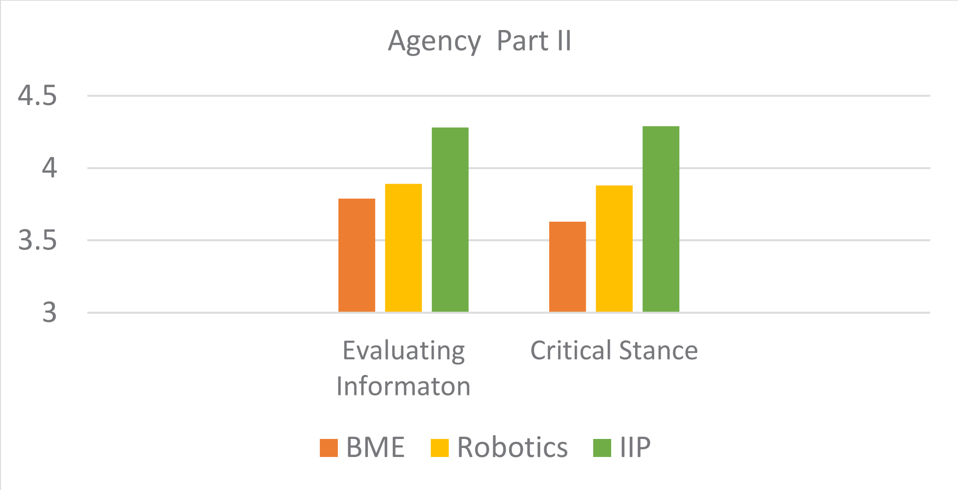
Table 7 averages part II

	EVALUATING INFORMATION	CRITICAL STANCE
IIP	M = 4.3 (.40)	4.3 (.49)
ROBOTICS	M = 3.9 (.42)	3.9 (.50)
BME	M= 3.8 (.65)	3.6 (.67)

Here we find a significant difference between IiP vs Robotics < .001 an IiP and BME .002 on Evaluating Information. The construct Critical Stance is significant <.001 between IiP vs Robotics and BME. Between Robotics and BME, we do not find a significant difference in Evaluating Information and Critical Stance.

Effect sizes being large again for Evaluating Information eta squared is .21, and for Critical Stance, the eta squared is .20. Albeit a little less than personal development, the impact still mainly shows the importance of evaluating information against professional standards with real stakeholders and learning to take a critical stance when dealing with peers, staff and stakeholders in real challenge situations. Although the Robotics group does have a slightly higher mean on individual items, they did not yet seem to have practised enough with these skills and remained close to the BME course, particularly on taking a critical stance.

Table 8 Visualisation Part II



Collaboration

The Construct Collaboration consists of the sub-constructs of Communication with peers and staff and Interprofessional Competence where the Communication with external stakeholders is emphasised and allows for reflection on the context of different disciplines, and provides insights and foresight to change these contexts. The means (rounded) averaged and standard deviations are reported below.

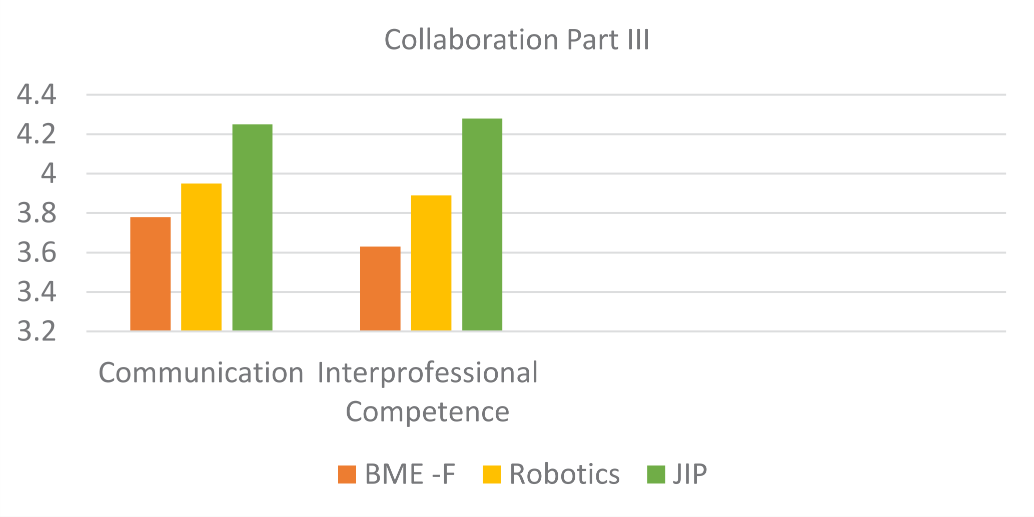
Table 9. Average Part III

	COMMUNICATION	INTERPROFESSIONAL COMPETENCE
IIP	M = 4.3 (.49)	4.3 (.49)
ROBOTICS	M = 3.9 (.56)	3.9 (.53)
BME	M = 3.8 (.48)	3.6 (.75)

The analysis of Communication shows significant differences between IiP and Robotics .017 and IiP and BME <.001. Robotics and BME do not significantly differ in Communication. For the interprofessional competence, we find both significant differences <001 for IIP vs Robotics/BME and non-significant differences between Robotics and BME.

Effect Size on Communication is moderate eta squared .12 and on interprofessional competence large .17. It shows that Communication within academia is at the end of the 1st year of normalised professional capability irrespective of the level of autonomy of students, the openness of the challenge brief and the reflection. However, for interprofessional competence, we again find that interactivity with external stakeholders and with peers and staff from other disciplines is of importance for the development of professional capability.

Table 10 Visualisation averages Part III



Contextual insight

Finally, contextual insight consists of having an Informed vision of the disciplinary context and ethical sensitivity. These skills should allow for contextualisation, determining one role and flexibly adapting based on individual values, responsible and moral judgement.

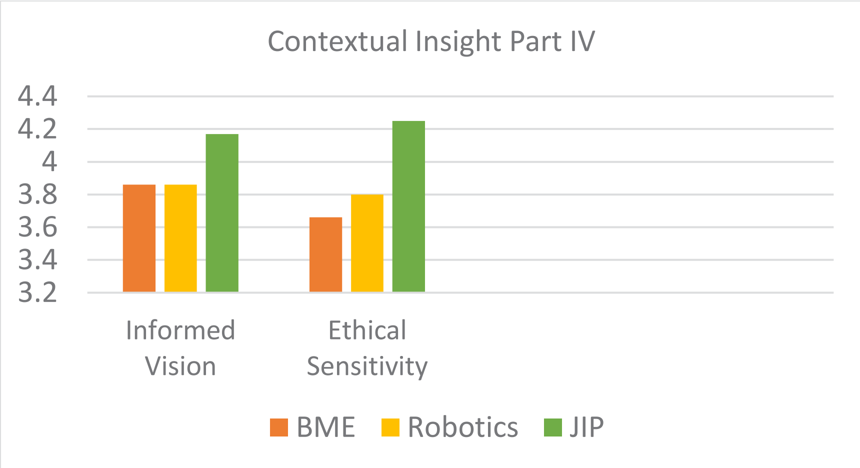
Table 11. average Part IV

	INFORMED VISION	ETHICAL SENSITIVITY
IIP	M = 4.1 (.40)	4.2 (.67)
ROBOTICS	M = 3.9 (.39)	3.8 (.70)
BME	M= 3.7 (.50)	3.7 (.63)

gain, significant differences at the <.001 level between IiP and Robotics/BME for informed vision and no significant differences between Robotics and BME. For Ethical Sensitivity, we find a significant difference at the .007 level between IiP and Robotics and .001 between IiP and Robotics, showing the Robotics group is much closer here to the IiP. For Robotics and BME, we did not find significant differences.

Effect sizes for informed vision are large .17 and for ethical sensitivity .12 moderate. Noteworthy on individual items is that the robotics students find it hard "to put themselves in the shoes of someone whose life could be affected by a project result". However, this fact may also be related to the fact that Robotics is focused on the artefact to a larger extent than the other two courses and possibly causes an indirect impact or no impact at all. Another Item is "I am aware of the historical development of my disciplinary field", in which Robotics scores (M = 3.6) are much lower than the BME (M= 3.8) /IiP (M= 4.0) courses. Possibly, as there is not much history yet. The item "I am aware of the wider (societal, academic, technical) system in which my discipline operates" is scored on par with the IiP at 4.0.

Table 12 Visualisation average Part IV



Focused Interview results

In this section, we include some of the major outcomes of the post-it notes (of the Miro board) on learning. One of the questions we have asked the student is what did you acquire in terms of professional skills during the BME and Robotics programme. Included below are the quotes.

Personal Development students mentioned;
BME – student; *"it is a good course to help the students understand their role as engineers and direct them to future choices*."
BME – Students: "*Looking back I can say that it was good to think about my role in society and I have learned a lot from the self-reflection assignments."*
BME – Mentor; *"Thought of role, they were never confronted with before, which may help them for the future."*
BME – Mentor; "*I liked that the course forced participants to think of engineering in a social context. It is an area often overlooked, or secondary to professional development, but ultimately it holds great importance and is key to the success of the individual."*
Robotics- students: *"Providing feedback and taking feedback in a constructive and valuable way."*
Robotics -student: "The portfolio was hard to set up in the beginning but helped me in my personal development, and I think it was very good to have, by design, spread out over the 1.5 years."

Professional skills:
BME- students: – "*Some workshops, e.g. on the debate, were really appreciated."*
Robotics students: - "*Communicating with many different backgrounds and being open-minded."*

Robotics students: "*I like the variety of the assignments and the connection to developments in the outside world; it always felt like we were working on contemporary topics.*"

Engineering knowledge:
Robotics students:
- *"it is always important to go back to the general question and not to get lost in details. "Breaking down the problem helps with developing a solution."*

Students in the BME course asked for more interaction with the stakeholder field and external professionals or involvement from the industry. Additionally, they asked for more professional skills training. And their wish for a stronger focus on personal development. Equally, better mentorship guidance would have been appreciated. Indeed, the Robotics students noted that the mentor's guidance was valuable in becoming more autonomous learners. In IiP, the continuous feedback from peers and external stakeholders, together with the reflections on content and personal development, forced them to work independently very quickly.

CONCLUSIONS AND SOME EXTRA OBSERVATIONS

In this study, we have learned that students value working on personal development from the very start of their Master's Programme. However, in the 1st course, students are not confronted yet with real-life cases; they are experimenting with a technical solution for a BME problem and focus on discovering who they are and their role—resulting practically in less pronounced development in professional capabilities. This result could either be due to the limited maturation of the students or the fact that they did not get challenged and autonomous enough during this course.

Furthermore, professional capabilities such as Agency, supporting how to give expression to myself, Collaboration: having insight and foresight to change future practice and contextualisation are particularly acquired in a situation where challenge-based education with real-life cases, external stakeholders and different academic disciplines are brought together. Although the maturation of students may also have affected these results, reflection at each level is one of the key tools to accomplish a greater mastery of professional capabilities. The portfolio reflection particularly helped students with their personal development and expression of their ideas, but only to a limited extent for the other professional capabilities. The CBE course for Robotics may have come too late in the process, as growth truly occurs when integration of the engineering knowledge, skills and personal development come together. An integration which the students highly appreciate. Equally, mentor coaching and InterVision in the robotics programme were highly appreciated and felt as if students were better prepared for their final thesis work.

DISCUSSION

In the introduction, we asked the central question: **What are the professional capabilities students feel they have acquired during courses, including elements of challenge-based education and reflection on personal, professional, disciplinary aspects?".**

We conclude that programmes where students work on real-life challenges with third party stakeholders, address personal learning goals, and critically reflect on their personal, professional development, and engineering knowledge seems to yield higher learning awareness levels. This increase in learning awareness levels can either be achieved through early integration in the programme or when students have a higher level of maturity. It might be more effective to offer students challenge-based education over a more extended period than to offer them internships, although this bold statement should be investigated.

When particularly looking at the course design, we note that:

- More attention should be given within the curriculum to evaluative judgement and critical thinking, and taking a stance
- Interprofessional skills informed visions, and ethical sensitivity is particularly learned when external stakeholders and a real-life challenge are available
- Personnel development can best be developed with goal setting, discovering who you are, beginning at a very early stage with the support of a portfolio, leading to more autonomy and maturity.
- Integrated curricula with self-management are likely to better prepare students for their master thesis work.
- Creating learning awareness should start early on through reflection and skills training, which may support motivation and autonomy.

In line with Biesta's observations, we feel that attention to Subjectification and Socialisation processes leads to better professional capabilities.

Limitation of study

This study has been realised with small numbers and should be replicated to substantiate the results. We intend to collect more data in the next academic year to get more data points and longitudinally analyse the impact of the intervention embedded in the programmes/courses. Also, more data points may allow for Confirmatory factor analysis of the theoretical framework to further validate the questionnaire. Nonetheless, we consider the results here as sufficiently validated as we worked both with validated questionnaire items and results showing despite the small group numbers, relatively large effect sizes, and a substantial impact across different course contexts. We equally felt the focused group interview substantiated the survey observations and gave them more depth.

Naturally, having said this, it should be noted that the issue requires additional study. In particular, a more detailed overview of the CBE elements that directly contribute to one of the four levels of reflection and learning awareness. This investigation should include teachers triangulating results and matching these results against the summative assessment results of students, in parallel with the study of the reflection portfolio across different contexts. However, as the embedding of these professional capabilities elements becomes more necessary today in higher engineering education to tackle the complexity of today's world, extended and continuous research seems the only answer.

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Annex 1

Professional Capabilities Questionnaire

Measured on a 5 point likert scare from 1 strongly disagree to 5 strongly agree.

Personal- Part I Personal Development
Self

- Q1 I am aware of my engineering role(s)
- Q2 I have become aware of my passions
- Q3 I have been able to make choices that fit my personal values
- Q4 I can articulate what I need to personally grow

Emotional reflexivity

- Q5 I tend to reflect and discuss positive/negative experiences
- Q6 I feel more confident
- Q7 I feel more independent – in control
- Q8 I stay calm when under pressure
- Q9 I am better able to make decisions
- Q10 I can empathize better with people in different (professional) positions

Resilience

- Q 11 I am better able to ask for help
- Q 12 I ask more questions based on my reflective activities
- Q13 I feel confident to share my ideas
- Q14 I have learned from my own mistakes
- Q15 I feel engaged with the offered learning materials
- Q16 I am proactive in seeking new learning experiences
- Q 17 I recognize the need for professional boundaries
- Q 18 I persevere in difficult circumstances

Part II Agency

Evaluating Information
Q8 The ability to evaluate the quality of information presented
Q9 I am aware of the assumptions I make with respect to the problem at hand
Q10 I recognize assumptions others are making with respect to a problem discussed
Q11 I validate the inference I make from data (truths or falsification)
Q12 I am aware when certain conclusions are drawn following from information in given statements

Critical Stance
Q13 I interpret and weight evidence and decide if generalization or conclusions are warranted
Q14 I recognize relevant and irrelevant arguments given to solve a particular problem
Q15 I make judgement on the basis of accumulated evidence and reasoning
Q16 I find it easier to establish what to do or what strategies to adopt to the problems we are solving.

Part III Collaboration
Communication
Q17 I am good at trying to understand the perspective of other team members. D
Q18 I am good at making sure that all the necessary information is shared with other team members. D
Q19 I am good at explaining my ideas in ways that other people can understand. D
Q20 When someone disagrees with me, I am good at paying close attention to see if I can learn something from their alternative perspective. D
Q21 I can normally work productively with another team member even if I am angry or frustrated with them. D

Interprofessional Competence
Q22 I am good at recognizing the knowledge and skills of different professions involved in a project team. E
Q23 I am good at being sensitive to the way in which different professions may use the same word. E
Q24 I am good at clarifying with people from other professions how their knowledge and skills contribute to each stage of a project. E
Q25 I am good at identifying the skills or knowledge that other professions in the team have, which I should try to develop. E
Q26 I am good at sharing responsibility with the other professions in the team for the overall success of a project. E

Part IV Contextualisation

Informed vision
Q1 I feel committed to sustainable development goals such as; equitable economic opportunities, environmental awareness, sustainable production etc.
Q2 I am able to envision alternative futures for the improvement of my disciplinary field
Q3 I am aware of the historic development of my disciplinary field
Q4 I am aware of the wider (societal/academic/technical) system in which my discipline operates
Q5 I am aware of the political, national/global contexts
Q6 I am aware how these context shapes individual lives
Q7 I am aware of the different stakeholder perspectives

Ethical Sensitivity
Q27 When working on a project, I am good at asking myself if a project like this could have a positive impact on someone else's life. C
Q28 When working on a project, I am good at asking myself if a project like this could have a negative impact on someone else's life. C
Q29 I am good at putting myself in the shoes of someone whose life could be affected by a project's results. C
Q30 I am good at identifying all the people who could be impacted by a project, no matter how directly or indirectly. C

ENGINEERS' PERCEPTIONS OF THEIR ROLE IN SOCIETY: THE SOUTH AFRICAN CASE

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ABSTRACT

Being sparked by interactions with students in the context of a course called 'Engineer in Society', this work-in-progress study explores how engineers conceived of their role during the period of apartheid in South Africa. The literature suggests that engineers consider their contribution to society in solely technical terms rather than in social or political terms. Using interviews with engineering academics, this paper examines how respondents' navigated engineering practice and academic work. The findings indicate significant complexity in terms of how engineers conceived of their role in relation to society, a relationship that was mediated by politicised academic institutions and differentiated cultural norms. This also has an impact on the notion of the culpability of engineers and the question of whether they resisted or complied with the pervasive and brutal regime of apartheid. Although the study revealed a variety of positions and dispositions taken on by engineers, an interesting stance was that of 'technical activism' which involved engineers resisting apartheid by exploiting the liberal spaces that were made available in the context of their engineering work.

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1 INTRODUCTION

Given the nature of the engineering curriculum, it is not surprising that engineering students tend to view their contribution to society in solely technical terms [1] while being inattentive to the political dimensions of society. A new undergraduate course offered at the University of Cape Town in 2020 called 'Engineer in Society' aimed to bring the social aspects of engineering to the attention of students. Given that the first democratic elections in 1994 was such a singular moment in the history of South Africa, the course deals directly with apartheid – the infamous political regime that gripped South Africa for 48 years before democracy – and its impact on engineering activity.

Interactions with students in this course prompted the launch of a research project to investigate two things: (i) the transformational learning that was a specific intention of the course and; (ii) the role of engineers – both academics and practitioners – in South African society, focusing on how they negotiated apartheid. Some work has been done on the first part [2] and this paper is a work-in-progress for the second part of the project. While the intention is that these findings feed back into the course to provide the students with a more nuanced understanding of how engineers negotiated society under apartheid, this phase has not yet been initiated.

1.1 Background

To provide some background, it is worthwhile describing how the broader research project emerged from the Engineer in Society course. At the beginning of 2020, when the course was being offered for the first time, two lectures were set aside to introduce students to the role of engineering in South Africa. The first lecture was billed 'part 1' and it focused on the role of engineering during apartheid; the focus of part 2 was the role of engineering in society after the first democratic elections.

Part 1 sketched the history of engineering in South Africa, starting with the discovery of gold which caused a sudden influx of engineers in the late 1800s and marked the start of engineering education in that country. It also delved into the details of a few large engineering projects, pointing out the political dimensions of these projects and how they supported apartheid in one way or another. The intention was to then open the floor (this was about a month before the Covid-19 pandemic hit South Africa) for discussion. The question put to the students was whether engineers have 'blood on their hands' [3] for their role under apartheid. But before opening the floor, it dawned on the lecturer – who is one of the authors of this paper – that the political dimension of engineering is very seldom discussed.

As might be expected, the student discussion was lively. Most students were of the view that engineers who worked in South Africa during apartheid are guilty for not standing up to such an unjust system. Some empathised with the inaction of engineers, pointing out that engineers were probably weighing up the personal cost, and the cost to their families, if they spoke out against what was a very brutal regime. One student suggested that engineers were not liable because they were just doing their jobs but this was not a popular perspective.

It is important to point out that all of the students in the class were born after 1994 and therefore had not experienced first-hand what apartheid was like but were reflecting on the issue from what they had learned in school and heard from others. Given that the class was made up of a diverse cohort of students, ranging from those whose parents and families had been severely oppressed by apartheid laws, others with families who benefited from apartheid, and a few international students, a variety of perspectives was to be expected.

As mentioned above, this experience sparked the launch of a research project and this paper is a work-in-progress on the second part of the project which focuses on how engineers negotiated South African society, particularly under apartheid. It addresses the following research question:

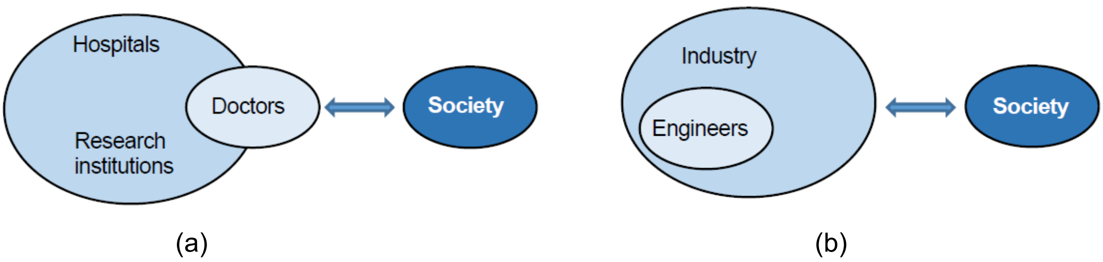
How did engineers conceive of their role in relation to society during the period of apartheid in South Africa?

What follows is a discussion of the role of engineering and engineers in society, as framed by [4] and [5], followed by the research approach. The initial findings are then discussed and conclusions are drawn that consider the particular dimensions of the South African case.

2 CONCEPTUAL FRAMING

Engineers play an important role in society. Definitions of engineering emphasise the technical aspect, but they also frequently include the social aspect of engineering. The national body for accreditation of engineering programmes and professional registration, the Engineering Council of South Africa (ECSA), defines engineering as 'the practice of science, engineering science and technology concerned with the solution of problems of economic importance and those essential to the progress of society' [6]. Other definitions point to the role of engineers in advancing or improving society for the benefit of humanity.

Exactly how engineering does this is complex. Unlike doctors who have a more direct relationship with society, Aslaksen [4] suggests that engineers are almost completely embedded within industry which mediates the relationship with society.



Illustrating the indirect interaction between engineers and society, in (b), as opposed to the direct interaction between doctors and society (their patients), in (a) [4].

The term 'industry' is used here in a broad sense to refer to the engineering enterprise as well as government entities and even educational institutions [4]. However, in the context of this work it is important to distinguish between engineers who work in industry and engineering academics who work at universities.

This framing has implications in terms of the potential benefits that engineering holds for society. The technical expertise of engineers is vital for the growth of industry and, through this means, has the capacity for improving humankind. As the world becomes increasingly globalised, engineering is adapting and remains important for the growth of industry in general. However, Cech [5] critiques the norms and values embedded in engineering, noting the narratives of heroism that the profession uses to present itself in relation to society. This is evident in the *Grand Challenges* [7] document produced by the US National Academy of Engineering that Cech [5] targets but can also be clearly seen in the centenary publication of the South African Institute for Mechanical Engineering (SAIMechE) [8] that was published in 1993, one year before the fall of apartheid. Such documents tend to valorise the technological aspects, narrowly conceiving of social change as technological change with scant regard for the ‘religious, political, environmental, and cultural factors that are interwoven in societal change’ [5].

This research paper contributes to Cech’s [5] call for increased reflexivity – that is, a ‘critical examination of engineers’ role in the past, present and future of societies’. It does this by drawing on the context of South Africa, a country with a history of a political system which discriminated on the basis of ‘race’[2], resulting in a legacy of social and economic injustice. In exploring how engineers understood their role under apartheid, in terms of valorising technological aspects , it provides a critical evaluation of the role of engineers in society more generally. Following this, it explores the extent to which engineers saw themselves, within the context of a pervasive and brutal regime, as contributing to, or resisting, apartheid.

3 METHODOLOGY

3.1 Research design

A qualitative research design [9] was developed for this study. Semi-structured interviews were the primary source of data with the intention to access the perceptions and experiences of the participants. This paper is a work-in-progress piece, reporting on the findings of the first five interviews with engineering educators.

3.2 Data collection and analysis

The interview schedule was developed by all the researchers at the start of the project, revisited before data collection took place and adjusted as themes emerged from the interviews. The interviews were conducted face-to-face or online via Zoom or MS Teams. Respondents were selected through purposive sampling with the aim of ensuring some representation of the sub-disciplines of engineering (mechanical, electrical and chemical). All of the respondents selected for this initial stage were white males who had worked in academia for between 22 and 43 years, thus having experienced the workplace during apartheid. The respondents had a mix of university and industry experience. One respondent had spent significant time in industry – 20 years – before joining the university but most combined industry work with university research in some way. One respondent – who saw himself more of an

[2] It is acknowledged here that ‘race’ was used as a construct to institutionalise oppression in South Africa. Such references are not intended to entrench racial classifications. However, given the history of South Africa and the nature of this study, it is impossible to avoid the use of these designators.

activist than anything else – left engineering during his undergraduate studies although he remained active in engineering education.

Ethics approval for the research was obtained through the Faculty Ethics Committee to ensure that issues such as protection of information and informed consent were addressed. Pseudonyms were used when storing the data and reporting the findings. Further permission was required from the UCT's Human Resources division since some of the respondents were employees of the university.

The table below provides a brief description of the trajectories and positions of the research participants. The interviews that were conducted in person were audio recorded; those conducted online were video recorded. In both cases the recordings were transcribed which formed the basis of the findings. A methodology of narrative inquiry in the mode of Polkinghorne [10] was employed for the data analysis. Narrative inquiry is particularly suited for the topic of this paper since a 'storied narrative… preserves the complexity of human action with its interrelationship of temporal sequence, human motivation, chance happenings, and changing personal and environmental contexts'. Polkinghorne [10] identifies two forms of analysis in his work but this paper draws on 'paradigmatic analysis' which analyses a set of narratives, the aim being to 'identify particulars as instances of general notions or concepts'.

Table 1: Research participants

Pseudonym	**Background**
Nikolai	Engineering academic involved in theoretical research around the deformation of materials at an English-language university during apartheid.
Gary	Grew up in Rhodesia (now Zimbabwe) to English-speaking parents, Worked in engineering consulting for 20 years before working part time at the university and consulting.
Zachery	Studied engineering but switched to a degree in applied mathematics. Took a university post as a way of being an activist in the higher education space.
Ryden	Born into an Afrikaans-speaking family and served two years in the military during apartheid. Worked for an engineering company that consulted for an arms procurement company under apartheid. Currently an academic at an English-language university.
Barry	Grew up in South West Africa (now Namibia) and studied in South Africa. Now an engineering academic at an English-language university.

4 FINDINGS AND DISCUSSION

Although this paper draws on only five interviews, the results demonstrate a complex interaction between institutions, engineering activity and the political complex that had an overbearing effect on social activity. This in turn affected how engineers understood their role in South African society during this time. Although the interviewees were all engineering *academics*, there was significant overlap in terms of their work for (private) industry and university work which involved academic research and associated activities such as publishing papers and attending conferences. Of course, successful technical research in the university context often leads to collaborations and contracts with industry. However, the findings suggest even more of an overlap through a close, symbiotic relationships between industry work and university research, as well as dual roles via part-time appointment arrangements.

This has implications for understanding the impact of engineering activity on society since a mutually beneficial relationship between the university and industry suggests even more embeddedness. For example, if an engineer working on a particular technology dedicates time to writing research papers for publication because of the prestige and reward this provides in the university space, this takes time away from the development of technology and its application which arguably has a greater chance of impacting society.

For this initial analysis, it is useful to focus on the armaments industry and the electricity industry although other industries, such as the synthetic fuels industry, were also mentioned. Nikolai was involved in theoretical research around the deformation of materials. This work was relevant to the arms industry but the English-language[3] university at which he was employed prohibited academics from associating with industry in any way, whether private arms companies or the arms procurement agency of the South African Department of Defence, Armscor. Nikolai relates how he found himself in a ‘lose-lose situation’ because, while he was prohibited from associating with any organisations that supported apartheid, he was treated as if he belonged to an apartheid state when travelling overseas for conferences.

In contrast, Ryden was born into an Afrikaans-speaking family, went to an Afrikaans high school and then served two years in the military which, at the time, was compulsory for all school-leaving white males. He then went to an Afrikaans university and studied engineering. Immediately after graduating, he started working for an engineering company which consulted for Armscor. During this time, he retained ties to the university in terms of lecturing and he also studied his Master’s:

> … I actually did my Master’s on the aerodynamics of a mortar bomb. And I remember at that time, I thought, ‘I don’t know… this is not ideal’ and so on but, you know, it's a cutting edge project, that's what do you think, you know, I do this cutting edge project and CFD modelling and wind tunnel work and all that. But… but the application, I guess I told myself, ‘Well, we’re protecting the country’. I mean, I was in the army for two years... I mean, you are dulled a little bit to this… you know, you don't think too deeply about all the other stuff.

What is interesting about these stories is the very circumscribed way in which engineering work impacted society. Nikolai was very much embedded in the English-language university at which he was employed. Its policies limited his interactions with industry so that he researched in a rather isolated way. Interestingly, the stand that the university took against apartheid (although whether it went far enough is contested) also meant that he identified with its struggle against apartheid. As well as setting limits on association with industry, the university partnered with progressive corporations that funded programmes for the admission and academic support of black students a decade before these students were officially allowed onto

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[3] As a result of its colonial past, South Africa was divided into English- and Afrikaans-speaking universities under apartheid.. Afrikaans is a derivative of Dutch which was spoken by the first European settlers.

the campuses of 'white' institutions. In the case of Ryden, he was also very much embedded in industry, even working for a company that Nikolai was prohibited from interacting with. The difference was that his upbringing and army experience 'dulled' his conscience about the possible consequences or implications of his engineering work on society.

Another of the respondents, Gary, spoke at length about the embeddedness of engineering in industry. He worked for about 20 years in electrification before he joined an English-language university in 2000. This meant that much of his work occurred during the apartheid years which resulted in him building up tremendous experience in low-cost electrification. He put this to use in the strong drive for electrification after apartheid fell and became involved in work with the national utility, municipalities in South Africa, electricity entities across sub-Saharan Africa as well as becoming involved in electrification policy at various levels. He shared how he has even given comments twice to the Federal Energy Regulatory Commission in the USA. About embeddedness, he had this to say:

> The technical has no impact except through social, economic, and legal provisions. We kid ourselves that we're important as engineers. But it's not our engineering that's important, it's our *outputs* and our *outcomes*… through assimilation in society, [this] gives the *impact*, which is quality of life or economic activity or things like that. We are at the bottom end of this chain. And most engineers don't operate... don't even get into the assimilation areas, don't… don't even look at it.

The extent to which this embeddedness relates to the culpability of engineers in relation to apartheid is interesting. One might expect that, since engineers are so embedded in industry (broadly speaking), they see themselves as being less culpable or responsible for the injustices of apartheid. Interestingly, both Ryden and Nikolai acknowledged some guilt in terms of not standing up against apartheid, even though they were in very different social circumstances. Speaking about himself, Nikolai said:

> …my wife and I had a view that you are either against apartheid and you were an activist, or you basically just sat through the middle of it and allowed these things to happen around you. And you were – if you did that – you were just as guilty…

Ryden spoke about the difficulty of recognising that apartheid was wrong when you were raised in a system that supported – and was supported by – apartheid: '…it is very difficult. I mean, I would definitely say I have contributed to something that in the big picture is not right…'

Gary and another respondent, Zachery, both argued that one had to exercise as much agency as possible, in whatever position one found oneself, to challenge the system. Everyone was aware of the very serious consequences of becoming known to the Bureau of State Security (BOSS) who tapped phones, sorted to tactics of intimidation, and incarcerated – or worse – dissidents for transgressing apartheid laws. To avoid this meant trying to find ways to oppose the systematic injustice that pervaded society while 'keeping your nose' clean (in the words of Nikolai).

Since the areas that Gary's consulting firm were assigned to were designated 'black' by the government, he saw his electrification work as significantly improving the quality of life of the recipients of his efforts. Although he was not a supporter of the regime, and he recognised the social and political factors at play in engineering, he took this stance: ‘I made it clear that my contribution was technical.’ He related many instances of how he worked hard to ensure good access to electricity at a reasonable cost, even if his client was not supportive of this effort.

Zachery is an interesting case because he saw himself, firstly, as an activist and then as an educator. The English-language university at which he worked was simply the context he chose to push against the pervasive injustices of apartheid that he recognised, both before *and after 1994*. About the role of engineers under apartheid he made this comment:

> …whether you are an engineer, or whether… it didn't matter what you were, and, and, you know, because it was so tightly controlled… as long as they were pushing the boundaries, you know, as long as they were willing to push the boundaries. In other words, they can't just accept that in fact, the plan is that these people aren't going to have electricity… the issue was to push; push in the liberal spaces that were created. And to always have to keep your eyes open to look below the surface as to what's happening.

5 CONCLUSION

The emerging findings from this study suggests indicates, as expected, that the embeddedness of engineering activity mediates the engagement of engineers with society. However, the multiple dimensions of the relationship between engineers and society show that this process of mediation is extremely complex. The ways in which the participants navigated apartheid society was influenced by the academic institutions at which they were employed, and the ways in which academia interacted with the engineering industry. Furthermore, the differences between the cultural norms within society (in this case, between Afrikaans- and English-speaking segments of society) added another layer of complexity. These differences extended to the overlapping constituencies of academic institutions, engineering industry and the state.

This complexity plays out in terms of how engineering academics conceived of their culpability in relation to apartheid. The framing of the lecture given in the Engineer in Society course assumed inaction and complicity on the part of engineers, but this research indicates a range of reflexivity. Some respondents did conceive of their relative inaction as contributing to the systematic oppression of apartheid (Nikolai and Ryden) although this was couched in explanations about the difficulty of standing up the regime. Others saw themselves as alleviating the suffering of black people through their engineering work and associated technical prowess (Gary). While this does not equate to a narrative of engineering heroism in the sense of Cech [5], it can perhaps be understood as ‘technical activism’ on the part of South African engineers who saw themselves as resisting apartheid by exploiting ‘liberal spaces’. Others, such as Zachery, considered themselves as activists under apartheid, and emphasised the importance of ‘look[ing] below the surface as to what’s happening’ rather than allowing their conscience to be ‘dulled’ by the prevailing political system. Across the spectrum, these perspectives provide valuable insights and much-needed material for students to understand the South African case, the complexity of society and the role of engineers within it.

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EMOTIONAL EMPATHY AND ENGINEERING STUDENTS' MORAL REASONING

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ABSTRACT

Although engineering education is often characterized as a principally rational activity, research suggests that emotions are vital for learning at all levels of education. In ethics education in particular, there is evidence that including mild emotional information in case studies can enhance learning. Evidence also suggests that specific emotions such as guilt and shame can impact on motivation to act in ethical scenarios. The place of emotions in ethics education remains controversial, however, since emotion can be perceived as a source of bias rather than as a valuable factor in learning and in motivating action. While some specific emotions have been explored in ethics research, there is a lack of empirical research addressing the relationship between ethical judgement and emotional empathy. In this research, therefore, we

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aimed to investigate the impact of mild emotional empathy on engineering students' ethical judgements. We conducted this study as an experimental design with 305 participants in two groups. Both groups took a modified version of the Engineering and Sciences Issues Test (ESIT) with an experimental group in which we induced a low level of emotional empathy and an emotionally neutral control group. Results show that a low level of emotional empathy does not impact participants' ethical decisions/judgments. Since the prior research evidence suggest that low level of emotional content improves learning, and given that it does not introduce biases in moral reasoning, we conclude it would make sense to include a low level of emotional content into ethics case studies.

1 INTRODUCTION

The role of emotions in engineering education has been the subject of increased research in recent years [1]. There is also a growing literature on the role of emotions in moral decisions in engineering and in ethical decision making more generally. Researchers even have latterly begun to focus on the various effects of some specific emotions which are called moral emotions such as empathy [2], shame [3], embarrassment, and guilt [4] in engineering and science education. However, given that emotions are vital for learning at all levels of education, the area is still under-researched.

In engineering ethics education, the importance and use of ethics cases, which are framed as a moral dilemma, is frequently highlighted [5, 6]. For example, Kerr, Brummel, and Daily stated that the use of case studies in engineering education is one of the most prominent methods of ethics training [7]. Some of this literature indicates that emotions can be important for the educational process related to using case studies to learn ethics. For example, Thiel et al., found that emotional case content stimulates the retention of cases and facilitates the transfer of ethical decision-making [6]. The researchers stated that emotions also make cases more realistic, an essential component for effective case-based instruction, and are an inherent part of ethical decision-making.

However, the place of emotions still remains controversial. There is evidence [8] that highly emotional cases can reduce student learning from case studies, and perhaps such cases should be avoided. This is an interesting finding given that many engineering ethics cases involve large scale death and destruction (Challenger and Columbia Space Shuttle disasters, Netherlands Flood Disaster of 1953, the Ford Pinto Case, Volkswagen emissions scandal, Hyatt Regency Walkway collapse, Chernobyl, the Bhopal Union Carbide disaster, and others). Indeed, it has frequently been argued that emotion may play a potentially harmful role in biasing rational judgement [9]. On the other hand, there is also evidence that experiencing no emotion during an ethical event may actually impede moral judgement [4] while some of the empirical literature also highlights emotion’s role in moral motivation [10]. This leads to our research question: If our goal is to enhance learning without biasing moral judgement, what is the appropriate degree of intensity of emotional content in engineering ethics case studies?

The literature thus far has explored some specific emotions. Johnson and Connelly, for example, found that feelings of guilt are positively related to making ethical decisions [11]. Higgs et al., supported the proposition that guilt, shame, and embarrassment exert differential effects when making ethical decisions [4].

Furthermore, Han et al., not only addressed the importance of moral emotions in all stages of the moral decision-making process but also indicated the effects of suppressing these emotions on ethical decisions. They argue that suppression of guilt and shame influences each of the three stages of the moral decision-making process; judgment, intention, and behavior differently [12].

While some specific emotions (guilt, shame, etc.) have been explored in ethics research, there is a need to look at emotional empathy. This provides a more focused research question: If our goal is to enhance learning without affecting moral judgement, what is the appropriate degree of intensity of emotional empathy in engineering ethics case studies? In this research, as a first step, therefore, we aimed to investigate the impact of mild emotional empathy on engineering students' ethical judgements by using the mild emotion-induced case studies.

2 METHODOLOGY

2.1 Method

We conducted this study as an experimental design with 305 participants in two groups. Both groups took a modified version of the Engineering and Sciences Issues Test (ESIT) with (a) an experimental group in which we induced a low level of emotional empathy and (b) an emotionally neutral control group.

2.2 The Engineering and Science Issues Test (ESIT)

In this study we used the ESIT test as a measure. In engineering ethics education, researchers have commonly used the Engineering and Science Test (ESIT), which is based on neo-Kohlbergian understandings of ethics [13]. The ESIT was developed by Borenstein et al., and includes six ethical dilemmas [14]. These dilemmas are related to engineering and science, in response to which participants are asked to make a choice. For each dilemma, participants rank the relevance of twelve considerations to their decisions. Then, they pick and rank the four most important considerations. Based on Kohlberg’s theory [15], to assess engineering students’ moral development, each of the twelve considerations corresponds to either the (a) pre-conventional, (b) conventional, or (c) post-conventional schema, or (d) a nonsense category, included as a check to ensure participants are considering and completing the ESIT in earnest. Rankings are analysed to determine the prevalence of post-conventional reasoning, measured by the P-score, and scores for conventional and pre-conventional moral reasoning can also be calculated. Another measure used is the N2 score which assesses the prevalence of post-conventional relative to pre-conventional reasoning [14].

2.3 Emotion Induction in the Case Studies

In this study, we induced emotional empathy into the six case studies of the ESIT to apply to the students. We have adapted these case studies to generate a mild feeling of emotional empathy. We did this by adding the following features to the experimental group’s cases: (i) an emotional target (people that could be empathized with), (ii) a similarity between decision-maker and target group (since empathy is typically enhanced by perceived similarity), and (iii) evidence of potential distress of target (which might give rise to empathy). In order to ensure comparability of control and experimental case studies, the emotional target was also added to the control case studies. For example, in the original version of the ESIT, the first case study is as follow:

Case 1 (Stock)

> Engineer Jameson owns stock in RJ Industries, which is a vendor for Jameson's employer, Modernity, Inc., a large manufacturing company. Jameson's division has been requested by management to cut one vendor: either RJ Industries or Pandora Products, Inc. Pandora Products makes a component that is slightly higher in quality and slightly more expensive than that made by RJ Industries. Management and the other engineers in her division do not know that Jameson has a financial interest in one of the two vendors.

Firstly, we only added an "emotional target" (added in red) to this case for the control group as follow:

> Engineer Jameson owns stock in RJ Industries, which is a vendor for Jameson's employer, Modernity, Inc., a large manufacturing company. [Jameson has a lot of interaction with the main sales representative for his company's products in both RJ Industries and Pandora Products], Jameson's division has been requested by management to cut one vendor: either RJ Industries or Pandora Products, Inc. Pandora Products makes a component that is slightly higher in quality and slightly more expensive than that made by RJ Industries. Management and the other engineers in her division do not know that Jameson has a financial interest in one of the two vendors.

Then, we added "similarity between decision-maker and target group" and "potential distress of target group" for the experimental group as well as an "emotional target" as follows:

> Engineer Jameson owns stock in RJ Industries, which is a vendor for Jameson's employer, Modernity, Inc., a large manufacturing company. [Jameson has a lot of interaction with the main sales representative for his company's products in both RJ Industries and Pandora Products], [both of whom are a similar age to Jameson and all three also graduated from the same university]. Jameson's division has been requested by management to cut one vendor: either RJ Industries or Pandora Products, Inc. Pandora Products makes a component that is slightly higher in quality and slightly more expensive than that made by RJ Industries. [Jameson knows that this decision could have a negative impact on the career of the sales representative affected]. Management and the other engineers in her division do not know that Jameson has a financial interest in one of the two vendors.

The 'Jameson has a lot of interaction with the main sales representative for his company's products in both RJ Industries and Pandora Products' here can be seen as an "emotional target". Being 'a similar age' and graduating from 'the same university' can be seen as a "similarity between decision-maker and target group". And, 'the decision could have a negative impact on the career of the sales representative affected' can be seen as an "emotional empathy of target group".

2.4 Participants and Data Collection Procedures

Participants were assigned to a control or experimental group randomly and they took either the standard (control) or modified (emotion induced-experimental) version of the ESIT. The tests were administered on-site in December 2021 at a large technical university in mainland Europe. The tests lasted 40 minutes. Participants were not asked for any identifiers (e.g. name or other ID). Basic demographic data were collected (e.g., age, gender, main field, work experiences in engineering or technical domains). An overview of the participants is included in Table 1.

2.5 Data Analysis

We excluded questionnaires from the analysis if they met one of several criteria below because they were either too nonsensical or had omitted too many questions to be considered reliable:

- Failed to complete 24 or more rating questions (equivalent to two dilemmas)
- Failed to complete 9 or more ranking questions (approximately two dilemmas)
- Received a “nonsense” score of 11 or more points.

After applying the above metrics to the participants' responses, we excluded 5 questionnaires out of 305 from the analysis. In total, we included 300 (150 control groups and 150 experimental groups) questionnaires in the analysis. In our study, first, we performed the descriptive statistics for all data. Then we computed participants’ post-conventional score (Post-S), pre-conventional score (Pre-S), conventional score (Con-S), and N2Score (N2-S). Post-S is based on a participant's ranking of prototypic items written for Kohlbergian Stages 5 and 6 (Post-conventional level). The Post-S is interpreted as the relative importance participants give to principled moral considerations (Stages 5 and 6) in making a moral decision. Similarly, while Pre-S is interpreted for Kohlbergian Stages 1 and 2 (Pre-conventional level), Con-S is interpreted for stages 3 and 4 (Conventional level) moral reasoning. Since it uses both rating and ranking data than the Post-S, the developers of the original test prefer to use the N2-S. The N2-S assesses the prevalence of post-conventional relative to pre-conventional reasoning [14].We used specific calculations that Borenstein et al., (2010) formulated in their study for calculating Post-S, Pre-S, Con-S and N2-S scores. Then, we conducted two-sample t-tests or ANOVA on the differences in each mean and score for the groups. The results of these tests are provided in Table 2 across several groupings. We marked the results in the Table 2 that are significant at the 5% level or better.

3 RESULTS

Table 1. Descriptive statistics and scores of the groups

		Post-S	Pre-S	Con-S	N2-S
Group	Control (N:150; 50%)	0.47	0.14	0.30	4.81
	Experimental (N:150; 50%)	0.47	0.13	0.32	4.84
Gender	Male (N:163; 54.3%)	0.46	0.15	0.30	4.57
	Female (N:133; 44.3%)	0.48	0.12	0.33	5.06
Age	18-20 years old (N:157; 42.3%)	0.47	0.14	0.31	4.59
	21-23 years old (N:113; 47.6%)	0.48	0.13	0.31	5.23
	24-35 years old (N:30; 9.2%)	0.45	0.15	0.32	4.60
Level of Study	First Year Student (N:140; 46.7%)	0.47	0.14	0.32	4.73
	Second- & Third-Year Bachelor (N:89; 29.7%)	0.46	0.13	0.32	4.64
	Post Bachelor (N:59; 19.7%)	0.49	0.14	0.31	5.31
Main Field	Engineering (N:97; 32.3%)	0.46	0.15	0.31	4.73
	Natural Sciences (N:49; 16.3%)	0.52	0.12	0.28	5.32
	Social Sciences (N:53; 17.7%)	0.46	0.13	0.33	4.71
	Computer Sciences (N:21; 7%)	0.44	0.14	0.34	4.17
	Other (N:80; 26.7%)	0.47	0.13	0.31	4.90

Note: To protect anonymity, we do not present data for groups with a small number of participants

Table 1 breaks down the participants' demographic statistics for the study. The number of participants in both the experimental and control groups was roughly equal; there were 165 males (54.3%) and 133 females (44.3%). The vast majority of participants were between either 18 and 20 years old (42.3%) or 21 and 23 years old (47.6%); whereas, only 9.2% of the participants were between 24 and 35 years old. Most participants were either first-year students (46.7%) or second- and third-year bachelor students; whereas, 19.7% of the participants were Post-Bachelor. The largest group of participants were those from the engineering faculty (32.3%); 17.7% of the participants were social sciences majors; 16.3% were natural sciences majors (most of these also graduate with an engineering degree); while 7% were computer sciences majors (again, these all also graduate with an engineering degree); whereas, 26.7% of the participants reported that their majors were as other.

Table 2. t-Test statistics of the experiment and control groups

	Scores		t-test for Equality of Means						
	Experiment	Control	t	df	Sig (2-tailed	Mean Difference	Std. Error Difference	95% Confidence	
								Lower	Upper
Post-S	.472	.479	-.44	298	.656	-.006	.014	-.035	.022
Pre-S	.132	.140	-.78	298	.434	-.008	.010	-.029	.012
Con-S	.320	.304	1.30	298	.192	.016	.012	-.008	.040
N2-S	4.84	4.81	.110	298	.912	.033	.299	-.556	.622

To analyze the effect of emotion-induced content on the participants' moral reasoning, we looked at the Post-S, Pre-S, Con-S, and N2-S scores for each of these measures (Table 2). Significant differences were not found between experiment and control groups scores; Post-Conventional Scores [Experiment (M=.472, SD=.12) and control (M=.479, SD=.12) groups; t(298)=.44, p=.656, d=.05)], Pre-Conventional Scores [Experiment (M=.132, SD=.08) and control (M=.140, SD=.09) groups; t(298)=.78, p=.434, d=.09)], Conventional Scores [Experiment (M=.320, SD=.11) and control (M=.304, SD= 10) groups; t(298)=1.30, p=.192, d=.15] and N2-Scores [Experiment (M= 4.84, SD=2.62) and control (M=4.81, SD=2.56) groups; t(298)=.11, p=.912, d= .01]. In other words, there is no evidence that including emotion content biases participants' moral reasoning.

Table 3. t-Test statistics of the males and females

	Scores		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	Females	Males	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
Post-S	.489	.460	-1.9	294	.048*	-.02909	.01464	-.0579	-.00028
Pre-S	.117	.154	3.5	294	.000*	.03743	.01056	.0166	.05821
Con-S	.326	.302	-1.9	294	.052*	-.02415	.01235	-.0484	.00016
N2-S	5.06	4.57	-1.6	294	.098	-.49767	.30024	-1.088	.09323

Although some researchers [14] did not find significant difference in the scores between male and female participants, we found significant differences between the scores of males and females except for N2-scores (Table 3). Significant differences were found between females and males Post-Conventional Scores [Females (M=.489, SD=.11) and males (M=.460, SD=.13); t(294)=1.9, p=.048, d=.24)], Pre-Conventional Scores [Females (M=.117, SD=.07) and males (M=.154, SD=.09); t(294)=3.5, p=.000, d=.45)], Conventional Scores [Females (M=.326, SD=.10) and males (M=.302, SD= 10); t(294)=1.9, p=.005, d=.24]; while a significant difference was not found for N2-Scores [Females (M= 5.06, SD=2.49) and males (M=4.57, SD=2.62); t(294)=1.6, p=.098, d=.19]. However, the effect size was found to be small almost in all scores.

Table 4. ANOVA statistics in terms of participants' level of study for all participants

		Sum of Squares	df	Mean Square	F	Sig.
Post-S	Between Groups	.030	3	.010	.629	.59
	Within Groups	4.782	296	.016		
	Total	4.813	299			
Pre-S	Between Groups	.010	3	.003	.399	.75
	Within Groups	2.529	296	.009		
	Total	2.539	299			
Con-S	Between Groups	.078	3	.026	2.329	.07
	Within Groups	3.294	296	.011		
	Total	3.372	299			
N2-S	Between Groups	18.584	3	6.195	.923	.43
	Within Groups	1987.524	296	6.715		
	Total	2006.108	299			

Note: Levels of study are "first year", "second and third year", and "post-bachelor".

Some researchers have also found a relationship between measures of moral reasoning on the DIT-2 and other factors such as age, level of study, or main field. In our study, dividing the students into groups based on their age and level of study yielded no significant results with respect to the scores (Table 4). No significant differences were found between participants in scores for level of study; Post-Conventional Scores [F (3,296) = .629, p= .59], Pre-Conventional Scores [F (3,296) = .399, p=.75], Conventional Scores [F (3,296) = 2.329, p=.07] and N2-Scores [F (3,296) = .923, p=.43]. This suggests that age and level of study of the participants do not impact moral reasoning.

Table 5. ANOVA statistics for engineering programs' students only in terms of participants' level of study

	Groups	N	Mean		Sum of Squares	df	Mean Square	F	Sig.
Post-S	First Year Student	78	.462	Between Groups	.044	3	.015	.840	.474
	Second- & Third-Year Bachelor	45	.497	Within Groups	2.850	163	.017		
	Post Bachelor	39	.491	Total	2.894	166			
Pre-S	First Year Student	78	.140	Between Groups	.009	3	.003	.342	.795
	Second- & Third-Year Bachelor	45	.130	Within Groups	1.484	163	.009		
	Post Bachelor	39	.137	Total	1.494	166			
Con-S	First Year Student	78	.310	Between Groups	.016	3	.005	.441	.724
	Second- & Third-Year Bachelor	45	.300	Within Groups	2.004	163	.012		
	Post Bachelor	39	.305	Total	2.021	166			
N2-S	First Year Student	78	4.54	Between Groups	18.768	3	6.256	.846	.471
	Second- & Third-Year Bachelor	45	4.80	Within Groups	1205.305	163	7.395		
	Post Bachelor	39	5.36	Total	1224.073	166			

The literature thus far has also found that engineering education did not lead to increases in moral reasoning over years [16,17,18]. We wanted to check if we have a similar pattern in our data. For this purpose, considering our findings presented in Table 4., we also performed data analysis only looking at those who will graduate with an engineering qualification (those from the engineering faculty, natural science, or computer science) and excluded those from social sciences and others. The results did not show significant differences between the groups' scores in terms of their background; Post-Conventional Scores [F (3,163,166) = .840, p= .47], Pre-Conventional Scores [F (3,163,166) = .342, p=.79], Conventional Scores [F (3,163, 166) = .441, p=.72] and N2-Scores [F (3,163,166) = .836, p=.47]. (Table 5).

4 CONCLUSIONS

In this study we aimed to investigate the impact of mild emotional empathy on engineering students' ethical reasoning by using mild emotion-induced case studies. It is known that some emotional content can improve students learning from engineering and science ethics case studies, however it is also feared by some that including emotional content may give rise to bias. Our study found no evidence at all that including emotional evidence biases moral reasoning: the overall results showed very little differences between the experimental and control groups' scores–any differences were not statistically significant. In other words, a low level of emotional empathy in case studies does not impact participants' moral reasoning.

Engineering ethics case studies often involve large scale death and destruction. This represents a high level of emotional content (even if emotions are not made explicit). Evidence from prior studies [8] suggests this should be avoided as it can reduce student learning from case studies. Our study focused on mild level ‘emotional empahty’. We addressed this by (a) identifying people/a person who was potentially impacted by an ethical decision and (b) identifying a source of empathy for them. Since empathy is linked to in-group relationships, we also sought to (c) increase an in-group relationship within the case study. This method could be used by others who are seeking to enhance a mild level of emotional content in case studies. Other methods used in other studies include explicitly identifying an emotion felt (“X feels guilty…”).

Numerous studies have found that engineers are somewhat unusual in that they do not seem to show much growth in moral reasoning over the course of their engineering education – this is at odds with the normal pattern of development in other professional domains [16,17,18]. We found a similar pattern here – there is little evidence that our student moral reasoning improved over the course of their studies. Hence our data reconfirms an imperative need to improve the quality of engineering ethics education.

The results of this study showed no impact on students' moral reasoning as a result of the inclusion of low to moderate levels of emotional empathy in case studies. Since the evidence [6] suggests that emotion inclusion can facilitate retention and transfer of the case’s knowledge content it would make sense for case study designers to include emotional information. Since low to moderate emotion does improve learning, and since we now know it does not impact moral reasoning, we recommend the inclusion of mild to moderate emotional empathy in case studies.

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DESIGN FOR IMPACT (D4i): A FRAMEWORK FOR TEACHING SUSTAINABILITY IN ENGINEERING DESIGN

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ABSTRACT

Sustainability has become an integrative part of engineering education since it is not possible to discuss sustainable development without also talking about innovation capability. Political and environmental frameworks request for a drastic change in the industrial landscape and also in the way design is carried out. This paradigm change forces new approaches to education that align with the prospects of the industry and also embed considerations related to the Triple Bottom Line (i.e. economic, ecological, socio-cultural elements). Addressing the complexity of sustainability requires innovative practices for teaching and learning, leading to new methodologies that aim to develop the broad sets of competencies required from the students. In Engineering Design, theories and methods related to sustainability have been mainly focused on the Design for X elements, material circularity, and product lifecycle leaving behind the importance of contextualized knowledge of regulations, or human-related aspects that motivates the students to tackle these challenges. Therefore, this study proposes a holistic approach that encompasses a broader understanding of what educators can exploit for capacitating future engineers in sustainability-related complex problem-solving. The framework highlights three main areas to be considered when teaching sustainability for Design Engineers: i) Context & Resources, ii) Human factors & Competencies, and iii) The D4i design process. A simplified version of this framework in class as a lecture-workshop format are presented and discussed along with multiple directions for future research.

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1 INTRODUCTION

Undoubtedly sustainability is an integral part of Engineering Education (EE) and vice versa. Learning and teaching frameworks are instrumental to guide and reflect on teaching practice and to engage in academic conversations as well as consider strategies that integrate sustainability concepts and applied industry cases into nearly all core teaching subjects as part of active learning.

Despite the inherent urgency and general knowledge about the importance of sustainability for all societal segments, engineering students and educators might find themselves struggling to understand how to tackle such complex topics within the educational timeframes and how to effectively embed methodologies that promote the development of competency and of a lasting mindset of sustainability.

UNESCO (2002) promotes that “Education for sustainability seeks to empower people of all ages to assume responsibility for creating a sustainable future”. Therefore, reformation of the educational systems and open dialogue became necessary to prepare future engineers and managers to have the readiness to lead sustainability policies [1]. There is a need for embracing the individual capability of the engineer into creating lasting positive impact as a byproduct of personal drive and professionalism, and for extolling sustainability as a core competency to be taught and developed during engineering education.

This study proposes the development of a human-centric framework for teaching and learning sustainability in engineering education that aims at catalysing dialog between faculty, students, and industry stakeholders in order to answer the following questions:

- How can we promote an open discussion on sustainability as a core competency in design education?
- How can we integrate a holistic human-approach to sustainable design?
- How can we empower the designer as the decision-maker towards a sustainable mindset?

Therefore, we present the Design for Impact (D4i) framework for integrating sustainability within the engineering design curricula, and present initial feedback from students after the introduction of this methodology to their studies. D4i builds upon Design for Sustainability (DfS) methodologies and looks into equipping the designer with the capabilities to assess and reflect on the impact of a given product, service, or system with a positive impact for businesses by deconstructing knowledge silos via systemic thinking. D4i looks into a transversal approach to the triple bottom line of sustainability, empowering the individual designer to develop solutions that provide positive or even regenerative impact with depth and scale in product development. This approach positions the designer as a decision-maker who is responsible for administering a systemic overview of the impact and value creation for their concept developments.

This article examines the development of this teaching framework and provides insights from a study case where a short version of the D4i methodology is tested in a lecture-workshop class.

2 THEORETICAL BACKGROUND

2.1 Design for Sustainability

Over the years, several theories provided the foundations for building an understanding of how design researchers could start linking design theory and practice with sustainability transitions, in what we know today as Design for Sustainability (DfS). Models, tools and methods can be found in the literature for sustainable product and service design, but the authors recognize limitations in their implementation and in generating sustainable solutions [2]. Therefore, DfS needs to develop towards being strongly linked to the conditions and characteristics of circular economies, overlooking digital business models [2][3], where producers and consumers are an active part of a paradigm change and are aware of subjects such as closed material loops, reuse, remanufacturing, waste reduction and recycling and even of biological cycles [5].

2.2 Sustainability education in Design Engineering

The concept of "Education for Sustainable Development" has been explored over the past three decades and many educational associations focusing on sustainability have been established. In engineering education, this concept not only develops and guides the engineering curriculum to cover sustainability issues but also requires the engineering process to meet current challenges [6]. In this way, most approaches used to integrate more practices in the engineering curricula are through capstone design courses and senior graduation projects. Engineering design courses can increase the sustainability practices of future engineers by creating and implementing their designs while considering the sustainability triple-bottom-line and measuring sustainable performance indicators or other metrics. Accreditation Board for Engineering and Technology (ABET) criteria for accrediting engineering programs [7] also emphasized the need for considering sustainability as one of the outcomes related to design ability.

More than a practical skill, Goekler [6] argues that students effectively learn about sustainability when they develop the ability to think in new ways and engage with different worldviews. For students to engage with the complex challenges involved in Design for Sustainability and towards creating impactful design they need to engage in a deep cultural critique on the present ways of production and consumption, and be equipped with a set of competencies that build on the pre-requisite abilities to think, do, analyze, plan and make decisions. This wholeness of the individual character brings the need for a human-centric understanding of the designer, moving away from the exclusively technical allusion of DfS, and reflecting on what we understand as a Sustainable Mindset [8] as an integrative part of the designer's professional identity [9] that is developed throughout their education.

2.3 The need for a new framework

Within design education, some competencies can be acquired through formal learning, while some are embedded in one's personality. It is the educator's role to identify these competencies and direct their pedagogical approach and curriculum towards nurturing these different aspects of competencies. There has been considerable previous research that looked at educational practices and desirable competencies in design

[10], at dedicated competencies for building assessment framework [10][1], and at various pedagogical approaches to improve the efficacy of sustainability education in engineering such as project-based learning [12], guided-discovery learning [13], and problem-based learning [14]. Research has also focused on identifying goals and strategies to consider while performing design activities that can be adapted to sustainable design. However, existing literature and training on sustainable design does not propose any specific activities [15] nor extensively explore the role of intrinsic motivations and mindsets in the development of policies in EE.

Learning and teaching frameworks are instruments that invite faculty to reflect on their teaching practice and to engage in conversations on the teaching values that define their work at an institutional level [16]. Therefore, there is need for a framework that includes human aspects of the design engineer in the equation of sustainability teaching and learning. The designer's personal drive and mindset and its reflection in terms of professional identity is an important element of agency and professionalism that dignifies sustainable solutions and entices decision-making and behavior towards sustainability. For this purpose, we have developed and assessed a new framework.

3 DESIGN FOR IMPACT (D4I) FRAMEWORK

Design for Impact (D4i) is an experimental educational framework that builds upon DfS and looks into equipping the designer with the capabilities to assess and reflect on the impact of a given product, service, or system. Sustainability is currently defined through the interconnected domains of environment, economy and society, which is defined as the triple bottom line (TBL). Much has been discussed about new ways of seeing the interrelation of the TBL approach for sustainable development, where sustainability lay in the cross-section of equal-sized components and is now understood as facets or even layers within each other. The argument for what is now described as a “strong sustainability” approach follows a logic flow where economy is a feature of human society, which is in itself embedded in the biosphere of the planet. To take it a step further, Stockholm Resilience Center [17] introduced the concept of transversality with the “wedding cake” approach to the United Nations’ Sustainable Development Goals (SDG) while talking about the impact of pervasive systems.

Inspired by these new constructs, D4i attempts to look into a transversal approach to the TBL of sustainability, and on how to empower the individual designer to develop solutions that can tackle complex real-world problems in the digital age and provide positive or even regenerative impact with depth and scale. This approach positions the designer as a decision-maker who is responsible for administering a systemic overview of the impact and value creation for their concept developments. An illustration of the development of this understanding on sustainability approaches is presented below in Figure 1.

The core aspect of D4i as a methodology is the human-centric approach to sustainable development by placing the designer as a change-maker, i.e. a professional who can contribute to the development of a fair and sustainable society through the design of digital/non-digital products, services, and systems with transversal positive impact.

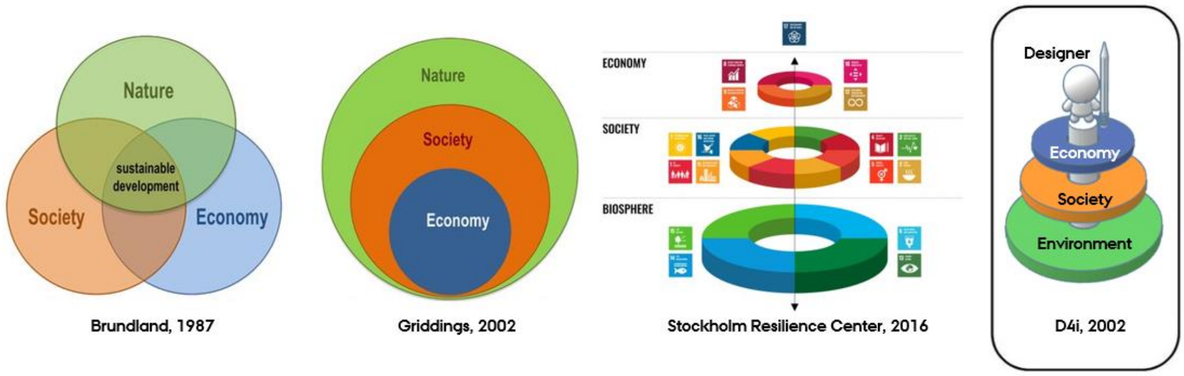

Figure 1. Evolution of sustainability models and the D4i approach

The structure of the D4i framework focuses on the need for integrating a holistic framework that relates contextual and humanistic factors with a systemic approach for technical elements as well as business understanding. The D4i framework is conceptualized as a toolkit that brings together an inventory of methodologies and techniques to facilitate a holistic understanding of the impact of a given design concept or product, aiding decision-making based on the engineers' personal drive for creating impact and business value. In this toolkit, the visual overview of D4i components tries to connect current global frameworks, human-centric aspects, and product development methodologies. D4i has three core components:

1) Context and Resources is the component that contains an assortment of existing knowledge that can guide and support the development of a new sustainable Products, Services and Systems (PSS). This component is divided into four aspects: a) Global Frameworks, which provide an overview of current assessment opportunities; b) Regulatory Framework, which provides an overview of policies, restrictions, and possibilities in relation to developing compliant solutions; c) Business and Implementations, which presents an assortment of tools and methodologies that ensure successful deployment of a solution; d) Methodologies and Resources, which provides a pool of design approaches and tools for successful engineering development. This component can be integrated in the Engineering Education (EE) as a complementary part of the traditional curricula, focusing on introducing updated frameworks and core knowledge of business along with technical methodologies. It aims at providing the students with capabilities related to systemic thinking and the overview of contextual/legal constrains. A practical example would be, in a course where the students develop new products, to present The European Union's Ecodesign Directive (Directive 2009/125/EC).

2) Human Factor is the component that contains the individual agency of the engineer. This component is divided into three aspects: e) Personal Drive, which reflects the motivation and behavioral aspect of the individual; f) Acquired Knowledge, which reflects the cognitive process and expertise of the individual; g) Professional Practice, which reflects the will for engagement with developing a solution. This component can be assessed in EE as part of a course learning outcomes, where the educator can evaluate the engagement and performance of the student. It aims to consider individuals along with their psychological states as fundamental parts of the design process. A practical example of the implementation of this component in a course would be based on regularly monitoring the level of commitment and interest of the students, thus providing adaptations in content or approach that promotes higher engagement.

3) D4i Process is the component where all the above comes together as a design process and professional practice for the solution development and is divided into four aspects: h) Design Process; i) Impact Assessment (TBL); j) Business Potential; and k) Purpose & Impact. This component is where the individual dares to question traditional approaches by making use of critical thinking to evaluate the impact creation of their solution across the TBL and its value chains, and it can be assessed in EE as innovative approaches or outcomes. It aims at consolidating the framework's components 1 and 2 into the design process. A practical example of utilizing this component in a course would be a holistic approach to PSS development, starting with an innovative concept and ending with the communication of purpose and impact based on assessments developed as part of the design process.

Based on the components listed above, the D4i framework proposes an overview of areas of interest as means to open a dialogue on what is needed to know and to do when developing sustainable solutions. Acting as a map, the information structure of D4i framework relates contextual aspects to the PSS development, assists in systemic thinking, and includes human aspect in relation to impact creation. Figure 2 illustrates this structure and the flow of information of the D4i framework, also positioning the design engineer as the mediator between information and action.

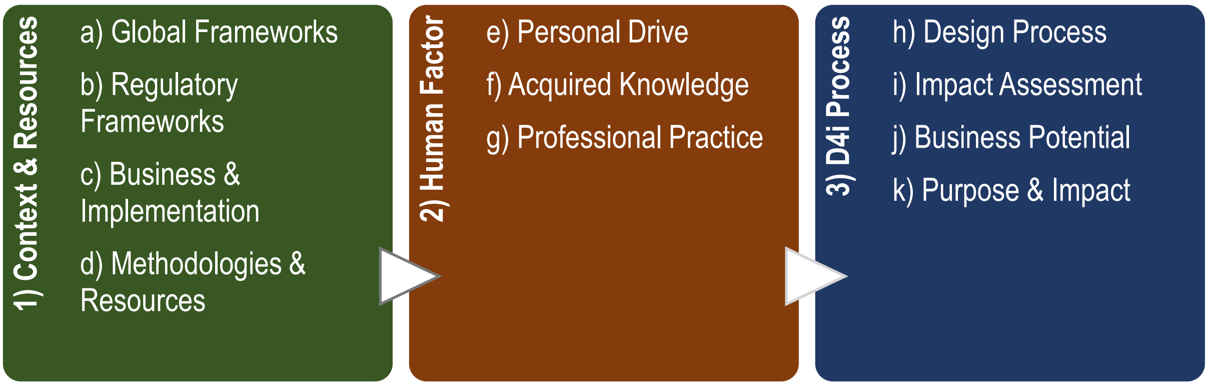

Figure 2. Information Structure of the D4i framework

The integration and testing of this framework within an educational setup should be simplified and adapted to fit into existing courses and curricula. The D4i framework can be used as an instrument for educators to plan and develop meaningful coursework that focuses on unveiling knowledge gaps, deconstructing pre-established assumptions, and communicating impact to a given concept or philosophy such as Agile (continuous iterations for integration), Lean (continuous improvement to minimize waste) or Design thinking for co-creation with users and society. Aspects of this framework are meant to be co-developed further and updated frequently in the light of new knowledge as well as changes in context or resources.

4 CASE STUDY AND RESULTS

At this stage, the D4i framework is being developed with the purpose of assisting teaching and an open discussion in higher education setups. Therefore, we further examine the deployment of the framework and provide insights from a case study where it was tested in a lecture-workshop class for the course Advanced Product Development at Master level, from the Technology Based Business Development (TBBD) degree at Aarhus University in Denmark.

4.1 Framework adaptation for case study

In order to iterate the D4i framework, and given the time limitations for deployment in a 4h lecture, we have developed a concise version of the framework focused on specific aspects. The program was divided in two parts: i) Lecture and ii) workshop. The first half of the program focused on the D4i component of ***Context and Resources***, where the students were presented with an overview of current global actions, policies and regulations in relation to sustainability and product development. The aspect of ***methodologies and resources***, was the least exploited subject during the program due to the fact that the overall TBBD curricula covers extensively these topics. Therefore, we have only focused on introducing the concepts and briefly presenting sustainability-oriented methodologies that could serve as inspiration. The second half of the program focused on the aspect of ***Practice*** by making use of a workshop format as a space for the students to explore the ***D4i Process*** component.

The students were therefore encouraged to apply a pre-developed toolkit[*] into their semester-long projects. The toolkit guided the students into three sets of activities during the workshop session: 1) Concept diagnose (individually), 2) Evaluating areas of improvements and discussing within the groups, 3) Communicating impact and potential value creation. At the end of the session, the groups pitched their products in the light of their newfound understanding of impact creation. Hence, the students were able to navigate through several aspects of D4i process and reflect upon the decisions and solutions they have been developing.

4.2 Application of D4i in a Lecture-Workshop format

This case study is centered on three student groups consisting of 2-3 participants that worked together during the class using their main course assignment as a subject. This course assignment was to develop of a product-service system throughout the whole semester, where they integrated the knowledge of all the lectures provided by the curricula. The students' projects featured in the course were very distinctive between the groups, which provides D4i with a broad scope of applications. The students' highlighted the benefits of using pre-developed templates such as the toolkit for systematically navigating the complexity of the D4i framework topics. However, the limited lecture time restricted any in-depth exploration of concepts such as Life Cycle Analysis (LCA) and materials' metadata, which created uncertainty for their solutions.

[*] *Toolkit templates available upon request to the authors.*

After going through the exercises of the D4i toolkit, the students were encouraged to hand-draw a poster about their solutions as shown in Figure 3, and provide a 5 min pitch presentation as practice in communication of impact related to their solutions.

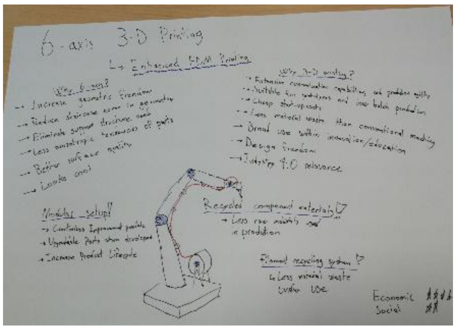

Figure 3a

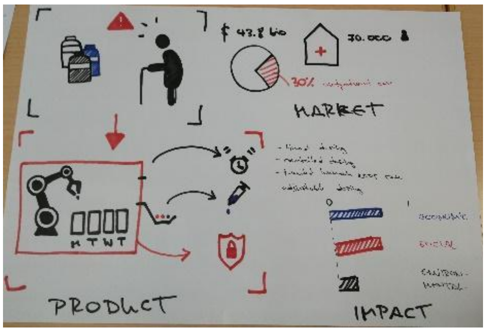

Figure 3b

Figure 3c

Figure 3. the student posters developed during the lecture in sustainable product development using the D4i framework referencing to their different group products a) a 6 axis robotic 3D printer for recycling plastic material, b) a robotic medical pill dispenser for sustainable use of medicines in elderly care dormitories, c) an industry 4.0 drone manufacturing line for repair and reuse of drones and its component materials.

The pitch and discussion session opened the opportunity for giving and receiving feedback from their peers as well as reflecting on the process of going through the exercises. The pitching practice aimed to develop communication capacity in relation to value creation across the TBL, and a space for peer discussion and support as well as to facilitate a simplified diagnosis for impact assessment as an exploratory tool for systemic thinking during product development, starting with the overlook of broad aspects related to the concept such as Product Systems Services (PSS) type, competitors and market potential, and driving to more specific design aspects such as manufacturing and components, value chain, usability and lifecycle. The students reported this class to be their first contact with a structure that allowed them to reflect on sustainability from multiple perspectives and throughout the product value chain. The toolkit and D4i framework has assisted with providing guidance and a thought flow, which inevitably aids the communication aspect of product development.

The process of assessing their previous work and evaluating impact creation in the work they developed throughout the semester has shown to provide a space for reflection and reconsideration. Among the feedback provided by the students in relation to the framework and their learnings, we observed that students present very distinct backgrounds and might not be familiar with traditional design methodologies or approaches, including basic eco-literacy, and are not familiar with the available tools for sustainable product development. As an example, despite having had previous contact with the UN SDGs, the students reported to not have a clear picture of how to integrate the goals into their concept formulations or to use the framework to reflect on the impact of their concept. Only one student had used the SDGs before as a tool to communicate value creation. By using the framework, students were able to provide clear communication on the possible impacts of their products and reflect upon the TBL aspects of their concept in relation to both manufacturing processes and usability.

5 CONCLUSIONS AND ACKNOWLEDGMENTS

This study proposes the development of D4i as a human-centric framework for teaching and learning sustainability in engineering education that aims at enticing dialog between faculty, students, and industry stakeholders in order to answer the following questions: i) How can we promote an open discussion on sustainability as a core competency in design education?; ii) How can we integrate a holistic and humanistic approach to sustainable design?, and iii) How can we empower the designer as the decision-maker towards a sustainable mindset?

The consolidation and iteration of the D4i framework shed light on the promotion of pedagogical methodologies that promote open discussion about the implementation of sustainability as a core engineering competency, and the mechanisms that support achieving this goal such as re-orienting education towards a purpose-driven practice-based-learning approach that provide tools to build long-term sustainable mindsets. Since D4i framework serves as mapping tool to identify learning gaps and promote structured reflections, educators can easily implement such framework and design their own toolkits as part of their already existing curricula and coursework, with minimal use of external resources. The limitations are mainly related to the available time during class for exploration of complex topics. However, different formats can allow for more time and for the association with multiple courses within an EE program.

This study gave us invaluable insights on the structure and usage of such a framework, approaches on how to integrate holistic elements of sustainability into restricted educational timeframes, and feedback from an initial implementation in class. Furthermore, it sheds light on new research pathways and areas that require more attention when developing useful tools for teaching, learning, and assessing competencies in the context of sustainable mindsets, professionalism in engineering, and design for sustainability approaches in education. Future work could aim to evaluating the D4i framework in a course-long setup as well as investigating what are the areas of strength and any knowledge gaps in current engineering curricula.

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STUDENTS' PERCEPTIONS OF A MAJOR ENGINEERING CURRICULUM REFORM

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ABSTRACT

As the demands of industry are evolving and new generations of students are entering universities, many engineering faculties invest time in curriculum reforms based on inspirational innovations, underpinned by engineering education research. The Faculty of Engineering Technology (FET) of KU Leuven had an additional argument to implement a huge programme reform: this faculty, hosting more than 6000 students spread across seven campuses in Flanders (Belgium), was an amalgam of different traditions and visions. Their merger into one faculty in 2013 aimed to optimize the organisation of research, education and community service.

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The goal of the programme reform in 2020-2021 was fourteenfold: enhancing our typical profile of (1) hands-on engineering in (2) strong interaction with the labour market and setting up (3) a technology hub with more attention to (4) multidisciplinarity, (5) professional competencies, (6) personal development & support, (7) lifelong learning and (8) challenges including (9) complex problem solving. The reform also aims to increase the (10) attractiveness and (11) social relevance of the programmes. By strengthening the internal coherence in the faculty, we can exploit the (12) multicampus narrative to offer students more choices and develop their (13) future disciplinary self, supported by (14) choice guidance.

This paper describes how the curriculum was adapted in order to achieve these goals and presents the results of perception measurements organised among freshmen who followed the old programme in 2019-2020 and freshmen registered in the new programme in 2020-2021. Of foremost importance is the increased feeling that the professional competencies are essential for an engineer.

1 INTRODUCTION

All sectors of society are witnessing great changes. Higher Education in general, and engineering faculties more specifically, play an important role as leaders in teaching and learning of the future engineer. The actual engineering student should be prepared for the challenges of tomorrow. It is the task of the engineering faculties to empower engineering students by helping them to achieve the relevant competencies needed in their future professional life.

Van Damme [1] states "Universities are doing reasonably well in translating changes in scientific knowledge into course contents but do not identify similarly important changes in skill demand in the external world and transform their education programmes accordingly." Indeed, engineering education research confirms that the skill set demand in the field of engineering is broad [2], role-specific [3] and in constant evolution (e.g. responding to the challenges of the Sustainable Development Goals [4]). Engineering faculties are responding to these social and technological developments in different ways. Hadgraft and Kolmos [5] list some responses they have detected in new types of engineering programmes: "These responses are student-centred learning, integration of theory and practice, digital and online learning, and the definition of professional competencies." In her 'Global state of the art in engineering education' Graham [6] has identified the 'current' and 'emerging' leaders in engineering education and she concludes with the following list of features of this new generation of engineering programmes: "Distinctive educational features of the 'emerging leaders' include work-based learning, multidisciplinary programs and a dual emphasis on engineering design and student self-reflection.".

This paper explores how engineering students have perceived a major engineering curriculum reform in the Faculty of Engineering Technology (FET) of KU Leuven. It was developed from a blank slate, based on 14 goals which were established through a collaborative process. The research question of this paper is formulated as follows:

"To what extent have the students experienced our 14 objectives?".

The context and the 14 goals of this collaborative curriculum design process are described in section 2. This is followed by a description of the implemented methodology to monitor the students' perceptions. And in the two last sections, the results of this monitoring process are given and discussed.

2 CONTEXT AND GOALS

KU Leuven is a comprehensive, research-intensive university, active at different campuses. The university is highly ranked (most innovative university of Europe) and counts more than 60000 students.

The new Faculty of Engineering Technology is a multicampus faculty spread over seven campuses in Flanders (Belgium) and is established in 2013 after a merger of the engineering departments of six different University Colleges of Applied Sciences. The faculty has a total student cohort of over 6000 students, of which more than 1000 are in the first year of the Bachelor's programme at the time of the curriculum change. These first-year students do not have to select their major or discipline when registering at university. The selection of one of the four the disciplines (civil engineering, chemical engineering, electromechanical engineering or electronics & ICT engineering) is made at the beginning of the second year. By consequence all first-year students take the same courses.

The curriculum development process started in 2017. Three years later, in September 2020, the first cohort of students started in the new three-year Bachelor's programme. This cohort will start the new one-year Master's program in 2023-2024. This paper only focuses on the experiences of the first-year students of the first cohort.

Since this faculty is the result of a merger of six institutions with different traditions, the curriculum development process started with an in-depth review of the faculty-wide goals. This collaborative process at different levels of the faculty resulted in 14 goals for the revision of the curriculum across the whole faculty. We discuss them one by one in a logical sequence, not influenced by relative importance.

2.1 Multicampus education

In order to exploit the multicampus context, the programme of the first year of the Bachelors is *identical on all campuses*. This allows (1) to reduce the number of majors/disciplines on some campuses without limiting the choice of a student since they can move from one campus to another, and (2) to intensify cooperation among the teaching staff in faculty-wide teaching teams.

The curricula of the Masters on the other hand are on purpose very diverse across the campuses and based on the research activities performed on each campus. By consequence, a graduated Bachelor's student has a huge choice of possible specialisations if the student is willing to move from one campus to another.

This supports the idea of a student-centred learning environment that emphasizes 'student choice', our second goal discussed in 2.2.

2.2 Choice guidance

Students have to make several important decisions while studying, such as 'pick a major', 'select a specialization in the Masters' and 'choose a job'. Starting from day one of the Bachelor's programme we support our students in these decision-making processes by intra- and extracurricular activities and clear communication (e.g., a first-year project covering the four disciplines, orientation days, job shadowing, etc.).

2.3 Supportive programme

Higher Education in Belgium has an open admission policy, resulting in a very diverse population of incoming students in terms of prior knowledge. We support our first-year students with extracurricular activities before the start of the academic year (e.g., MOOC basis mathematics, on-campus summer course, etc.) and during the first year (e.g., online tools, on-campus private or group sessions, etc.).

2.4 Challenging programme

This diversity requires support for some students and extra challenges for others. In general, the faculty engages in initiatives to motivate students to push their limits (e.g., a project with a bonus for those who go the extra mile, international experiences, etc.). This is in line with our focus on a student-centred learning environment that is attractive for potential engineering students.

2.5 Technology from day one

At KU Leuven three types of engineering curricula are organised: engineering technology, bio-engineering sciences and engineering sciences. The programmes within the Faculty of Engineering Technology are more applied, technology from day one is an important element to distinguish us stronger from the other programmes. Basic sciences and technical knowledge remain important, but the programme is broadened. The new curriculum sequence 'engineering experiences (EE)' in the Bachelors (EE1 in year 1, EE2 in year 2 and EE3 in year 3) offers students the chance to operate as engineers from day one. 'Integration' is the key word.

2.6 Professional competencies

The new programme emphasizes the increased importance of professional competencies. Experts in professional competencies organize seminars about these professional competencies, integrated in the EE-curriculum sequence. Moreover, these professional competencies such as communication, leadership, project management, team dynamics, etc., are not only 'teached' in colleges, but are also 'trained' and 'evaluated' during the regular courses such as laboratories and projects. This integration is essential since this is also the way it will be applied in the professional context.

2.7 Multidisciplinarity

Engineering problems are becoming increasingly multidisciplinary. Students have to learn to think and work across disciplines. At least during EE the students have to work multidisciplinarily, but also other activities support multidisciplinarity. This starts simple in EE1 where they have to integrate the content of different general courses in the integrated lab/project and it becomes a real multidisciplinary project in EE3.

2.8 Practice in the programme

The focus on practical engineering underlines our specific profile. It is not only realised in EE, but in almost every course since most courses are split in three parts: colleges (theory), exercises and laboratories. These laboratories are expensive learning environments, but essential to understand the theory in an applied way. This profile enhancing focus is moreover for many students an attractive feature.

2.9 New technology

Technology evolution speeds up. We invest a lot of money to give students the opportunity to have hands-on experiences with new technology in projects and laboratories. But we also focus on introducing new technology through lectures and contacts with industry (e.g., company visits, Master's theses in collaboration with industry, etc.).

2.10 Interaction with the labour market

The Faculty of Engineering Technology has a long tradition of cooperating with the labour market. This programme reform wants to reinforce it by implementing e.g., job shadowing during the first year, intensified company visits, guest lectures, partnerships with some companies, etc.

2.11 Disciplinary future self (DFS)

Freshmen are usually still figuring out who they are and what they want to become in the future. We support students by developing a learning environment in which they can reflect on who they are and want to be (e.g., PREFER-explore and -match test, personal development plan, etc.).

2.12 Complex problem solving

Engineering problems are becoming increasingly complex. It is important to learn students how to deal with this complexity by building in progressively more and more complexity throughout the curriculum. The way we approach this is very similar to the way we 'teach' multidisciplinarity. It starts very simple with for example with the training of the ability to solve exercises combining topics from different chapters within one course and it ends in the Masters with dealing with authentic engineering problems which are by definition complex.

2.13 Lifelong learning

Lifelong learning is the buzzword of the moment, but not without reason. This is essential when it is our goal to empower our students to be ready for the future. Self-regulation is for example an essential competency of lifelong learners..

2.14 Socially relevant programme

We want to educate social responsible engineers, ready to tackle the Grand Challenges for Engineering. We want to stimulate this responsibility and awareness by giving them the opportunity to take part in for example community-based social projects, student competitions with a focus on sustainability, etc.

3 METHODOLOGY

A multidisciplinary team has translated each of the 14 goals (‘scales’ called from now on) into 3 to 4 targeted questions to measure the perceptions of the students. The questions can be answered with a 6 point Likert scale (from ‘totally disagree’ to ‘totally agree’). This resulted in an online survey of 54 questions given to 943 first-year students in May 2020. This was at the end of the academic year 2019-2020, the last year the former programme was organised for first-year students (old cohort). The response rate was 48% or 450 students completed the questionnaire. In May 2021, at the end of the academic year 2020-2021 in which the new programme was initiated, 798 first-year students were invited to complete the questionnaire and 267 effectively did (new cohort). This resulted in a response rate of 33%. Normality of the distributions of the scales was checked using the Shapiro-Wilk tests. Since they were not normal distributed, the perceptions of the old and the new cohort were compared with Wilcoxon rank sum tests.

The reliability and validity of the survey with 14 scales was measured with Cronbach’s Alpha and an exploratory factor analysis. A confirmatory factor analysis confirmed a necessary reduction of the scales.

4 RESULTS

The validity of the survey is discussed first, followed by the results of the perception measurements. A discussion of the (non)significant changes in perceptions between the old and new cohorts constitutes the conclusion of this paper.

4.1 Reliability and validity of the survey

The internal consistency of the scales of the survey is given in Table 1.

Table 1. Cronbach’s alpha of the 14 scales ordered in sequence of Cronbach’s alpha.

Scale (goal)	Cronbach’s alpha	Scale (goal)	Cronbach’s alpha
Interact with labour market	0.78	Choice guidance	0.67
Supportive programme	0.77	Socially relevant programme	0.58
Challenging programme	0.74	Disciplinary future self (DFS)	0.56
Complex problem solving	0.73	New technology	0.52
Practice in the programme	0.7	Multicampus education	0.51
Professional Competencies	0.69	Lifelong learning	0.49
Technology from day 1	0.68	Multidisciplinarity	0.46

Cronbach’s alpha’s of less than 0.7 are in principle not acceptable. The exploratory factor analysis also did not confirm the 14-factor model. Implementing a promax rotation and a cut-off of 0.3 for the factor loadings, 5 items of the survey were rejected, and 7 factors selected. This was confirmed with the scree plot and a confirmatory factor analysis (CFI=0.86; RMSEA=0.051). Five original scales remained, and two new scales were developed (see Table 2). The new scales are shown in italic in Table 2. ‘Lifelong learning’, ‘multidisciplinarity’, ‘Disciplinary future self’ and ‘socially relevant programme’ are not withheld.

Table 2. Cronbach’s alpha of the final 7 scales

Scale (goal)	Cronbach’s alpha
Challenging programme with complex problem solving	*0.82*
Interact with labour market	0.78
Supportive programme	0.77
Student centred programme (multicampus, choice guidance and DFS)	*0.76*
Practice in the programme	0.7
Professional Competencies	0.69
Technology from day 1	0.68

4.2 Changes in perceptions between the old and new cohorts

The results of the Wilcoxon rank sum tests are given in Table 3. The perceptions of the students of the two cohorts can be compared. Only for three scales (or goals) a significant change is measured: ‘interact with labour market’, ‘supportive programme’ and ‘ professional competencies’. Unfortunately, only for ‘professional competencies’ the students have experienced an increase so far.

Table 3. two-sample t-tests for the two cohorts in the 7-factor model.

Scale (goal)	Old cohort M (SD)	New cohort M (SD)	p-value
Challenging programme with complex problem solving	4.51 (0.58)	4.41 (0.68)	n.s.
Interact with labour market	3.96 (1.02)	3.12 (1.03)	<.001
Supportive programme	4.58 (0.78)	4.37 (0.85)	<.01
Student centred programme (multicampus, choice guidance and DFS)	4.03 (0.70)	4.12 (0.75)	n.s.
Practice in the programme	4.34 (0.71)	4.12 (0.75)	n.s
Professional Competencies	4.27 (0.83)	4.46 (0.76)	<.01
Technology from day 1	4.58 (0.64)	4.62 (0.65)	n.s.

5 DISCUSSION

The answer to the research question can be short: the first-year students of the first cohort who have followed the new curriculum do not have the impression that the interaction with the labour market has improved, neither they have an increased feeling of support yet. But they have fortunately experienced that the professional competencies are an essential part of the broad skill set. For the other four goals no conclusions can be made at this point.

This limited result is understandable considering the following contextual factors:

1. The focus was only on the first year of the programme. Not all 14 goals are achievable in the first fourth of the new curriculum. On the other hand, a first basis can certainly be laid for the 7 corrected goals. For example, we invested quite some time in a new initiative of job shadowing. This seems not to have effect, on the contrary, the interaction with the labour market was appreciated less. There is clearly something else going on.
2. Starting from March 2020 Covid-19 had a major impact on education. The old cohort was partly hindered. The new cohort started at university during the pandemic. Laboratories (practice in the program) were less frequently organised, job shadowing (interact with the labour market) and supporting workshops (supportive program) were online, etc. This puts this work in perspective.
3. And last but not least, during the first year of a huge programme reform not all that you would like to do has been achieved yet. We have the intention for example to implement in near future a personal development plan and a more intensive support programme.

As we are now only reporting on the first step of a longitudinal study, it is important to have a critical look at the survey the coming years. Not necessarily all validation recommendations of this paper should be considered in near future. After all, we have validated the survey only with first-year students. 30% of them drop-out after the first year, so they are not a representative sample of our population. A new validation should be done the coming years.

Concluding, this study proves that it is possible to make students aware of the importance of professional competencies. Since we are not the only faculty integrating professional competencies into the core of the curriculum [7-10], this is hopeful information for many curriculum reforms. Improvements are still possible, such as a stronger integration of the professional competencies in the engineering courses and not only in EE. Also, the development of a supported framework to track and evaluate the professional competencies might be helpful.

6 ACKNOWLEDGMENTS

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Relevance of Digital Education and its different aspects of development

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ABSTRACT

The ongoing digitalisation of the learning processes has both opportunities and obstacles for the educational attainment of students in STEM subjects. In this paper, we summarise student experiences with digitalisation during the COVID-19 pandemic and provide recommendations for how to improve teaching methods of STEM education. The research was conducted through focus groups in a workshop format at 15 European STEM universities across 8 different countries obtaining 147 responses from students. This paper also aims to analyse how the digital competency of both students and professors has been impacting the effectiveness of new teaching methods and education tools during online classes since the start of the pandemic. Students have a variety of needs, with some students preferring the flexibility and anonymity online work gives them, while others thrive better when they are face to face with instructors and dislike the limitations that exist in virtual communication. In addition, we looked at how students view changes in the evaluation of projects and tests that have occurred to prevent cheating. The results show the relevance of digital education and which aspects of it need to be developed further. The paper further explores possible solutions for the issues identified in this research, including learning, methodological and skill development aspects. Overall, we propose hybrid classrooms where students have the choice to explore which method of learning best fits them and how professors can support them to ensure the best educational outcome.

1 INTRODUCTION

1.1 General overview

The educational crisis caused by the COVID-19 pandemic affected students worldwide, while teaching has been digitally transformed in the form of online learning as an alternative approach to education. This change has had a large effect on students in STEM fields since a substantial part of their program depends on project work and practical learning, which requires access to technology and close communication with instructors and group members.

By testing out the new hybrid educational model during the pandemic [1], the approach to learning has shifted to student-centred learning (SCL) where students are encouraged to take more responsibility for their education. The requirements of the digital era applied to students as the next labour force even before the pandemic, and the sudden need to shift the educational model accelerated the process of the universities acting as facilitators of the SCL model [2]. Many stakeholders have been investigating online learning in European universities stemming from the pandemic and tried to identify the differences between individual universities (tools, platforms, applications). The need to analyse students' input on challenges and opportunities for improvement has become evident.

1.2 Goal and objectives of the research

The main question tackled by this study is how COVID-19 has impacted Higher Education in terms of three objectives.

<u>To address Objective 1:</u> *Gather and examine the actions that European STEM Universities have taken in reacting to the COVID-19 pandemic of the goal,* this study sought to map innovative teaching methods, digital assessment methods, and support needed by educators and students.

<u>To address Objective 2:</u> *Gather students' perceptions and opinions*, this study aimed to evaluate how the measures taken as part of the digital move have impacted the engagement of students with their studies; and locate the main roadblocks and catalysts of the digital move for students, both in terms of digital tools and accessibility, and of digital skills.

<u>To address Objective 3:</u> *Analyse the learnings*, the study aimed to help define the most effective balance of online and offline education in the post-pandemic context; and to enhance and complement the engagement of in-person education with an optimised online one-way information transfer.

2 METHODOLOGY

2.1 Data sources

During this study, primary and secondary research were conducted in the period of January until April 2021. Primary data sources were collected through in-depth interviews of students from each target university with the goal of probing what new changes were introduced to the Higher Education activities portfolio, including the possible new teaching methods, new equipment, or infrastructure used for learning processes and support given to students and educators. Data collected through primary research was analysed and used in the creation of secondary research.

Secondary data has been collected mainly through focus groups, obtaining 147 responses from students. Focus groups were conducted in a workshop format from 15 European Universities with the goal of gathering information on students' opinions about the transition to digital education and what obstacles they have experienced, as well as what opportunities for improvement they have observed. The workshop consisted of an introduction, statement voting, brainstorming and clustering of the identified problems and opportunities. The last section was conducted in the format of World Café, the students had to focus on 5 different areas: Digital competencies; Digital tools; Teaching methods; Assessment methods; and Interaction. Methods used for data analysis include the statistical method, the method of induction and deduction and the comparative method.

3 Results

3.1 Digital competences

Firstly, this section investigates the influence of students' competences in digital education. Secondly, this section analyses the impact of the educators' digital competency on the learning process [3]. Digital competences encompass responsible usage, and interaction with digital technologies in the following areas: Information and data literacy, communication and collaboration, digital content creation, safety, and problem solving [4].

3.1.1 Results

Fig. 1 demonstrates that most of the students think that they have barely sufficient digital competencies to move digital education without hindering the learning process. Therefore, there is still a portion of students that the learning process has been limited by their digital competencies. As it can be seen in Fig. 1, students' opinions on engagement are similar to the learning process.

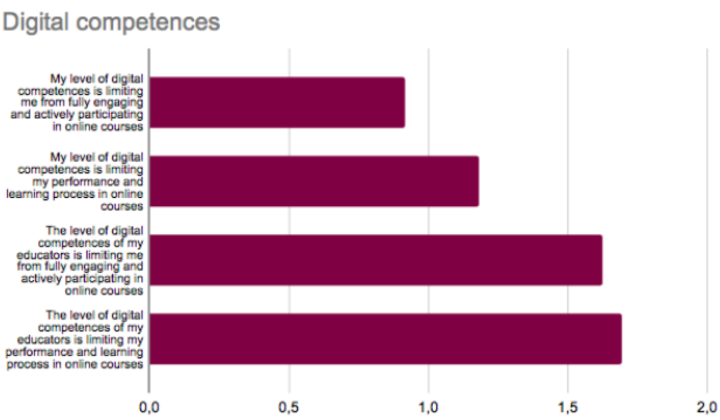

Figure 1. Histogram showing students' answers to the following questions, normalised from a minimum of 0 to a maximum of 3; with 3 being absolute agreement and 1,5 being a neutral opinion and zero being disagreement.

On the contrary, students' opinion on the limiting impact of educators' digital skills is dominant. Learning process and engagement have a similar trend. During the World Café, students mentioned the hindered impact of the poor digital skill level of professors. 87% of students stated that professors could not display information in an efficient way. Besides that, some of the professors were not capable of using the features of the digital tools in a way to engage students more in the lectures (40%).

3.1.2 Recommendations

Transitioning to digital education has allowed students to practise their digital skills, and their current level of digital skills didn't hinder their learning process significantly. Educators' digital competencies improve the learning experience by helping professors pedagogically [3], but educators' poor level of digital competencies hindered the learning process. In order to improve the learning experience in online education, universities should focus on educators' digital skills and provide training courses to use online platforms efficiently [5]. It would be needed to conduct a thorough study on digital skills of educators and assess their needs to improve digital competencies.

3.2 Teaching Methods & Digital Tools

Through teaching methods, students can engage in learning activities, reflect on them, use higher-order thinking and work in groups. Previous studies in STEM education have found that active teaching and learning methods, focused on interaction, provide more interest and engagement in the students' activity in the class [6]. Learning to use digital tools to deliver lessons has positively affected online teaching methods in most universities [7]. The aim of this section is to analyse the effort and attitude of universities facing this challenge, and in which way they chose digital tools to enhance teaching and learning opportunities. In that direction, universities had to use online platforms to enable interaction during lectures and group work, which is a crucial aspect of the learning process. Microsoft Teams, Google Classroom, and Miro are some of the online platforms which enable the interaction and collaboration between peers in the online environment [10].

3.2.1 Results

According to the presented data, it was stated by a majority (Fig. 2) that being able to follow recorded lectures at the preferred place and at the chosen schedule was a great advantage. This fact had an impact on the understanding of the subject and the final results of the final evaluation. During the class an enormous potential to make use of different information sources and activities exists. On the other hand the students admitted that online environments are full of distractions and difficult to remain focused, signalling caution on their extended use. They are related to the high amount of tasks, lack of physical contact and interaction and the content of the lectures. One of the problems stated by more than 67% of the students is that practical lectures in person are crucial for a complete and efficient learning experience. The tools (ppt) and format (non-interactive lecture format) were maintained and only the platform changed, and some courses with easy possibility to be adapted were not. This was seen as a lack of innovation and adaptation to the new environment.

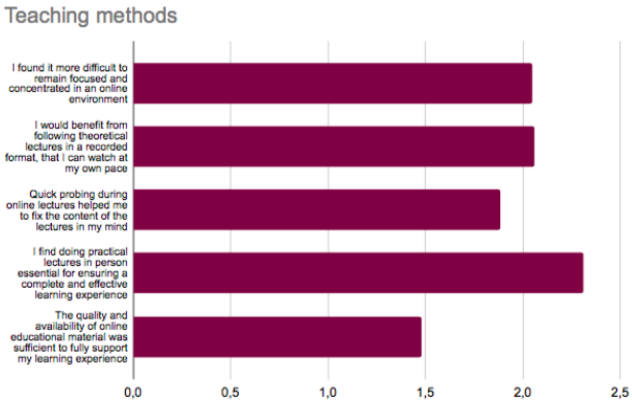

Fig.2: Engagement and learning process benefits from following lectures in a recorded format. The answers are normalised from 0 to 3; with 3 being absolute agreement and 1,5 being a neutral opinion and zero being disagreement.

Students from six universities declared the environment was monotonous and the tools were not used to their full potential in order to engage the people present in the class. The results of the focus groups show that 73% of universities used recorded lectures, which allowed students to rewatch the lectures at their own pace and choose their own learning schedule. It was also shared that with the usage of different tools, it is easier to keep the engagement of the students in the lecture. Furthermore, there were mentions of significant improvements in the usual platforms universities use, as not all learning materials were centralised in a fully-integrated platform before.

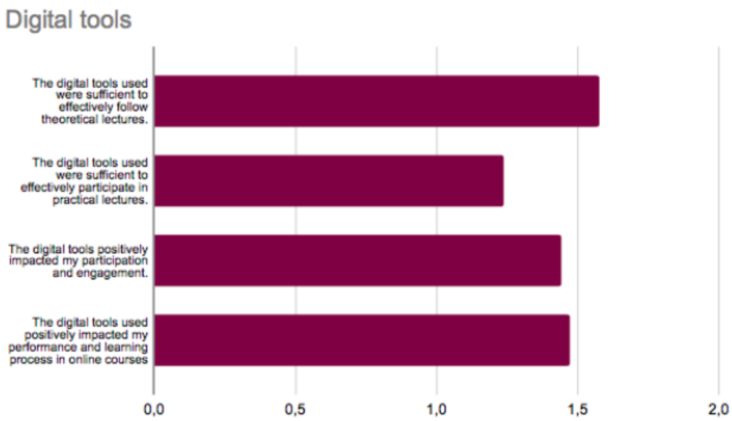

Figure 3. Overview of the impact of used technological tools in online education. The answers are normalised from 0 to 3; with 3 being absolute agreement and 1,5 being a neutral opinion and zero being disagreement.

Fig. 3 shows the impact of technological tools used in the courses from the perspective of students. There is a significant shift toward the mindset that technological tools used were sufficient for students to effectively follow online lectures. In comparison, the balance is significantly shifted towards tools not being sufficient for the practical lectures, with almost 60% of students' voting so. There is a

balance between students deeming tools affecting their participation and engagement both positively and negatively. However, as it is shown, technological tools didn't have a significant impact on students' performance nor learning process in online classes. Access to a stable internet network, as well as equipment that supports digital tools is crucial, and 60% of our respondents shared they encountered issues with it. The main issue identified for STEM students was the lack of tools that simulate practical activities, especially for work with advanced technology and laboratory work, which was noted by 73% of university students.
Fig. 4 demonstrates that students have diverse opinions on this comparison with a slight bias towards decreasing productivity with online group work. It seems that the lack of interactivity among them sets a major drawback to their productivity. Nonetheless, the non-negligible portion of students thinks that online group work increased their productivity.

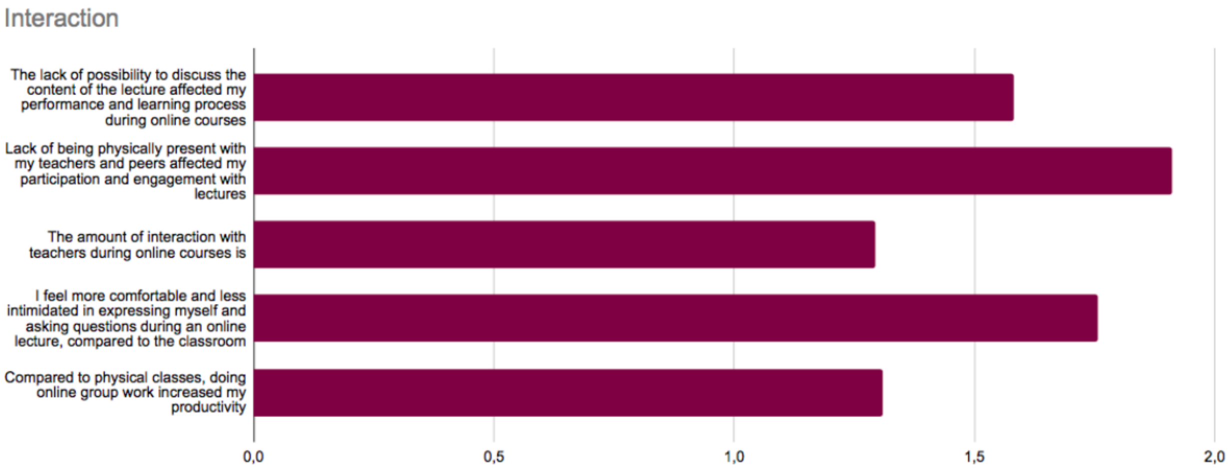

Figure 4. Histograms showing how productivity changed for students in online group work. The answers are normalised from 0 to 3; with 3 being absolute agreement and 1,5 being a neutral opinion and zero being disagreement.

A highly mentioned problem (47%) is the ineffective communication in digital education with their colleagues and teachers. According to students, their performance has decreased on group projects and exams, as a result of ineffective communications during online lectures. Another opportunity mentioned by students (33%) is flexibility to plan their schedule around online education. Lastly, workshops have investigated how the lack of being physically present at the university affected the participation and engagement with lectures. As depicted in Fig. 4, there is an outweighing opinion that lack of physical presence hindered the engagement and participation of students in the lectures.

3.2.2 Recommendations

Modifications in teaching methods have not been substantial, mainly tackling the platform used, not the content itself. Practical lessons are an essential part of some degrees and these were evaluated by the students to be better done in an onsite manner. Students feel like their learning and understanding are increased when they are able to perform the experiment or the project themselves. For teachers, more time is needed in order to revise their teaching methods for the new environment and also for students to adapt to the new online tool.

Recommendations for how to improve teaching methods of STEM education are the following: a) having all the lectures, guidelines and practical courses on a platform, so that students will be able to access them anytime; b) preparing exercises based on the lectures/videos previously provided on the platform and discussed during the actual hour; c) having the possibility to work both alone and in teams; d) providing the possibility to work with scientific tools and analyse real data from laboratories/industries; e) creating preparation tests for the final exams that can be retaken for as many times as needed and with different possible questions; f) giving students the opportunity to participate in class in smaller groups/specific laboratories; g) engaging the students to interact with the actual research topics in their fields - example: using these references for presentations. Teaching approach in this new, digital environment depends heavily on professors' ability to learn, and ultimately manage digital tools [8]. The difference in the digital competence of students and their professors is evident, where professors are expected to be experts and mentors, while in reality, they are still adapting to digital tools. To properly introduce the hybrid model, educators need continuous training and an environment where experimenting and innovating in both choices of digital tools and their purpose of implementation is encouraged. To ensure a proper environment, it is advised that universities tackle internally the choice of digital tools, via a centralised approach, and reduce the workload of professors when it comes to lecture design.

It is noted that some courses cannot be well adapted to online education, thus there is a high need to develop tools that accommodate the need of STEM students for practical lessons. While complete substitution of hands-on practice is not recommended, there is a remarkable space for improvement of existing tools used for practical learning, with many different potential ways open by designing remote practicals through recordings, simulations, quizzes, real and simulated data and augmented reality technology or gamification [9]. There is a significant distinction in the answers to the posed questions which addresses productivity and expressing themselves during lectures. These results demonstrate that students have varying preferences according to their personality or need for flexibility.

A majority of students agreed on a certain opinion: Lack of physical presence has negatively impacted students' participation in and engagement with their lectures. In addition to that, the perception of educators towards digital education is an important factor for the engagement of students with lectures. Educators should have a positive perception towards the usefulness of digital tools as a facilitator of the lectures [3], and motivate students in a way to participate in lectures as a helpful educator [11,12].

3.3 Digital Assessment

Our goal regarding this section is to show how much the assessment methods have changed during the pandemic, how the evaluation changed, how the teachers assure the fairness of their students and what are the main positive and negative aspects of online assessments from students' perspective.

3.3.1 Results

Most of the universities presented a significant or partial change in assessment methods - for example: cancelling an exam and moving the grade to a project, changing a closed book exam to an open book exam, etc. According to the received responses, four main assessment methods (Fig. 5) that have been used during the evaluation of the students are further considered: written exams in universities, written online exams, oral online exams and assignment-based examinations.

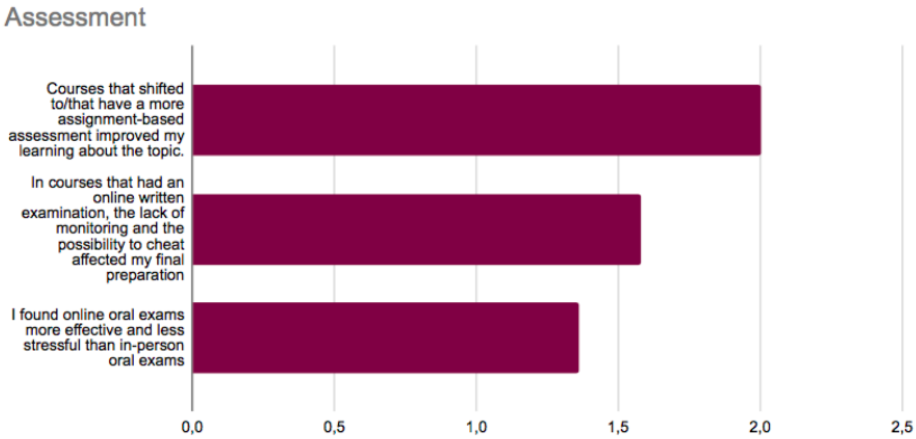

Fig. 5: Histogram with an overview of the assessment methods used.The answers are normalised from 0 to 3; with 3 being absolute agreement and 1,5 being a neutral opinion and zero being disagreement.

One of the main fears from the beginning of the global crisis caused by the pandemic was the assurance of qualitative education and the academic integrity of the students. The reformation of the evaluation to a method where controlling the class is less crucial was desirable and a common approach was the change to an assignment-based assessment. One result was the clear trend in which students found the assignments a way to improve their learning. Some students also stated that mid-term exams, projects and continuous assessments (in the form of assignments) helped them to reduce the workload of final exams and develop a deeper understanding of the subject matter.

There were also some disadvantages noticed by students. Almost all of the World Cafe groups (67%) mentioned that they were overworked by the larger number of assessments that were used to (partially) replace traditional exams. Some students even stated that they were suffering from burnout. Another interesting point: the online-only format of a lot of group projects and labs was considered less efficient, causing students to spend more time on these tasks (33%). Some assignments also cannot be properly translated to an online format and this caused less impactful learning for the related projects (25%). Some students mentioned as a problem that the exam was made harder than in previous years (42%), time requirements were more strict (33%) and students were not allowed to go back to modify answers they previously submitted (33%). Despite these measures, students still found that cheating was possible with relative ease (42%). Furthermore, students' performance during assessments was disrupted both by logistical issues and by a misunderstanding how certain digital tools worked (42%). The most-mentioned advantage of online assessment was that this kind of assessment (be it oral exams, project presentations, thesis defences, etc.) is less stressful. This lack of stress had a positive impact on performance in the exam (67%).

3.3.2 Recommendations

With the COVID-19 outbreak, most of the universities (75%) changed their assessment method to one of three formats: written online exams, oral online exams and assignment-based examinations. These methods are less considered stressful and time-saving by students. Another clear advantage that came up with the adaptations is the learning outcome: Project-based assessments and open book exams are preferred compared to conventional final exams with respect to understanding the subjects throughout the course. On the other hand, adaptation in the assessment method also brought some problems. Assignment-based examinations caused students to be overworked with more assignments, which is why this format is considered less efficient by students. Logical issues and measures against cheating negatively impacted the students’ performance during exams, nevertheless measures against cheating were considered ineffective. The recommendations would be to use „open-book” evaluations, presentations-based ones or team-based evaluations using the analysis of experimental data sets.

4 Summary

The pandemic made universities and educators shift online, but only some have managed this transformation successfully. Some mirrored the same teaching and assessment methods from live to online environment, which affected students negatively. Mainly it channelled outwards through higher disengagement rates, increased stress, etc. However, there are cases of universities which transformed their methods by incorporating digital tools which positively affected interaction in the digital classroom. This change enabled effective usage of digital tools, online collaboration and knowledge transfer. Further research needs to be conducted to have a full understanding and overview of the digital education, from both students’ and educators’ perspective.

Lessons learned, can be summarised as following:

- Digitalisation is an opportunity to improve the learning process;
- Professors need to improve their digital competences and incorporate improved teaching methods which are adjusted to the online environment;
- If digitalisation is done properly, the learning can be more engaging and effective, and pandemic can be used as an accelerator of this change.

This paper invites professors and universities to start investing in structural changes regarding teaching, to unleash the potential of digitalisation.

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TRIGGERING, DEVELOPING AND INTERNALISING TEAMWORKING SKILLS IN NEURO-TYPICAL AND NEURO-ATYPICAL STUDENTS WITH A COMPUTER ORCHESTRATED GROUP LEARNING ENVIRONMENT: A MULTI CASE STUDY

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ABSTRACT

Project-based learning and flipped classroom approaches are often used for developing team working skills in graduates. However, many engineering schools face efficiency and effectiveness challenges when it comes to facilitating students in these settings. For neuro-atypical (NAT) students, such as those with Attention Deficit Hyperactivity Disorder (ADHD) or Autism, support for developing teamworking skills can be limited. Even neuro-typical (NT) students find teamwork challenging and can benefit from an intervention that supports development of such skills. Self, Co and Shared regulation skills are considered important for effective team working. Regulation is a multi-staged process, which includes goal setting, planning, doing, monitoring and evaluating own and a team's work. Research on use of computer scripts to successfully orchestrate the multiple stages at a shared level shows only partial success. Many Computer Supported and Collaborative Learning studies cite over-scripting as a common criticism related to orchestration of shared regulation and team work. This work investigates "How computer orchestration scripts affect the triggering and internalisation of Self, Co and Social regulation skills in NT and NAT students when using a Computer Orchestrated Group Learning Environment (COGLE)?". COGLE was used with first year neurotypical and neuro-atypical engineering students to study its impact on triggering existing and/or internalising new regulation scripts in team working. Qualitative data from two literal replication cases were analysed. This work shows how different types of scripts in COGLE helped trigger, develop and internalise regulation skills and highlights areas where more work is needed.

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1 INTRODUCTION

1.1 Increase in collaborative approaches within Engineering Education

Collaboration skills are considered important within most professions. In engineering, team working skills are one of many crucial skills for the success of any real-world open-ended project. Higher engineering education curricula, in the UK and elsewhere, have seen recent changes in response to the calls from industry and professional bodies to increase focus on problem solving and team working and the use of collaborative approaches to develop these graduate skills [1-3,8-9]. Learning in groups within engineering has been shown to have greater achievement, with a moderate effect size (d=0.25), than learning individually [4]. As a result, collaborative approaches such as Flipped Classroom (FC) and Project Based Learning (PjBL) have gained popularity over the years within Engineering Education [5-6]. In FC, students are expected to prepare the content themselves and take part within collaborative active learning activities in class [5, 7]. In PjBL, students work collaboratively in a group, on a defined real-world project and are expected to learn what is needed to deliver the project. The popularity of such approaches has meant that there has been a shift in the expected role of the academics from being a 'sage on the stage' disseminating information to a more supporting 'guide on the side' role [6]. There are, however, many challenges that come with this shift in expectations and practice.

1.2 Challenges collaborative approaches bring to Engineering Education

Without theoretical knowledge that underpins the change in their role and the skills needed by staff in facilitating groups, staff often face challenges when adopting PjBL or FC approach [6-7]. Not just staff, the students also find it hard to develop and use interpersonal skills if they have not had and do not have access to any formal team skills training [6-7]. Furthermore, PjBL is resource intensive and requires more staff to facilitate teams and to put in extra effort in guiding students. This is particularly important where students are from multicultural backgrounds [6]. As PjBL needs more resources from schools or departments, it can lead to a reduction in institutional support for such approaches over time [6]. This puts any benefits of the PjBL approach, where realisable, at risk. Likewise, students find it time consuming and hard to prepare on their own in the FC approach. Due to limited student preparation, staff find it tricky to carry out their planned collaborative activities in a way that is fair and benefits the entire class [10]. In practice, staff often find themselves performing both the roles of teacher and facilitator, especially when students complain about not being able to learn or work on their own on open-ended real-world problems without being taught first and a similar criticism is faced by flipped classroom approach [6,10].

1.3 Context and Rationale

More and more NAT are entering higher education as diagnosis rates are on the rise. NAT is an umbrella term that includes (ADHD and Autism Spectrum Disorder

(ASD) students. Researchers have claimed that NAT students are more likely to study engineering and technology courses [23]. As a result, it is very likely that most engineering cohorts will have a mix of NT and NAT students learning together. Formally diagnosed, or not, these students face socio-communication challenges that may affect them in realising their full potential [23]. Social interactions and communication are crucial for success within PjBL and FC activities, making it harder for NAT students to succeed. In addition, reasonable adjustments are needed by law and teaching NT and NAT students alongside each other can pose problems [24]. In practice, the demands of PjBL and FC can put most students under pressure, including NT, diagnosed NAT and those that remain undiagnosed [25]. Therefore, the challenges faced in social interactions and communication within group work can limit the success of FC and PjBL for NT as well as NAT students.

Both FC and Project based learning are used within the School of Energy and Electronic Engineering at the University of Portsmouth. Here, teams of students may need to collaboratively design, build and test say a communication system as part of a PjBL project or collaboratively discuss design challenges related to electronic subsystems within FC activities. Disability data from Higher Education Statistics Agency show 0.9% (male), 0.2% (female) & 3.6% (other) current UK domiciled students have ASD or other social communication disorder [24]. Research suggests females can be better at masking social behaviours common in NAT and are not being diagnosed as a result [23]-[24]. As NAT students are more likely to study engineering [23], supporting the already small % of female students entering engineering degrees becomes even more important. In the last three years alone there has been an increase in students with specific learning disabilities (including ADHD) and ASD to 15.7% and 1.2% respectively within the school. This increasing trend in NAT students joining our courses, combined with potential benefits to NT students from an intervention that can cater to both NT and NAT students learning together, provides the rationale for this study. COGLE may provide an approach to teaching that is inclusive for students with socio-communication challenges and enhancing their learning and team working experience.

2 METHODOLOGY

2.1 The intervention: Computer Orchestrated Group Learning Environment

COGLE was developed within the School of Energy and Electronic Engineering at the University of Portsmouth. It orchestrates small face-to-face groups of students watching together short videos followed by orchestrating them practice related questions till they all achieve group-wide mastery, i.e. they can all show that they understand the content by answering questions. During each session students are paired several times to carry out peer instruction with those who get the questions wrong. COGLE runs within a web browser with videos hosted anywhere on the web, for example YouTube®. The questions are carefully designed to encourage discussions between students. To achieve group-wide mastery all students in a team have to get 10 questions correct in a row. Anyone making a mistake resets the count to zero and the team must continue. COGLE plays a remedial video based on the most prevalent mistake in the group.

Working iteratively to build understanding, in a constructivist way, towards a shared goal of GWM is seen as crucial in triggering and achieving SRL, CoRL, and SSRL and team effectiveness. Triggering and internalising regulation, particularly SSRL skills, through orchestrating a simple goal of achieving GWM has not been studied before.

2.2 Underpinning pedagogical theories

Zimmerman's SRL theory and its extension into the social in the form of CoRL and more recently SSRL, explain how shared goals, planning, monitoring and reflection can make individuals become more effective in regulating collaboration at different levels [11]. The repeated orchestration through textual scripts in COGLE has the potential to aid the triggering, development and internalisation of regulation skills, as predicted by *Script Guidance Theory* [25]. This theory posits that a target behaviour, such as SSRL, can be modelled in individuals by scripting it repeatedly, causing internalisation of an appropriated version of the external script [25]-[26]. Scripts can orchestrate and model collaborative behaviour and are therefore used to *"Enhance the probability that knowledge generative interactions such as conflict resolution, explanation or mutual regulation occur during the collaboration process"* [21, p. 1]. Another theory that underpins the success of scripting regulation skills is the Self-Determination Theory of motivation [27]. It posits that learners become self-motivated in a learning environment that makes them: more self-confident by making them more competent; more part of a team by enhancing their relatedness to their teammates; but also, more autonomous as they take control of the tasks themselves and internalise or remember the triggered scripts. SSRL is seen as the highest level of regulation of collaboration [11].

2.3 Research site, participants and research design

Two Electronic Engineering modules, one at level 3 (first year of foundation degree) and one at level 4 (first year of undergraduate degree), were chosen where FC and PjBL activities were being used respectively. This formed the basis for students from level 3 to use COGLE to prepare for FC activity and level 4 students to prepare for PjBL task. The module co-ordinator confirmed observing similar challenges as noted above in both the modules. The two modules also benefit from covering the same basic material in the early parts of the course to ensure students are introduced to basics of electronics before moving on to advanced topics in level 4 module. In order to investigate the potential of COGLE in supporting NT and NAT students together within a real-world setting participants were invited from these two modules to join the study.

The study was approved by the University's research ethics committee and students from the two cohorts were invited, in particular those with ASD and ADHD, and give informed consent for taking part in this study. This was the only way we were allowed to recruit students as access to entire cohort was not permitted by the ethics committee. A total of 19 students joined the study, 9 from level 3 foundation course in Engineering and Technology and 10 from the BEng Electronic Engineering course. Three foundation students did not complete and left the study mid-way as one of their teammates, an international student, left without giving any explanation leaving a group of 2 who did not wish to continue. The remaining 6 level 3 students were put in teams of 3 each randomly and were put into the FC case-study. One level 3 student self-declared as autistic based on a diagnosis in their immediate family. Low diagnosis rates are a common issue and self-identification in this way can be helpful. The remaining 10 level 4 students joined the PjBL case-study and were put in random teams of 3 or 4 students. In level 4 one student was diagnosed with Autism (comorbid with ADHD) and one student had ADHD confirmed via consent by the disability support unit in the university. 16 students completed the two case studies.

Students on the FC case-study learned together for 4, two-hour sessions in their designated teams prior to attempting a two-hour FC collaborative design challenge in the same teams. Students on the PjBL case-study, did the same 4 two hour sessions and in addition 3 further two hour sessions (7 sessions in total) to master the content needed for the PjBL task in their designated teams. The FC task involved designing a bass and treble filter circuit to be used as input to a head-phone amplifier in a two-hour Student Orchestrated Working Together (SOWT) session. The PjBL task was more complex where the students were required to design both the filter circuits as well as the headphone amplifier within a two-hour SOWT session. The content used in the FC case-study was also used in the PjBL case-study in addition to more content on advanced topics as needed for the PjBL project. The two case-studies thus formed part of a literal replication multi-case study design used here [28]. The use of orchestrated group-wide mastery in two different case-studies should generate robust evidence advocating for using such an approach with NT and NAT students within Engineering Education settings to enhance their knowledge and internalise team working scripts used within COGLE.

2.4 Success and challenges in scripting regulation skills

Self-Regulated Learning (SRL) involves planning, monitoring and reflecting on your own actions to achieve individual goals against a set standard [11], [12]. Scripting of self and co-regulation of learning (CoRL), which involves regulating actions of some other teammates, has helped learners improve their group-awareness, socio-metacognitive and socio-emotional regulation skills [12]-[17]. For developing SRL and CoRL skills scripting information sharing, argumentation and negotiations has been effective, as defined in the collaborative framework by [18]. Very few studies, however, have investigated the transfer of these scripted skills into un-scripted environments. Transfer has been more successful where adaptable scripts are used [19] or where students practice the scripted interactions multiple times [16] and where there was support to help students in challenging situations [16]. SRL, CoRL and SSRL skills are considered as key to team effectiveness [11]. In most studies CoRL by others is shown to help develop SRL and self-efficacy [20]-[22]. Dependencies of later stages of regulation on earlier stages in SSRL and the diversity in learner knowledge and skills, makes it very hard for Socially Shared Regulation of Learning (SSRL) to be successful when each of these stages is scripted separately [13]-[14] and scripting SSRL may easily be perceived by learners as over-scripting [20]. Although some success in triggering, developing and internalising Self and Co regulation has been reported, successful scripting of SSRL in teams has been limited [13]-[14], [16]

2.5 Methodology for evaluation

COGLE plays a role is the development of team working skills of these students. After each session the students completed a Daily Events Survey (DES) with free text space to answer the following questions.

1. Describe what did and did not go well, when prompted by the system, to teach or explain to other student(s) a concept.
    a. Also, describe how the system made you or others in your team contributed to improving or worsening the situations you described as “did" or "did not go well” above respectively.
2. Describe what did and did not go well, when prompted by the system, to learn from other student(s), a concept.
    a. Also, describe how the system made you or others in your team contributed to improving or worsening the situations you described as “did" or "did not go well” above respectively.

In addition, qualitative data was collected through an hour-long interview for NT students and up to two hours for NAT students. The interviews were transcribed verbatim by a professional transcriber. This paper presents some key themes from the qualitative data from the DES that was analysed using grounded theory inspired thematic analysis [29]. A full analysis from all sources will be presented in a subsequent research article.

3 RESULTS

3.1 FC Case

The daily events survey was completed by all 6 students after each of the 4 sessions and the SOWT session. Then using grounded theory inspired thematic analysis, the themes shown in Table 1, emerged in the majority of the responses from a majority of the sessions.

Table 1. FC case: Themes from the DES

Theme/ Sub-theme	Description	Sample quotes
Orchestrates GWM and CoRL	GWM script paired teammates who taught each other.	"[Pairing] was a bit weird as explaining a topic [at first but it]… went well. [Pairing] allowed us to discuss the topic."
Teammates can takeover pairing.	GWM linked penalty caused positive frustration, that triggered overtaking COGLE's pairing.	"We all helped to explain and understand concepts [on our own] when it was required [to achieve GWM]."
Co/SSRL practiced and internalised	A simple goal of GWM made them switch between working under their shared scripts and COGLE scripts.	"I think [today] it was more of a team effort rather than the system that helped us progress this time."
Shared goal and working together	Aimed to finish the SOWT task by working together.	"We were very quickly able to come up with suitable numbers and circuits between us, …we did struggle… however we worked well as a team through the issue"
Team effectiveness and satisfaction	Felt teammates worked together	"We combined all our ideas together to get it all right."

Themes in Table 1, show that the repeated computer orchestration of pairing, although initially awkward, soon enabled the externalisation of knowledge between teammates in order to achieve the GWM goal. The pairing script at first triggered CoRL in teammates, and later the students took over the pairing themselves, showing early internalisation of CoRL. The GWM script triggered shared working, monitoring and reviewing as teammates wanted to complete mastery without having to do many more questions. There was no need to script these phases with separate scripts. Students were able to develop and internalise both CoRL and SSRL skills within just 4 sessions. The scripts were appropriated, internalised and also used in the SOWT sessions even when the COGLE scripting was removed thus showing transfer. The teams were able to complete the set task in the FC without any help from any staff effectively and efficiently. They were also satisfied with their solutions. The presence of a NAT student in a team of NT students did not cause any issues to either any NT or NAT student. Thus, showing the inclusiveness of COGLE.

3.2 PjBL case

Likewise, the daily events survey was completed by all 10 students after each of the 7 sessions and the SOWT. Then using grounded theory inspired thematic analysis, similar themes emerged in the majority of the responses from a majority of the sessions.

Themes in Table 2, show that the repeated computer orchestration of pairing, helped externalisation of knowledge needed to achieve the GWM goal. Here too, CoRL was triggered by script at first and later taken over by the students, showing early internalisation of CoRL. The GWM script triggered shared working, monitoring and reviewing as teammates wanted to complete mastery without having to do many more questions. There was no need to script these phases with separate scripts. Students were able to develop and internalise both CoRL and SSRL skills within just 4 sessions. The scripts were appropriated as they were internalised and were used in the SOWT sessions even when the COGLE scripting was removed thus showing transfer. The teams were able to complete the set task in the PjBL without any help from any staff effectively and efficiently. They were also satisfied with their solutions. The presence of a NAT student in a team of NT students did not cause any issues to either any NT or NAT student. Thus, showing the inclusiveness of COGLE.

Table 2. PjBL case: Themes from DES

Theme/ Sub-theme	Description	Sample quotes
Orchestrates GWM and CoRL	GWM script paired teammates who taught each other.	“The system prompted [collaboration] at correct times which made the session go well.”
Teammates can takeover pairing.	GWM linked penalty caused positive frustration, that triggered overtaking COGLE’s pairing.	“Sometimes it was difficult for other students to explain a topic [when picked by the system] but we would work together to help explain that topic”
Co/SSRL practiced and internalized	As simple goal of GWM made them switch between working under their shared scripts and COGLE scripts.	“If the [chosen] explainer wasn't explaining well, then the other person would chip into try and help, usually it worked.”
Shared goal and working together	Aimed to finish the SOWT task by working together.	“We managed to get a lot done… we worked efficiently and as team. Choosing resistor values cause a bit of a debate but we overcame this by agreeing to one value”
Team effectiveness and satisfaction	Felt teammates worked together	“We produced a reasonable design, and was mostly happy with the outcome”.

4 Discussion and implications for engineering educators

The two cases provide repeating results adding strength to the claim that COGLE’s simple GWM goal alongside flexibility in the pairing script is able to support a mix of NT and NAT students where both shared and practiced regulation and team working skills before demonstrating effective teamworking when orchestration was removed altogether. The flexibility to rely on scripts during learning sessions as and when needed or to takeover regulation themselves, helped students practice and gain confidence in regulation skills. It also allowed those with existing skills or those becoming more confident to takeover regulation from COGLE and practice it themselves. By externalising their scripts, students shared their skills with the others in the team. The frustration due to the penalty in the GWM script, whereby the count leading up to the target of answering 10 consecutive questions was reset if even one of the teammates made a mistake, helped trigger this takeover and the shared monitoring, working and reviewing took place between teammates. It also meant that when a shared approach was successful, students would use it in future too. COGLE encouraged being supportive of each other but also supported learners when needed. Regulation changed hands between COGLE and teammates and back until the teammates were ready themselves.

Due to changes in teaching approaches during the pandemic, many staff now use chunks of video and quizzes as normal teaching material. Although orchestrating the use of these videos and quizzes still present a challenge. As higher education settles into its new normal post pandemic, orchestration systems such as COGLE offer new ways in managing classroom interactions and activities, in addition to promoting the triggering, development and internalisation of regulation skills crucial to team working.

5 SUMMARY AND ACKNOWLEDGEMENTS

This work presented the evaluation of Self, Co and Shared regulation and team working skills in collaborative settings such as FC and PjBL after using a novel group learning environment, COGLE. It shows how both NT and NAT students were motivated to come together as a team within a computer orchestrated environment which used a GWM script to prepare them for collaborative activities in a SOWT session later on. They completed the FC and PjBL SOWT activity that followed successfully without being orchestrated by any computer scripts, indicating successful transfer of Self, Co and Shared regulation skills. Furthermore, COGLE was able to support NAT students in overcoming socio-communication challenges in an inclusive manner whilst learning alongside NT students. The use of COGLE frees staff from having to teach instead of focussing on guiding students during PjBL and FC activities, making it more efficient and effective. The post pandemic classroom needs more innovative solutions like COGLE to successfully transform engineering education from being more lecture based to more interactive, skills focussed and student centric. COGLE prepares students before they set foot on collaborative tasks that require both, team working skills and mastery of technical knowledge, the two most important pillars in engineering education. The two cases show the transferability of the intervention design for mixed groups of NT and NAT students in terms of triggering, developing and internalising regulation skill and effective team working skills.

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EARLY CAREER PATTERNS, EXPERIENCES, AND INFLUENCES: REFLECTIONS FROM WOMEN ENGINEERS IN SENIOR ROLES

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ABSTRACT

Early career experiences provide the foundation for career progression and inform career choices and decisions. For women in the engineering profession, positive early career experiences have been linked to persistence and retention within the profession A recent focus on early careers within engineering has provided insight into early career role types and related competencies, competency and capability gaps experienced by novice engineers, and their perceptions of meaningful engineering work. There is opportunity to diversify and contextualise this understanding by exploring early career experiences of women working within the engineering profession, and by considering the influence of gender on early career experiences and decisions.

This paper reports on an empirical investigation of the career experiences of 22 women engineers in senior roles within engineering organisations in the Australian context. Phenomenological and temporal analysis of their career reflections provides evidence of three early career patterns of varied sequence and focus. The influences shaping these career paths are described. By making explicit possible, diverse early career paths, determinants and outcomes, this paper aims to continue to bridge the engineering education-practice gap and to contribute to greater equality, diversity, and inclusion within the profession.

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1 EARLY CAREERS IN ENGINEERING

1.1 Early Engineering Careers

Engineering careers are diverse, with divergence observed from early career [1]. The understanding of early career experiences, as an aspect of engineering practice, is important as they provide the foundation for career progression and inform career choices and decisions.

Early careers within engineering have been conceptualised according to role type and focus, for example: technical, managerial, entrepreneurial, project-based [2]. An alternative approach by [3] provides a nuanced insight into the types of roles occupied by junior engineers by considering role expectations, rather than role type. Examination of engineers' pathways to senior roles provides information about the early career paths and mobility patterns. [4] found that the length of time spent in by engineers in early roles and the mechanisms by which they moved beyond these into more senior roles varied, according to the type of senior role.

The competencies and capabilities required to perform the early engineering roles have been identified. While there are generic graduate competencies [5], early career competency priorities vary according to the type/expectation of the role and the context of the role (i.e.: organisation, industry, country) [3]. Capability 'gaps' experienced by young engineers, encompass personal attributes, relational capabilities, cognitive abilities such as lateral thinking and problem solving, and industry-specific knowledge [6].

Exploring engineers' lived experiences has revealed motivations, values and meaning for early career engineers. [7, 8] highlight the importance of agency, relational and structural factors on the quality of early career experiences.

1.2 The Current Study

While it is recognised that women in the engineering profession experience reduced rates of participation and progress than their male colleagues [9], the 'early careers in engineering' research has not considered the career patterns and experiences of female engineers. To this end, this paper explores the early career experiences of senior women engineers in Australia. The aims of this paper are to identify and describe i) their early career patterns and ii) the key factors that have shaped their early career patterns and experiences.

The paper contributes to a more expansive, inclusive, and nuanced understanding of early careers in the engineering profession. By making explicit possible, diverse early career paths and determinants, this paper aims to continue to bridge the engineering education-practice gap and to contribute to greater equality, diversity, and inclusion within the profession.

2 METHODOLOGY

2.1 Theoretical Framework

This paper draws on a broader study informed by phenomenological and feminist perspectives to investigate women engineers' experiences of transition to positions of influence within technical organisations. The phenomenological perspective focused the research on the phenomenon of movement into management and leadership roles, and placed to accounts and experiences of the participants at the centre of the research [10]. The feminist perspective acknowledged gender as a basic organising principle, and that choices made and experiences relayed by participants were shaped by gendered social systems and organisations [11]. It also acknowledged the absence of women's perspectives from the current understanding of engineering careers.

2.2 Data Collection

Semi structured in depth interviews were conducted with 22 degree-qualified engineers who self-identified as female, and as working in a managerial or leadership role in a technical organisation within Australia for a minimum of 12 months. Participant recruitment used criterion and snowball sampling, drawing on the membership of Engineers Australia (the national peak professional representative body), and the authors' professional networks.

The focus on technical organisations excluded engineers who had left the profession or were pursuing alterative careers in non-engineering centric industries or organisations. An objective of the broader study was to understand the conceptions of management and leadership form the points of view of the participants. As such, a managerial or leadership role was not pre-defined.

Participants were employed in a range of industries and organisation types, including technical service companies, consultancies, government organisations and owner companies, across resource, infrastructure, construction, transport, and defence industries. The types of managerial and leadership roles that the participants held were predominantly in middle management. Managerial or leadership experience ranged from 12 months to over 20 years.

Interviews focused on engineers' experience of becoming manager and leaders in the engineering profession. Interviews lasted between 45 to 80 minutes.

2.3 Data Analysis

The Broader Study

Interview transcripts were analysed using phenomenological and temporal approaches, informed by Van Manen and Moustakas [10, 12]. Phenomenological analysis yielded ten key themes that were condensed into three categories, representing the influences shaping the women's transition to management and leadership roles:

- Individual: relating to participants' characteristics, motivations, agency, and identity.

- Relational: relating to the influence of other people on women's career advancement, including relational capitals such as reputation, credibility, and visibility.
- Structural: relating to the influence of 'structures' including the organisation, the engineering profession, and broader society.

Consideration of the move to management and leadership roles as an experience unfolding over time generated a series of transition phases: 'Getting Started', Making a Move', 'Encountering Change and Challenge', 'Negotiating the Environment' and 'Resolving and Reconceptualising'. A detailed discussion of identified themes and categories is presented elsewhere [13].

The Current Paper

While not a primary focus of the broader study, the detail provided in interviews by participants about their early careers was surprising and indicated the importance of this career stage. Women engineers' transition to manager and leader was revealed as a process commencing in and influenced by early career experiences.

For this paper, we revisited the participants' career narratives to focus on the early career stage. To address the first aim of the paper, a chronological sequence of roles preceding and following the first management or leadership role established for each participant. Role sequences were then categorised according to the types of roles characterising early career and the timing of the first manager/leader role. To address the second aim of the paper, interpretation of the phenomenological themes and categories focused on sections of transcript relating to early career.

In engineering practice research, early career is considered as the period following graduation from an engineering qualification at university and entry to the engineering profession as a graduate or novice engineer, to the point in time when a professional engineer can work unsupervised [14]. This may be marked by a professional or organisational norm such as chartership or reaching of a certain level within the organisation. For our study, we focused on the first 7 years of participants' careers. This is a critical career point for women engineers, after which their attrition from the profession is thought to peak.

3 RESULTS AND DISCUSSION

3.1 Early Career Patterns

Three early career patterns emerged from the data. They are presented in Table 2, with indicative early career role focus and timing of the move to first managerial role (as average years of engineering experience).

Table 2. Early Career Patterns of Women Engineers

Pattern **(Number of participants)**	**Early Career Role Focus**	**First M/L Role Timing (average years)**

Early Responsibility (6)	Technical, then quickly into a management/leadership role	2 years
Solid Technical (15)	Technical	11 years
Broadening (1)	Technical plus other functional roles	9 years

Most participants described a 'Solid Technical' early career pattern, characterised by technically focused engineering roles with increasing seniority and autonomy. This is akin to the 'technical' track commonly documented in engineering careers literature. The dominance of this career path is not surprising, given the technical basis of the engineering profession. [4] describe these early career engineers as highly driven problem solvers motivated by complex technical challenges. They make career choices to align with these preferences and are likely to occupy Technical Specialist roles later in their careers. This was partly supported by our findings. Some women with this early career path did display a strong technical orientation, however others used this as a mechanism for navigating motherhood during early career, going on to occupy broader roles in later career rather than remain as technical specialists.

A smaller group had 'Early Responsibility' moving into management/leadership roles quickly. This included women in the military, where technical and managerial responsibilities are combined from the start of career. Early career engineers following an Early Responsibility pathway moved quickly out of technically focused engineering roles into project management; broader roles with a technical aspect, but not a technical focus; or, per women in the military, integrated technical-management roles. Rottman and colleagues [4] describe these early career engineers as becoming *Company Men,* likely to be tapped for progression and eventually groomed for organisational leadership roles. In contrast, the early move to management/leadership roles seen in our study was primarily due to organisational design rather than relational factors or driven by the individual.

Only one participant's early career was categorised as 'Broadening', with movement through technical engineering roles, commercial and other functional roles within the same organisation.

Early roles had a bearing on the path or opportunities available later in career:

> *You can't be the head if you haven't got the grounding. It depends on which role you take as to what your opportunity may or may not be. (M9)*

A common thread linking the three career shapes was movement and mobility between sections of an organisation, from one organisation to another, from site to office-based roles, or between geographic locations. A particular mobility pattern was observed: most of the engineers with an 'early responsibility profile' oscillated between managerial and technical roles in their early career and did not follow a consistent and linear path of increasing managerial responsibility. For some, this was related to parental leave, but more often this was associated with international relocation. This oscillation pattern was also observed in the later careers of some participants. These patterns are consistent with non-linear patterns observed in women's careers beyond the engineering profession [15], but are not reflected in current early engineering career models.

3.2 Early Career Influences

3.2.1 Individual

Participants' early career was influenced by their **individual characteristics, abilities, and preferences**. Personal qualities such as confidence, ambition, curiosity, a desire for autonomy and willingness to lead were apparent. Many expressed a clear preference for certain types of work and were aware of these preferences from early career. Self-awareness of these qualities and the ability to choose roles that enable them to exercise their preferences was noted:

> *I didn't ever see myself as purely technical, no. I always thought that my skills were broader, and I could bring more to the profession than just technical skill. And I was interested in more than that. (M4)*

During early career, participants built their **human capital**. It was important to be a 'good engineer' in early career. Early career roles enabled the accumulation of technical and practical knowledge, described as "technical grounding", and demonstration of technical competence. This generated confidence which impacted their readiness to pursue senior roles and perceived ability to perform them in later career. Technical grounding was considered an essential foundation for becoming a manager or leader in engineering related industries:

> *You have to understand what it is that you are managing if you want to be a manager, so you need a good technical grounding and a breadth of experience in the field, I think. (P3)*

In addition to technical grounding, participants gained exposure to managerial work in early career. Roles in which they were second in charge (2IC), instances in which they themselves were "doing the job anyway", informal opportunities, or exposure through small projects enabled sampling of management work and building of experience and skill for official or larger managerial roles.

3.2.2 Relational

Participants described the relationship with the direct supervisor in early career as influential. **Relationships with superiors** facilitated or hindered access to subsequent roles. Good relationships with their superiors enabled participants to demonstrate their abilities rather than being held back. Poor relationships or conflict served to limit their career prospects.

Superiors were described as role models, providing a vision of a 'possible self'. Others saw them as mentors and guides who helped them to navigate early career and provided advice on career decisions or moves. One participant recanted advice received from her direct supervisor:

He said to me after five years 'get yourself a new job because you are not getting anywhere in this company, get out, you are not made for this job, you will never get anywhere, the company is too conservative'. (M17)

Beyond early career, supervisors and other colleagues became **mentors, sponsors, and advocates**. Positive shared work experiences provided a connection and established trust used in later career.

Relational aspects of **credibility** and **visibility** created opportunity for advancement and allowed the women to build relationships with others within their organisations, which became influential in later career.

In early career, credibility was linked to accumulation of practical experience and demonstration of technical competence. Practical experience and the willingness to engage with hands-on work was especially important in establishing credibility with peers and those working in trade-based occupations:

I'd done work experience with Company A where I'd literally just driven trucks and shovelled dirt and that sort of thing. And whilst that didn't teach me a huge amount about individual sections of the work I managed, it gave you the ability to talk to the people that were doing that sort of work. (M2)

Linked to credibility and reputation, **visibility**, or being known or noticed by others within the organisation in early career was consequential in later career. In early career, visibility was established by working on high profile projects or taking on roles that gave exposure to people across the organisation. For some women, early career roles enabled the showcasing of both 'engineering' and 'non-engineering' skills:

I was involved on the bid team for the [large contract name] which was a really interesting experience. I think that might have been where others around me notice that I might have skills other than just engineering. (M3)

Gender, or being one of a small number of women, also provided heightened visibility. One woman was guided to use this point of difference to her benefit:

My supervisor always said 'Well, they'll remember you because you are a girl and there's very few other girls', he used to say it was a great thing to be remembered. (M16)

Descriptions of paternalistic relationships with a 'father / grandfather – daughter' dynamic were common and were perceived to facilitate career progression, consistent with [16]. Interestingly, this relationship dynamic was perceived as limiting in later career by some.

I won't say that I milked it, but I was grateful for it and therefore built relationships with men in that way. Sort of purged them for information that they had, that sort of thing. (M2)

Relational factors have been related to experiences of positive and meaningful work for novice engineers [7, 8]. Collaborating with others, feeling valued as part of a team, and receiving feedback and validation are important during early career. Our findings provide further detail of key relationships and relational mechanisms present in early career and highlight the gendered nature of these interactions for female engineers.

3.2.3 Structural

Organisational norms acted to facilitate and constrain the participants' early careers. Younger participants, or those that worked in government or defence organisations, accessed structured graduate programs. Other organisations did not have formal programs, but the organisational norms determined typical career and promotion pathways:

> *Yeah, it was very early. Company A were good like that. Company A were very much a sink or swim company… as a result they put you in these positions very quickly. (M2)*

Such structures enabled the building of human capital by providing developmental or significant experiences (such as site, field-based roles, or deployments) or formal professional development opportunities by design.

Prescribed pathways and **highly structured, visible, and explicit hierarchies** provided career path frameworks. Available career pathways, described as 'typical', 'well-worn, 'generalist' or 'technical' paths were also made visible by the choices and opportunities taken by others, revealing organisational values and shaping participants' impressions of career possibilities. While career pathways are highly visible and organised in many organisations, the process of accessing that path can be opaque and mysterious:

> *It was all a bit like secret men's business… there was no transparency whatsoever as how you go from A to B. (M8)*

Others felt constrained by their organisation. **Rigid recruitment criteria** – *"because of the structure of local government you have to fill the boxes"* (P2) - meant that promotions were applied for but not achieved. **Organisational attitudes** restricted women from accessing developmental experiences:

> *Most of the company's work was remote mine site construction and there was an element within the company that thought that women weren't suitable for that. Quite happy to have the site secretary and the site nurse being women, but not the engineers. (P3)*

Provision of clear and documented progression pathways have been recommended by multiple sources. Organisational culture has been posited as the key influence on women engineers' workplace experiences [9].

3.2.4 Gender

Gender was acknowledged by most women as a point of difference, however its impact in early career was contested. Some participants felt that being a woman was disadvantageous. Early career was perceived as a "hard road", or a "steeper curve" compared to their male colleagues. Others perceived their gender as having little or no impact. Regardless of position, the data revealed a focus on competence and merit as the determinants of career progression. The reaction to tempered opportunity or differential treatment was to prove competence and capability by working harder. One woman spoke of “working very tirelessly” (M8) in early roles. Another woman working in construction emphasised the importance of merit with regards to the availability of work roles through her career.

> *It wasn’t “You were given the role because you are female” I think you were given the role because of the experience that I had in the type of work that I did and the roles that I had previously. (M13)*

For women engineers, interactions and relationships in the workplace are coloured by gendered roles and stereotypes, and by heightened visibility from the beginnings of their careers. Our study highlights the gendered nature of some of these relationships and relational aspects, in particular paternalistic relationships, visibility, and credibility and competence. A strong focus on competence and credibility is a way of ‘doing gender’ in early career - that is, it is a tool for managing the male-dominated profession of engineering and masculine workplaces.

4 SUMMARY AND ACKNOWLEDGEMENTS

4.1 Implications, Limitations and Future Directions

Graduate engineers often have loosely held expectations of what their roles will entail, and the career paths available to them [17]. A misalignment between expectations and reality can lead to issues with performance and satisfaction. The possible, diverse early career patterns, the experiences (positive and negative) and drivers of early career presented in this paper contribute to a more accurate understanding of engineering practice. This serves to bridge the education-practice gap, by emphasising a variety roles and career paths available to junior engineers. This may be helpful for engineering educators who wish to better prepare their female students for engineering workplace by providing a realistic view of early engineering careers and provide focal points for skill development and provision of support. These findings are also relevant for organisations who wish to better support their women engineers.

A limitation of this study is that early careers of women engineers was not the primary focus of the broader study. Instead, the importance of this career phase emerged during the analysis of the study. In addition, several of the participants were very experienced engineers, and as such their ‘early career’ was some time ago. The nature of their early careers may be different to those of the present day. These limitations indicate an opportunity for a purposefully designed study of the early careers of women in engineering in the current societal context.

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A CONTRIBUTION TO STUDENTS' ASSESSMENT ADJUSTS OF MULTIPLE CHOICE QUESTIONNAIRES WITH FUZZY LOGIC

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ABSTRACT

In University environment, it is common to use multiple-choice objective tests with three or four possible answers, of which only one is correct and the rest are erroneous. In this type of tests, usually the wrong answers are penalized in order to avoid the effect of the random answers. However, there are questions that hardly students answer since their difficulty is high. On the other hand, there are also questions that answer virtually all students since their difficulty is simple. While sometimes the course professor chooses to suppress these questions, it is also common to leave them as part of the calculation of the overall score. This communication proposes a way of, without suppressing any question, making a readjustment of the grades based on fuzzy logic techniques. To do this, it is considered, on the one hand, the initial grade obtained by each student and, on the other, the total difficulty index of the test. With these two variables, an approximation can be made to a system of linguistic variables that allows correcting the final grades of each student based on the objective difficulty of the test and a set of rules established by the professor. This will revert to greater "justice" in students' mark system, since it will be a function of the difficulty of the test.

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1 INTRODUCTION

1.1 Assessment system

Student assessment is the process that allows knowing what is the level achieved by these students in certain formative objectives. A fair and transparent evaluation assessment system is the one that guarantees that the student body receives a grade that does not limit their future opportunities. Notice that to approve or fair unfairly is vital and the qualification must be, first of all, fair for each student, and as close as possible to the reality of the knowledge achieved for him/her, since each person is unique and, therefore, the assessment should take into account this diversity.

In order to assess the students' performance, in terms of knowledge acquired, one of the most widely used tests is the multiple choice questionnaire (MCQ), consisting of a question and three or four possible answers. Only one of them is valid and the others, called distractors, are false. These formats are known, in a short form, as MCQ-3 and MCQ-4, respectively.

Research of [1], [2] and [3] suggest the model with three answers (MCQ-3) since it saves response time to the student and does not oblige the professor, especially junior, to use improbable and/or defective distractors. On the other hand, the four-answer model is more suitable if there is a reasonable time available for the test or if the professor is already a senior.

On the other hand, since Zadeh [4] established the principles of fuzzy logic, this has been used to solve problems in very different fields, calling attention also in the academic field as it helps to obtain fairer grades in students and with greater transparency. For instance, in a course/subject rated over 100 points, in which at least 50 points are needed to pass it, the case of a student with a grade of 49 would be considered as a "questionable" mark since it could be considered approved or not, taking into account factors such as the time taken to answer the test, its difficulty, the importance of each question, the complexity in determining the correct answer, etc. Therefore, these factors should be considered in some way when course professor defined the mark obtained by his/her student. In addition, the teacher may have different types of students in his classroom with different learning rhythms or particular educational needs, which means that not all of them, perhaps, should be evaluated in the same way, since the classroom is a very diverse human space. With fuzzy adjusts it's possible be a more accurate assessment. With diffuse adjustments, it is possible that the evaluation is more precise and even fairer by being able to attend to particular cases.

1.2 Literature Review Concerning Recalculation of Students' Assessment Using Fuzzy Logic

Following [5], fuzzy logic is a generalization of crisp set theory and traditional dual-valued logic. In fact, in fuzzy set theory the range of the membership function characterizing a set is extended from *only two values*, 0 or 1, to *any* value between 0 and 1.

Most of publications related to student assessment with fuzzy logic techniques refer to seminal articles of Zadeh and Biswas [6]. The article by Chen and Lee [7], also related to students' assessment through fuzzy logic, is also cited profusely in the literature. Since then, fuzzy logic has been used in very different academic fields, being a current of interest the adjustment of the grades obtained by students taking different adjustment parameters and mixing fuzzy logic with other techniques traditionally associated with artificial intelligence (AI) as the case of data mining. One interesting example is in [8], [9] and [10].

They are in the literature many different approachs using fuzzy logic, as can see in [11] and [12], and also in [13] to [18]; in many approaches with multiple input variables, it seems reasonable to use a fuzzy inference model by successive steps, since it allows establishing the rule bases by pairs of variables, giving rise to small and simple base rules simply deductible by the experience.

Studies carried out related to the different fuzzy inference techniques should also be pointed out, and defuzzification methods like those of related in [19], [20] and [21]. In addition, many authors use Matlab® to implement their contributions.

Regarding the geometry of the fuzzy sets used, almost all the publications consulted refer to triangular or trapezoidal sets due to the simplicity of calculation since the differences that would be obtained with other joint geometries (sigmoidal –used by [12]–; Gaussian –used by Hameed and Sorensen [17]–, hyperbolic tangents, etc.) are not relevant to the outcome. Also, the use of other geometries that are not trapezoidal or rectangular are used only when the use of Matlab® software is available.

We propose in the following section a very simple method of calculation using the inference of Mamdani [22], and taking into consideration only the difficulty of the test and the qualification obtained. Some authors such [19] have used the difficulty of a certain competence based on students' marks who studied the subject before and with a difficulty level specified by the professor. In any case, the use of the difficulty index of an objective test has not been located in the bibliography consulted by authors.

2 METHODOLOGY

In an MCQ, the calculation of the difficulty index (*DI*) of each of the questions is the one expressed in (1):

$$DI = \frac{\#Correct\ answers}{\#Questions} \tag{1}$$

It is considered a classic classification of the difficulty scale, taken from [23], which is the one that can be seen in Table 1. The scale and difficulty may vary, but authors consider that that listed in Table 1 is very convenient for academic purposes.

The overall difficulty index of an entire test, DI_{TOTAL}, may be established by taking the average of all difficulty indexes for all questions, according to (2). Therefore, it is simple, by means of a simple table with a spreadsheet that contains in the rows to the students and in the columns the questions, to have in each cell the qualification obtained by each student in each question. Applying (1) to each column, you can determine the parameter DI and identify the difficulty of each question. In addition, applying (2) the difficulty of the test, as a whole, can be obtained.

Table 1. Classic interpretation of the difficulty index (DI).

Value	***Interpretation***	***Suggested Action for the question***
DI > 0.75	Very Easy	Dismiss definitively
0.56 < DI < =0.75	Easy	Candidate to be discarded
0.46 < DI < =0.55	Regular	Review
0.26 < DI < =0.45	Difficult	Candidate to be discarded
DI <= 0.25	Very Difficult	Dismiss definitively

For MCQ-3, the optimal total difficulty would be 0.67 [24]. However, it is considered average difficulty, in general, between 0.50 and 0.60 [25]. If possible, experts suggest that items should have indices of difficulty no less than 0.20 and no greater than 0.80. It is desirable to have most items in the 0.30 to 0.50 range of difficulty. Very difficult and very easy items contribute little to the discriminating power of a test [26].

$$DI_{TOTAL} = \frac{\text{Mean of Difficulty Indexes}}{\text{Number of Indexes}} \tag{2}$$

When differentiating one category of difficulty from the next using crisp values, it is difficult to consider that a question with DI = 0.55 is “regular” and that one with DI = 0.56 is “easy” so that it seems natural to consider this variable as a fuzzy set taking as many subsets as difficulty categories. Likewise, when considering the DI_{TOTAL}, the overall difficulty of the test can be established diffusely, considering that a test with DI_{TOTAL} = 0.55 is “regular” and one with DI_{TOTAL} = 0.56 is “easy”. For this reason, and taking as reference the crisp values of this indicator, a categorization based in fuzzy subsets is established such as the proposed in Figure 1. In this article, we use triangular membership functions because this shape has been proven popular in fuzzy logic and being used extensively in student academic performance assessment [26].

In Figure 1 it can be observed, respecting the spirit of the differentiation of difficulty index, that values below 0.25 and above 0.75 as well as those between 0.45 and 0.55, will only belong to one fuzzy subset, while that the rest of values will belong to two fuzzy subsets.

Taking as reference the crisp values of this indicator, a categorization based in fuzzy subsets is established such as the proposed in Figure 1. We use triangular membership functions [27], but other shapes are possible (that not has a significative difference respect to results).

Let us take as an example, a test with 5 questions in format type MCQ-3 (three answers per question, an answer right and two answers acting as distractors), in which five students participated. In order to discard the random factor and, in some way, discourage the student to try his luck in case he does not clearly know the answer. The amount of penalty would be established, in this case, by the expression (3) taken from [28] which, in turn, [29] cites and also is studied by [30] and [31]. The unanswered questions will have zero value and the wrong answers, will have the corresponding penalty according to their weight.

$$Penalty = \frac{1}{\#Possible\ answers - 1} = \frac{1}{3-1} = 0{,}5 \quad (3)$$

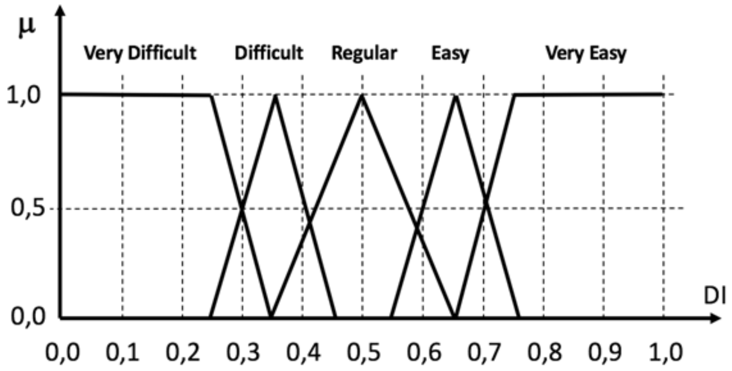

Figure 1. Fuzzy sets for difficulty index total, DI_{TOTAL}.

This means that, in case all the questions are MCQ-3 type, the penalty will be half the value of the right answered. If the number of possible answers is different in some questions, the local penalty for each different question would apply. Table 2 shows a hypothetical result of the presented example.

Table 2. Difficulty Index per question and global grade per student.

Question →	**1**	**2**	**3**	**4**	**5**	
Weight (%) →	**15**	**20**	**15**	**30**	**20**	
Student ↓						**Grade over 100 points ↓**
1 →	-7.5	0	15	30	20	**57.5**
2 →	-7.5	20	0	0	0	**12.5**
3 →	-7.5	20	0	30	-10	**32.5**
4 →	0	0	15	0	20	**35**
5 →	15	0	-7.5	0	20	**27.5**
DI →	*0.2*	*0.4*	*0.4*	*0.4*	*0.6*	

In example shown in Table 2, DI_{TOTAL} = 0.4. Thus, we can calculate the fuzzy difficulty index (FDI_{TOTAL}) with fuzzy sets shown in Figure 1. We want to highlight the use of Excel® for all calculations in this paper. After fuzzification, Table 3 shows the values of membership subsets.

Table 3. Fuzzy total difficulty index (FDITOTAL) of the questionnaire.

Fuzzy sets	Very Poor	Poor	Regular	Difficult	Very Difficult
FDI_{TOTAL}	0	0.5	0.5	0	0

In order to place the student grade in one of, for example, five categories, it is important to place his initial grade in a fuzzy environment like shown in Figure 2.

Some authors cited in [21] make a different proposal for the distribution of these subsets in order to categorize students' grades placing any grade between 0-0.2 points only in the category of 'poor' and between 0.85 and 1.0 only in the 'good' category. However, most of authors establish the limit of 'poor' between 0 and 0.1 and 'good' between 0.9 and 1.0. Continuing with the previous example, for calculate the membership to each fuzzy set, we need to obtain the equations of every subset segment, for example, for interval 0.1-0.3 (*Below Average*), the equation used is y=5x+1,5. Fuzzy grades for each student of the example are shown in table 4.

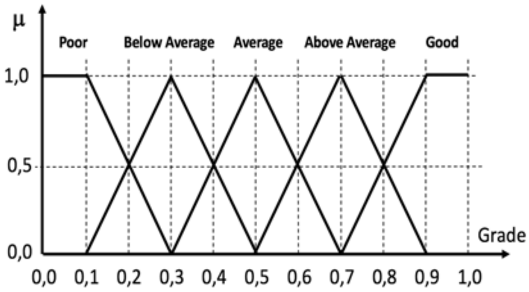

Figure 2. Fuzzy sets for grades.

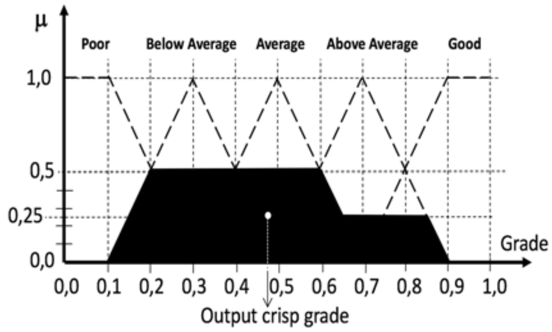

Figure 3. Output fuzzy subsets for student #4.

Table 4. Fuzzy membership grades for every student.

Student	***1***	***2***	***3***	***4***	***5***
Crisp Grade Normalized to 1	0.575	0.125	0.325	0.35	0.275
Poor	0	0.875	0	0	0.125
Below Average	0	0.125	0.875	0.75	0.875
Average	0.625	0	0.125	0.25	0
Above Average	0.375	0	0	0	0
Good	0	0	0	0	0

With this information, it is possible to make the rule base in terms of '*IF-THEN*' sentences. Consulted literature refers to different techniques for establish the rules; in this example (see Table 5), each category of output is present in five cells (it is possible to make small changes to this rule base for special cases).

Table 5. Rule base for fuzzy grades and difficulty index.

		Difficulty Index				
		Very Poor	***Poor***	***Regular***	***Difficult***	***Very Difficult***
Grades	**Poor**	Poor	Poor	B. Average	B. Average	Average
	Below Average	Poor	Poor	B. Average	Average	A. Average
	Average	Poor	B. Average	Average	A. Average	Good
	Above Average	B. Average	Average	A. Average	Good	Good
	Good	Average	A. Average	A. Average	Good	Good

Considering Mamdani inference, results of the example is listed in Table 6.

Table 6. Result of applying the base rules to each student.

	Student	***#1***	***#2***	***#3***	***#4***	***#5***
	Crisp Grade	*0.575*	*0.125*	*0.325*	*0.35*	*0.275*
Resulting fuzzy grades	Poor	0	0	0	0	0
	Below Average	0	0.5	0.5	0.5	0.5
	Average	0.5	0.125	0.5	0.5	0.5
	Above Average	0.5	0	0.125	0.25	0
	Good	0.375	0	0	0	0

If we take, for example, the student number #4, his score would be the result of calculating the center of the area resulting from the fuzzy subsets trimmed to each output value, as we can see in Figure 3.

Finally, it is necessary to return these assessment values to crisp quantities by means of one of the different defuzzification techniques that allow obtaining a unique numerical value that represents them properly in [32]. The technique of singletons [33] is the more easy and concrete way for accurate calculation. Applying singletons, the scores that the calculation would return values showed in Table 7.

Table 7. Results of defuzzified grades vs. initial obtained grades.

Student	***1***	***2***	***3***	***4***	***5***
Initial Grade Normalized to 1	0.575	0.125	0.325	0.35	0.275
Deffuzified Grade Normalized to 1	0.712	0.353	0.455	0.473	0.413

3 DISCUSSION

Some authors such as [21] rightly point out that the choice of defuzzification method depends on each context or on each specific problem, reaching the possibility of using different techniques depending on the fuzzy output subsets for each student, depending on what categories include and not use the same technique for students with grades that are *poor*, *below average*, *average*, since the same technique for all grading intervals can harm some students. This is completely true since a student with an initial score of 100 in a very easy test, could lose a grade and that would not be fair because he has guessed all the answers and should not be penalized, while a student with a poor grade in a high difficulty test, possibly know more than what the test has allowed him to manifest.

Likewise, other authors also indicate that not only is there no universal defuzzification operator but that their choice depends on factors such as the speed at which this operation should be done. For example, in the case of industrial controls in real time where computational efficiency is a very important factor or in the case of information support systems where the calculation time is not as important, as is the case of adjusting student grades. The method of extended intervals in order to defuzzify outputs is correct for the qualification in students, but considering that it will be necessary to take some correction elements to differentiate the cases in which the student may be affected by the calculation.

On the other hand, any fuzzy calculus technique is very variable since it depends on:

1) The number and geometry of linguistic subsets of each variable.
2) The number of input variables, since more variables can be used in addition to the rating and the DI_{Total}, as seen in the literature review.
3) Geometry and position of input and output fuzzy subsets.
4) Rules contained in the rules base. As it is said in [34], the rules have to be determined by expert experience and it is difficult to make a determination of a

system designed according to the fuzzy logic; that is, it cannot be estimated how the system reacts beforehand.

5) The way to make the inference, which is this case has been taken mamdani inference, but there are many other ways to do it (see, for example, [35]).
6) Defuzzification method used. They are multiple different defuzzification methods.
7) Etc.

Each change in the above factors will cause a different adjustment of results. However, at least, it is an adjustment that does not imply suppression of questions that all or no one answered correctly (with no or maximum difficulties), and should not harm anyone. In addition, it involves the concept of “justice” that each professor should establish and that, undoubtedly, it varies from professor to professor, since it is based on his personal way of understanding teaching, the fair assessment, and the corrective actions of results that are frequently doubtful.

Thus, the concept of “justice in assessment” that we apply in our case, obeys the following rules:

1) Students with an initial score of <= 10 points are considered suspended regardless of the DI_{Total} and do not considered in the correction grade.
2) Students with an initial score of >= 90 points are considered approved regardless of the di_{total} and do not considered in the correction grade.
3) Students with an initial score between 11 and 89 points, they will be compensated in function of the DI_{Total} and the corrected value will be taken.
4) If a student, after correction, obtains a negative grade, the grade will be 0 points.
5) If a student, after correction, obtains a grade higher than 100, the grade will be 100.

4 SUMMARY

This article has proposed a way of, without suppressing any question, making a readjustment of the grades based on fuzzy logic techniques. To do this, it is considered, on the one hand, the initial grade obtained by each student and, on the other, the total difficulty index of the test (overall difficulty index of an entire test, DI_{TOTAL}). With these two variables, an approximation can be made to a system of linguistic variables that allows correcting the final grades of each student based on the objective difficulty of the test and a set of rules established by the professor. This will revert to greater “justice” in students’ mark system, since it will be a function of the difficulty of the test.

The above method tends to benefit students with worse grades when the difficulty of the test is high, while not penalize students who have obtained excellent grades. The MCQ tests allow to obtain the parameter DI_{TOTAL} and, with this index, to be able to establish a re-calculation of the qualification of each student.

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EXPLORING STUDENTS' PERCEPTIONS OF ENGINEERING CULTURE: A COMPARATIVE ANALYSIS BETWEEN CHILE, COLOMBIA, ECUADOR, AND THE UNITED STATES

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ABSTRACT

Several studies have explored engineering culture in terms of how it is perceived by engineers, students, or faculty members. However, less is known about how engineering culture varies (or not) when considering national culture as the lens. This study aims to explore how engineering students perceive different dimensions of national culture and identify any patterns that connect to how they perceive their engineering programs. We use Hofstede's theory of dimensions of national cultures to measure culture in different ways in the student's perceptions of engineering. Data were collected using a validated survey that explores dimensions of culture and the sample included engineering students from Chile, Colombia, Ecuador, and the

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United States. The survey was translated into Spanish and was reviewed by several native Spanish speakers. We piloted the survey with several students. Data were analyzed using descriptive and inferential statistics. Results provide preliminary information on how students perceive aspects of culture like individualism, power distance, uncertainty avoidance, and masculinity. We discuss the comparison of the different countries and provide implications of these results to our understanding of engineering culture.

1 INTRODUCTION

1.1 Background

Given the central role engineering plays in technology and innovation, 21st-century engineering programs have been consistently called upon to help students develop the attitudes, mindsets, and practices that can drive innovation [1]–[4]. Similarly, the globalization of the contemporary world requires that those engineering competencies include a global perspective [5]–[7]. Culture, in this case, can be a lens that helps engineering programs understand barriers to transforming curricula, emphasizing the importance of innovation and global awareness in engineering curricula to drive knowledge-based economic competitiveness.

In this study, we focus on these issues via an exploration of culture in engineering. This approach is consistent with Matusovich et al.'s [8] argument that not only personal but collective beliefs and values are also essential in supporting change. As Godfrey et al., [9] note, calls to address change in engineering education through a cultural lens date back at least to the mid-1990s and encompass studies of national cultures, institutional and campus cultures, faculty cultures, gender, and more. Culture has been a prominent framework used with minoritized groups, particularly women, in engineering. Diverse perspectives in engineering are considered to drive innovation and global awareness, however, there is a lack of diversity in the field often attributed to cultural traits of the discipline, characterized as masculine, individualistic, and function-oriented [10]–[15].

In addition to specific work on the culture of engineering, several studies have looked at differences in academic disciplines with respect to teaching, learning, and practice. One of the earliest and most notable is Snow [16]'s Two Cultures, positing the growing divide between the "literary intellectuals" and the "physical scientists." Since then, a range of social science and education researchers have used empirical research to explore differences and similarities among disciplines more fully. Work by Becher [17], [18] focused on analyzing disciplinary differences from the micro-level (academic departments). Bradbeer [19] looked to the macro-level (interaction of different disciplines) with work based on understanding differences in disciplinary epistemologies, discourses, traditions for teaching and learning, and students' preferred learning approaches. Donald's [20] case studies examined structures professors and students create to construct and use knowledge. Nulty and Barrett [21] focused on experiential learning models. Neumann et al. [22] examined the nature of teaching, teaching and learning processes, and teaching outcomes across the different disciplines to propose broader disciplinary classifications.

As noted earlier, our particular interest in disciplinary cultures emerges from two intersecting needs: to help engineering students develop as innovators and to expand global awareness in the field. And, we argue, these two needs are intertwined. While existing work on engineering culture highlights several issues regarding the culture of the discipline, that work does not typically intersect with work on cultures that consider national differences. Similarly, much of the work on disciplinary culture seeks to describe differences in ways of knowing and learning but does not necessarily link those epistemologies to particular values or beliefs. Carberry and Baker [23] explain that cultural considerations in engineering and engineering education spotlight the importance of culture and its implications on learning, teaching, engineering practice, identity, and enculturation as an engineer. We argue that understanding our national culture's influence on the way we perceive our disciplinary culture is essential and has not been studied extensively in engineering education.

1.2 Purpose

The purpose of this exploratory paper is to present preliminary results of a larger study being conducted with engineering students in different countries around the world to compare how their national culture influences (or not) the way they perceive their disciplinary culture. In this paper, we report the results of a survey conducted in universities in Colombia, Chile, Ecuador, and the United States with undergraduate engineering students. Our overarching research question is: Are there any differences in the way students perceive their engineering culture in different countries?

In the following sections, we describe the theoretical framework used to shape this work, the context of the research in terms of the cultural differences among the countries studied, and the institutional context of the participants. Finally, we report our results and provide some discussion of our findings and directions for our future work.

2 EXPLORATION OF THE LITERATURE

2.1 Hofstede

To understand how national culture influences the perceptions of engineering culture students have, we used Hofstede’s [24] theory of dimensions of national culture to guide our work. Hofstede's [24]–[28] theory has been one of the most cited around countries’ cultural differences. His work started in the mid-1960s when he surveyed employees at IBM -with similar working conditions and responsibilities- in more than 50 countries. The survey explored employees’ values, and the information helped him identify the different dimensions in a culture that can demonstrate differences across countries. Hofstede [26] defined culture based on his data and explained that cultural patterns are rooted in the value system of major groups of individuals and became stabilized over long periods as the acceptable way of thinking. This includes patterns of thinking, feeling, and acting that every human being carries and that usually people will collectively share as the appropriate way of thinking based on where they are from. These patterns are created by social interactions and experiences collected since the early life of an individual, starting “within the family; it continues within the neighborhood, at school, in youth groups, at the workplace, and in the living community” [28] (p. 6). Hofstede’s [26] original dimensions of culture are:

- **Power Distance** addresses the degree to which the less powerful members of institutions and organizations within a country expect and accept that power is distributed unequally.
- **Uncertainty Avoidance/Acceptance** addresses how members of a culture can operate comfortably with uncertainty.
- **Individualism/Collectivism** addresses the relationship between individuals and the larger group. In an individualistic culture, individuals are loosely connected: everyone is expected to operate independently, and people do not strongly identify with a group norm.
- **Masculinity/Femininity** refers to the continuum representing how emotional roles are distributed across genders, with assertive roles aligned with the masculine pole of the continuum and caring roles aligned with the feminine pole.

Our study compares different countries in the world that are culturally different in terms of these dimensions. This paper focuses on Chile, Colombia, Ecuador, and the United States. Using Hofstede's online tool [29], it is possible to obtain an overview of some of the cultural dimensions of people in the countries we studied. Figure 1 presents a visual representation of the main dimensions.

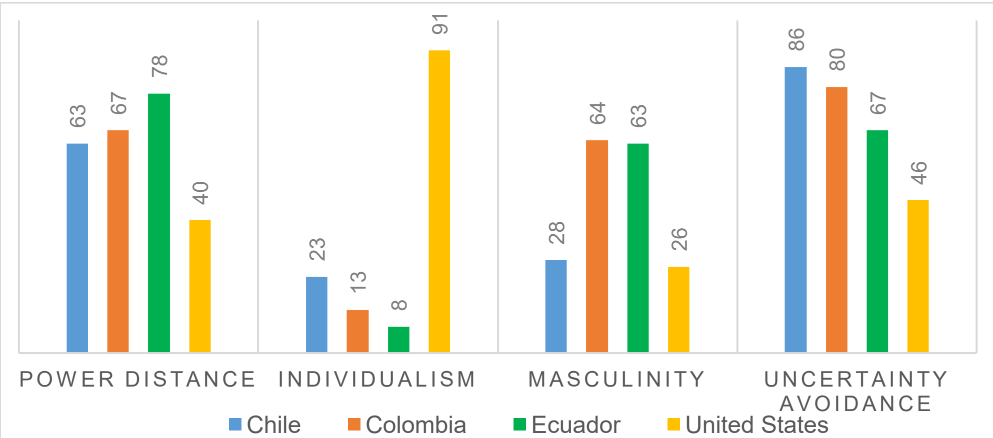

Fig. 1. Cultural comparison between the four countries in this study

From Figure 1, it is possible to see that, in terms of Individualism, the United States has one of the most individualistic societies. In contrast, Ecuador has one of the less individualistic ones. In terms of Power Distance, Ecuador has a very high power distance, Colombia and Chile are in the middle, and the United States has a relatively low one. Masculinity is also divided between Chile and the United States (low) and Colombia and Ecuador (high). Finally, uncertainty avoidance also has a significant division having Chile with the highest one followed by Colombia, Ecuador ranking in the middle, and the United States having a relatively low uncertainty avoidance.

3 METHODOLOGY

3.1 Context for the study

The study was conducted on 4 institutions in the different countries. In Colombia, the Technological University of Pereira it's a technical institution with 17971 students. The University has 93 academic programs. There are 6199 engineering students and 10 different engineering programs. In Chile, Austral University has 16893 students distributed among 52 academic degrees. There are 8 engineering programs with a. total of 2424 undergraduate engineering students. The University San Francisco de Quito in Ecuador is a private university located in Quito Ecuador and has about 7000 undergraduate students. Virginia Tech, in the United States, is a public land-grant research university and offers 280 undergraduate and graduate degree programs to some 34,400 students and manages a research portfolio of more than $500 million. The College of Engineering offers 14 undergraduate degree-granting engineering majors.

3.2 Data collection

To better understand the differences between engineering cultural perceptions of engineering students from Chile, Colombia, Ecuador, and the United States, data were collected quantitatively using a survey adapted by Sharma [30] to measure Hofstede's cultural dimensions within engineering students. This survey was validated by Sharma [30], but the authors also validated it for its use in academic disciplines [31].

Sharma's survey reconceptualizes five cultural factors--Power Distance, Individualism, Masculinity, Uncertainty Avoidance, and Long-Term Orientation as ten personal cultural orientations (PCO) and uses a 40-item scale to measure them. Sharma believed that Hofstede's national-level constructs "may not fully represent the diversity in the cultural orientations of the citizens of a country since they may not possess the same level of their national cultural characteristics" ([30], p.788); in other words, Hofstede's original scale presented challenges when measuring culture at an individual level. For our purposes, we focus on the first four original cultural factors and adapt Sharma's survey based on these factors alone. Below is a description of the four original factors reconceptualized as personal cultural orientations according to Sharma:

- Individualism-Collectivism as Independence and Interdependence, two negatively correlated dimensions in which Independence is associated with individualism and Interdependence is related to conformity
- Power Distance as Power and Social Inequality, two positively correlated dimensions, in which Power is associated with relationships between people and authority and Social Inequality is related to hierarchy versus egalitarianism

- Uncertainty Avoidance as Risk Aversion and Ambiguity Intolerance, two positively correlated dimensions, in which Risk Aversion represents reluctance to taking risks and Ambiguity Intolerance represents the extent of tolerance toward uncertain situations
- Masculinity-Femininity as Masculinity and Gender Equality, two independent dimensions, in which Masculinity represents assertiveness, self-confidence, aggression, and ambition, and Gender Equality represents the perception of men and women as equal concerning social roles, capabilities, rights, and responsibilities.

The survey was administered electronically using Google forms. It was distributed in all participating institutions in the four countries. The survey was translated into Spanish and piloted with experts. Participants included 131 Engineering students from Chile, 85 engineering students from Colombia, 167 engineering students from Ecuador, and 211 engineering students from the United States

Data were analyzed for initial differences, and in this paper, we present our preliminary results to show some of the differences between the countries selected. In the following section, we report on the mean for each of the constructs to show the general differences in each of those. In the next section, we provide some discussion.

4 RESULTS

4.1 Individualism-Collectivism

In individualism-collectivism (figure 2), Ecuadorian students reported being the more individualistic ones. These results are significantly different, with 95% confidence using the Tukey method. However, all countries have relatively high perceptions of this construct.

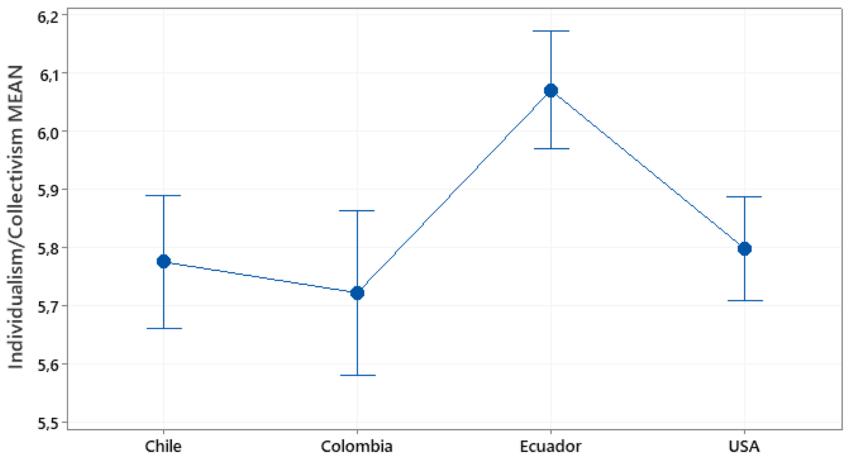

Fig. 2. Results for Individualism

4.2 Power Distance

In Figure 3, it is possible to observe that Colombia has the lowest Power Distance and Ecuador has the highest one, although all countries have a relatively low power distance perception.

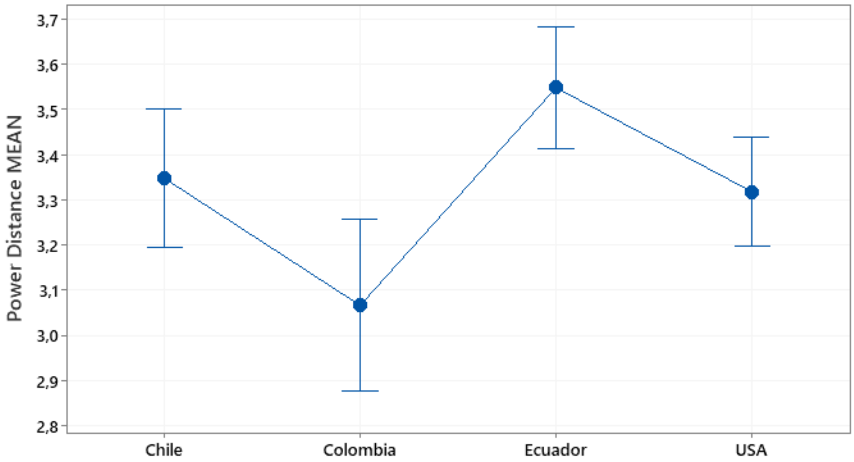

Fig. 3. Results for Power Distance

4.3 Uncertainty Avoidance

Regarding Uncertainty avoidance (figure 4), Chile ranks higher than other countries, and Colombia has the lowest one. All countries rank in the middle for this construct.

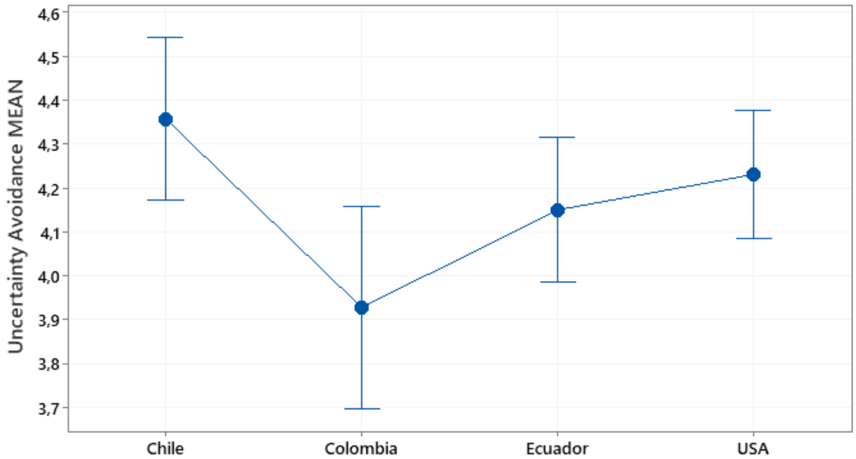

Fig. 4. Results for Uncertainty Avoidance

4.4 Masculinity – Femininity

There are no significant differences in this masculinity-femininity (figure 5), with all countries ranking high.

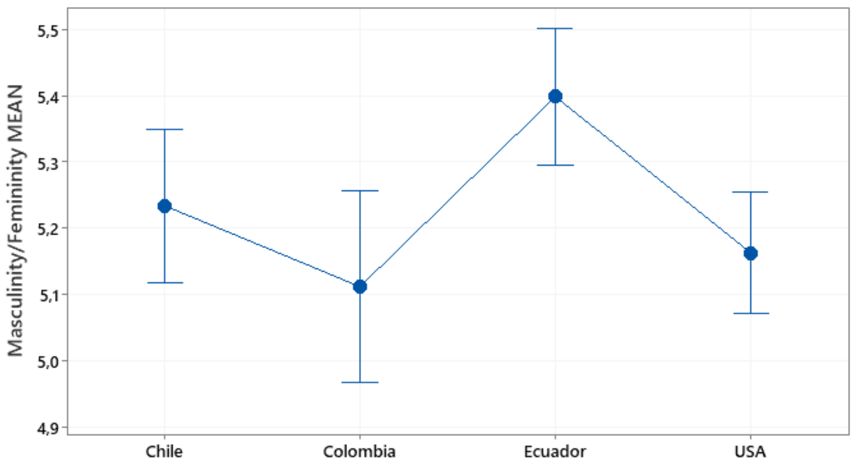

Fig. 5. Results for Uncertainty Avoidance

5 DISCUSSION

To understand the differences and similarities in engineering students' perceptions of engineering culture concerning Hofstede's dimensions of National Culture between Chile, Colombia, Ecuador, and the United States, we conducted a quantitative study. Our survey data were analyzed using descriptive and inferential statistics. We wanted to understand if engineering students' perceptions would match their national culture data when responding to the questions. We compared four institutions that, although they might look different, their engineering programs are structured very similarly.

The first interesting result is regarding individualism. Despite all 3 South American countries being very collectivistic cultures and the United States having one of the more individualistic societies, in our data, students in all countries report considerably high in individualism. Furthermore, Ecuador is one of the most collectivistic societies. However, in our data, students reported the highest perceptions of individualism. This result is interesting and worth exploring further to understand if the way that engineering programs are structured is fomenting the prevalence of individualism over collectivism, for example, the high focus on grades and the importance of finding the right solution -typical in an engineering culture- could be motivating this perception.

We were expecting some significant differences in terms of power distance, as Ecuador has one of the highest power distance indexes and the United States a relatively low one, having Chile and Colombia ranking in between. Our data confirm this finding; however, in general, our results show that all countries are ranking in the middle in power distance. Having Colombian students ranking the lowest and Ecuador, as expected, ranking the highest. It was also surprising to see the United States ranked the second-highest, despite the country having a lower power distance than Colombia and Chile. We also consider this result interesting and worth exploring further to better understand if power dynamics in engineering classrooms make students have a generally low perception of power distance.

Regarding uncertainty avoidance, we did not find any significant results. Instead, the patterns behaved similarly to what was expected based on the national cultural differences.

Finally, for Masculinity-Femininity, we expected Colombia and Ecuador to have higher scores and Chile and the United States to have the lowest ones; however, all countries ranked very high in our data. Surprisingly, we also had Chile and the United States with higher scores than Colombia. We also consider this dimension worth exploring further as it can be seen that the cultural perception of engineering might impact how students perceive this dimension.

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WHAT ABOUT SUSTAINABILITY? INVESTIGATING ENGINEERING STUDENTS' SUSTAINABILITY AWARENESS AND ATTITUDE

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ABSTRACT

Engineers have a growing contribution towards attaining the Sustainable Development Goals (SDGs). Thus, graduate engineering students' awareness and attitude will be crucial for dealing with these complex societal challenges. The purpose of this study is to investigate the sustainability awareness (SA) of engineering students from a developing country in comparison to that of those published from developed European countries. It also aims to explore engineering students' attitudes and willingness to consider sustainability challenges as an important part of their future professional role. We have conducted a quantitative

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online survey (n=253) with the participation of engineering students from different majors at Bachelors and Masters levels. The data concerning students' awareness and attitude underwent quantitative statistical analysis and was compared to that in the literature. The data was analyzed using SPSS to investigate differences and similarities between majors and validate its quality. The findings show good levels of SA and lower levels of knowledge in SDGs among engineering students compared to that presented by European studies. Thus, a gap in SDGs' awareness exists between students from developed and developing countries. However, students' positive attitudes and willingness to be involved in SDGs' practices were remarkably high in understanding the leading role of engineers toward achieving the SDGs. Our results confirm engineering students' motivation and strong positive attitude for resolving sustainability issues in developing countries despite challenging lifestyles. Our findings could be further used by engineering faculties in developing countries to minimize the gap and enhance future engineers' contribution towards a more sustainable society.

1 INTRODUCTION

Engineers are commonly acknowledged as having a critical and increasing role to play in achieving the Sustainable Development Goals (SDGs) and are required to promote the principles of sustainability [1, 2, 6, 7]. The role of future engineers is not only related to the emergence of technical progress, but they are also required to lead solving complex social and environmental problems [6]. To accomplish this mission, it is essential to train graduate engineers to acquire new sustainability competences. This is considered one of the major challenges faced by engineering education institutions [7]. Consequently, there is an ongoing transformation in all developed countries for implementing sustainability competences' development in engineering curricula. However, this is not the case in developing countries, where the education for sustainability is in its early stages with starting reforms [8, 9, 10]. In this situation, engineering students' sustainability awareness (SA) and their attitudes to SDGs play an important influence on the implementation of these reforms.

In our study, we investigated engineering students' SA from the University of Balamand (UOB), Lebanon, a developing country in the Middle East, and compared the results to that of those published from developed European countries. Additionally, we investigated the engineering students' attitude and willingness to consider sustainability challenges as an important part of their future professional role. Hence, the key research questions (RQ) addressed in this study are:

RQ(1): What is engineering students' understanding of sustainable development and SDGs?
RQ(2): What is engineering students' attitude towards considering sustainability challenges?
RQ(3): To what extent engineering students are aware that their profession has a fundamental role in achieving SDGs?

2 LITERATURE REVIEW

SA is defined as the process of expanding humans' ecological consciousness and their knowledge of the environment's importance as well as its fragility [1]. This definition shares similar goals with those of the engineering profession as it involves the ability to consolidate theoretical and structural knowledge through application, interaction and decision making, in favor of the biophysical environment and its problems [1, 2]. Thus, limiting and mitigating against present and future damages respectively.

According to Flament and Kövesi [3], the French engineering students' SDGs awareness as well as their insight and efforts on sustainable development (SD) is relatively limited. They confirmed that these students acknowledge the fundamental role of SD but "have a limited knowledge and understanding of SDGs". Also, French engineering students mainly focus on the environmental and economic factors of SD and often ignore the social aspects [3]. Nicolaou and Conlon [4] observed that, similar to the French study [3], with respect to three Irish universities, final year Irish engineering students have deficient knowledge of sustainability and mainly relate SD to environmental challenges. Thus, their knowledge of the economic and social pillars of SD is equally limited.

Regarding engineering students' attitude towards sustainability, Hamón et al. [5] focused on analyzing students' SA and learning taking into consideration three dimensions: knowledge, attitude and behavior [5]. They have found that Spanish science and engineering students showed the highest levels of knowledge and readiness in the three dimensions comparing to students from other faculties. They concluded that the students could become more aware of SD following the implementation of sustainable practices at their universities.

Concerning the question whether the engineering students are aware that their profession has an important role in achieving SDGs, we have convergent results in the academic literature. French engineering students understand the global and national importance of these SDGs, but they do not consider it as an integral part of their future professional practices [3]. Similarly, it was found that Spanish engineering students highly consider SD practices with respect to their personal life [5] and not much in their professional one. As such, they lack awareness of the crucial role their profession has toward reaching the SDGs.

3 METHODOLOGY

3.1 Study context

To answer our research questions, we have conducted a quantitative online survey at the Faculty of Engineering at the University of Balamand in Lebanon, a country that has endured hardship for over three decades. Lebanon socioeconomic problems are very much associated with the civil war that had stretched from the mid-1970s till the mid-1990s, which has meant that any SD implementation has been challenging. Many attempts have been put in place to implement SD in Lebanon and to adhere to the UN 17 SDGs through many Non-Governmental Organizations (NGOs) and by infusing the information in university curricula. The latter remains low in visibility despite all 8 QS ranked Lebanese Universities' efforts to adhere to the notion of SDGs. The University of Balamand is a young university, founded as recently as 1988, established on solid infrastructure with a relatively important student body of 4500 students. Its senior management team is undertaking a concerted effort to include SD in its scholarly activities, teaching, research and community services. We investigated engineering students' SA, attitudes and professional view which is facing detrimental environmental (inefficient waste collection/disposal, lack of water supply/storage), economic (lack of local production and industry, hyperinflation of local money) and social (missing social security, religion discrimination) problems.

3.2 Participants

For our sample selection, we have targeted engineering students at (1) Bachelor of Science (BSc), (2) Bachelor of Engineering (BE) and (2) Master of Science (MSc) levels.

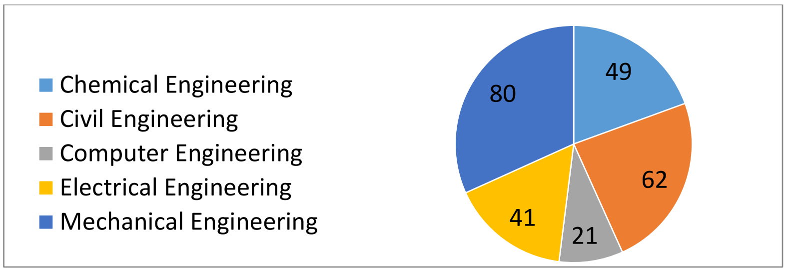

Fig. 1. Repartition of the surveyed engineering students by major

We sent out the survey to all engineering students of the faculty (total of 761) and received 253 completed surveys. We obtained a very satisfactory answering rate of 33%. We have 31% female and 69% male student participants of different majors that are considered as representative for the engineering faculty. As shown in Fig. 1, the Mechanical and Civil engineering departments have registered the highest participation of 31.6 % (80) and 23.7% (60) students respectively knowing that they have the highest number of students in the faculty.

3.3 Data collection

For our survey design, we exclusively used closed questions in line with the European questionnaires investigating the following three topics: (1) sustainability understanding and awareness, (2) attitudes to SDGs and (3) the role of engineering profession in achieving SDGs.

In the surveys introductory section, we have presented the ethical considerations of our study, i.e., detailing its objectives, confidentiality policy, participant's anonymity, data storage and handling.

We have conducted a pre-test of our survey with 15 students in order to collect their feedbacks. We then finalized the survey design by taking into consideration their comments and suggestions for improvements. The final version of our online survey was disseminated to all engineering students via email.

3.4 Data analysis

For our data analysis, we used SPSS software. At first, we have conducted a descriptive statistical analysis and then checked the quality of the survey, with regards to different tests: factorability, Kaiser–Meyer–Olkin (KMO), communality and dimensionality. The results were highly satisfactory with KMO ≥ 0.8; they highlighted that the survey is well designed, the questions were distributed without any redundancy and the participants' number is statistically acceptable. In conform to the survey's validity; we have completed a more detailed data analysis, with crossed tables to analyze the results with respect to different majors, study levels and genders.

4 RESULTS AND DISCUSSION

4.1 Level of awareness

We first displayed the level of SA among students concerning their understanding of the general sustainability concepts at different study levels. 27.1% of the BE undergraduate students selected that they are unsure of what SD means while 25.4% were neutral of the statement. However, the MSc graduate students are more aware about SD than their undergraduate counterpart. Only 15.2% MSc students selected that they are unsure of what SD means.

We further analyzed the level of awareness of engineering students per department. We can observe important differences, as shown in Fig. 2, between engineering students of different majors. Our findings show that 61.94% are familiar with the general concept of SD and only 36.94% have heard about the SDGs indicating a lack of awareness of SDGs.

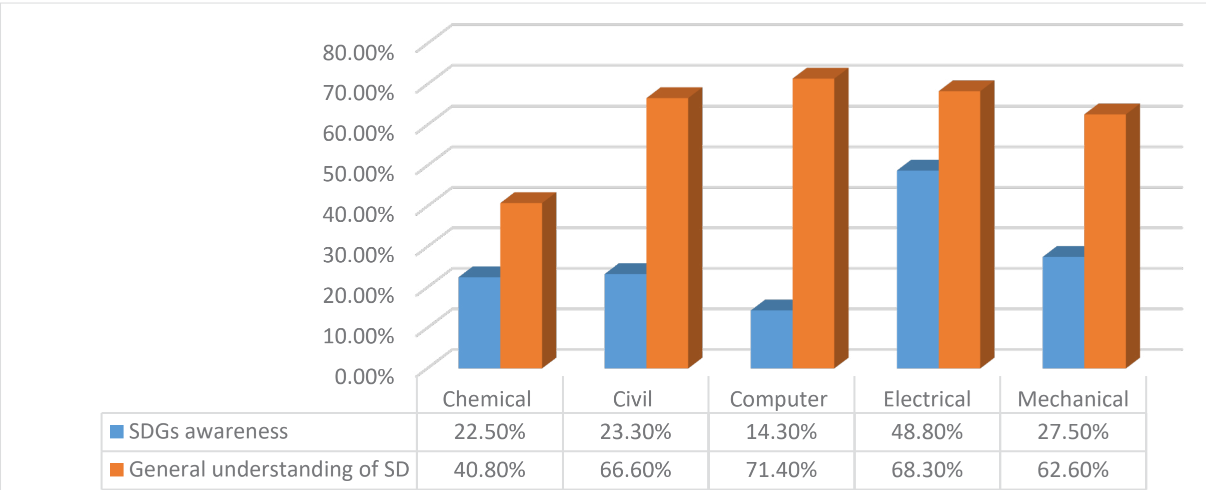

Fig. 2. Engineering students SDGs awareness and general understanding

To our surprise, the Computer and the Electrical engineering students show the highest level of SD awareness, with 71.40% and 68.30% respectively. Additionally, those majoring in Electrical and Mechanical engineering are the most aware of the SDGs, with 48.80% and 27.50% respectively. Even though, in the engineering faculty, the SD oriented projects are more active in the Civil and the Chemical engineering departments.

In contrast to the European findings in the literature, our results show a relatively good level of awareness in basic SD concepts (61.94%) and considerably lower levels of knowledge in SDGs (36.94%). In Ireland, 65% of final year engineering students could not define sustainability nor had a very vague understanding of the concept [4]. French engineering students showed better overall knowledge of the SDGs [3] and 73% of the Spanish students selected that they are familiar with the concepts of sustainability [5].

French engineering students mostly linked SD to environmental aspects with less emphasis on economic aspects and almost disregarding the social pillar [3]. In the present study, the emphasis on environmental aspect is as high as that found in France. In our results, 72.3% agreed that sustainability is more importantly related to the environment, 64.4% agreed that it is related to financial issues and 56% agreed that it is about social/cultural issues. As such, the Lebanese students acknowledged the importance of the economic and social aspects in SD too with more emphasis than the French study [3].

4.2 Attitude

Our results indicate engineering students' strong positive attitudes and willingness to engage in activities related to sustainability and its challenges. As per our analysis, 65.7% of the students are willing to help to achieve more of the SDGs. However, 28.6% of these students were unsure how to contribute. Similarly, 42.7% of Spanish engineering students' showed readiness for participating in the university's SD initiatives and 70.5% were motivated to learn more about such activities [5].

Moreover, in our study, 70.7% of the engineering students showed interest in attending workshops, courses or seminars on SD. Nearly similar to the results obtained for Spanish engineering students [5]. This confirm that engineering students in a developing country, with challenging situations and life conditions, are still motivated and eager to change their country's current circumstances. This high level of positive attitude reflected in students for each major is given in Fig. 3.

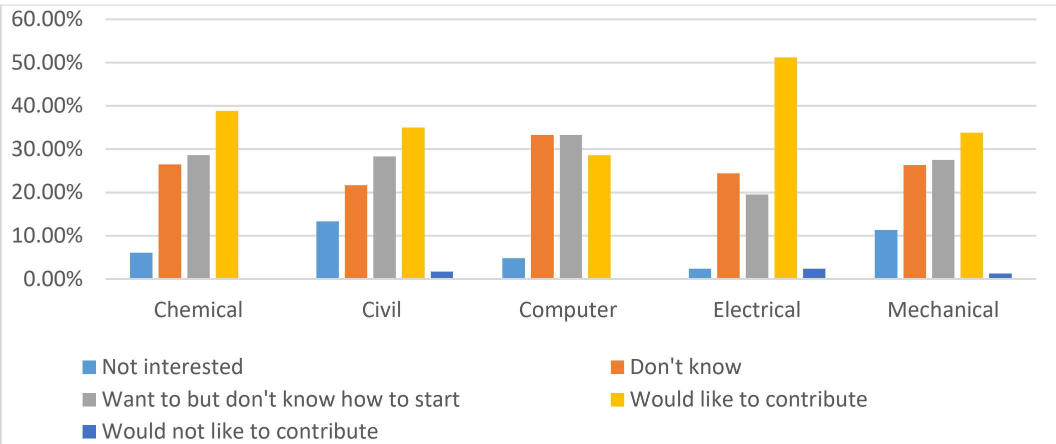

Fig. 3. Engineering students' attitude toward participation in SD initiatives

As shown in Fig. 3, 51.20% of the Electrical engineering students would like to contribute to SD initiatives, the highest amongst all other departments. Additionally, on average, 29.4% would like to contribute however do not know how to start.

4.3 Engineering profession role

Furthermore, our results show clearly that engineering students understand the importance of their responsibilities and they are very aware that their profession has a key role in achieving the SDGs.

Table 1: Engineering students' awareness towards their profession role in achieving SDGs

Q: Engineers are key players in achieving SDGs	Agree & Strongly agree	Neutral	Disagree & Strongly disagree
BSc	74.5 %	20.5 %	5.0 %
BE	81.4 %	10.1 %	8.5 %
MSc	94.0 %	6.0 %	0.0 %

As shown in Table 1, graduate students are more aware about the correlation between their profession and the SDGs than undergraduate students. In general, 83.3% agreed that engineers are key players in achieving the SDGs. However, we can see that engineering students do not have much confidence in their country, where 45.7% think that their profession in this particular country does not prepare them nor encourage them enough to apply essential SD practices.

5 CONCLUSION

The results confirmed the existence of a gap in engineering students' SDGs awareness between developed and developing countries. Similar to previous findings [3], the Lebanese students at the University of Balamand related SD to the environmental pillar as a priority. In addition, they acknowledged the importance of the economic and social aspects in SD more than the French students. They also showed positive attitude towards participating in future SD initiatives but do not know where to start. However, unlike other students from developed countries, they do consider their profession a key player in achieving the SDGs but have no confidence in the support of their country.

Our analysis highlighted the motivation and readiness of engineering students towards achieving the SDGs, despite the country's limitations and their perception of lack of support. For academic considerations, these promising results can be used to guide the implementation of SD education in different majors and for different levels, for minimizing the gap between developed and developing countries and spreading SA at a national level. Additionally, the results can assist in guiding an education for SD tailored specifically to improve the SA levels nationally and encourage the country's participation. Furthermore, it can help direct the universities' education goals to raise students' self-confidence levels and highlight their leadership role in initiating such SD practices and in building a better country.

In this study we have faced some limitations. We have surveyed engineering students from only one university from a developing country. The response rate was acceptable but a higher return would have provided a better picture.

Future work considers studying the SA of engineering students in different developing countries and comparing to students from multi-disciplinary domains.

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STUDENTS' PERCEPTIONS OF APPLIED EDUCATIONAL AND PEDAGOGICAL APPROACHES AT STEM UNIVERSITIES: A EUROPEAN OVERVIEW

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Keywords: *Engineering (STEM) universities, teaching structures, teaching practices, pedagogical and didactic approaches, students' perception*

ABSTRACT

Engineering (STEM) universities in Europe apply different pedagogical and didactic approaches, which are reflected in the structure of teaching and learning activities that are organised for the students. There is great variation in terms of both semester structure and how teaching activities are carried out. The aim of this study is to shed light on students' observations of the different teaching structures and teaching practices offered and to highlight the impact on students of the different teaching approaches.

The data for the study was collected through a survey distributed by the BEST student organisation with 351 respondents from students in 36 European countries. The survey contained multiple-choice questions that aimed to collect demographic data, but also focused on questions about how their programme and learning and teaching activities were structured and most importantly, their perception of the various approaches used.

Findings show the variation in teaching approaches such as the extent of teacher centred approaches, class sizes, laboratory components and project work. The variation in the delivery of project work, the number of projects, timescale and the extent of collaboration with industry are also described.

The study shows a picture of EU engineering universities from the perspective of the students. It highlights the diversity in structure and teaching activities and most importantly, the extent to which students disengage due to the way they are taught.

1 INTRODUCTION

Engineering education, in general, is very focused on how to develop the skills and competencies of engineering students, as new expectations and requirements emerge even faster each year. Concepts such as Industry 4.0, which requires competencies in digitisation and the UN's 17 SDG goals which provides a framework for sustainability, are both concepts which require universities to continuously develop their educational programmes. To meet this dynamic, it is important that universities not only pursue 'what to teach' but also progress their pedagogical and didactic methods by also pursuing 'how to teach'. Engineering institutions in Europe apply different pedagogical and didactic methods, which are reflected in the learning activities that are organised for the students. These activities provide students with different experiences in terms of both approaching their learning and their ultimate achievement.

The aim of this study is to shed light on the following questions: What are students' perceptions of the different teaching structures and teaching practices which are provided by European engineering universities and how do students encounter these different teaching approaches.

2 LITERATURE REVIEW

Understanding engineering students' perceptions of their teaching and learning experiences is an important issue in order to develop efficient, attractive and motivational engineering programmes. According to a study by Korte and Smith [1:12] engineering 'students often reported their most important learning occurred in labs and small group discussion sessions, as well as in study groups'. These teaching and learning experiences in small classroom settings not only encourages active learning but also offers opportunities for direct feedback. They also enhance contact and strengthen the social relationship between students and their lecturers by developing positive emotions and a good classroom atmosphere [2]. In their study, Klegeris and Hurren [3] investigated the impact of using PBL (Problem Based Learning) approaches in a large classroom setting and found a significant positive effect on students' motivation to attend and participate in the classwork.

As highlighted by Parpala [4], students' positive experiences of their teaching and learning environment results in a positive influence on deep learning approaches and negatively on surface learning approaches. However, we have to highlight that there are important disciplinary differences between students' perceptions of the concept of 'good learning'. In STEM disciplines, the analysis of students' best learning experiences showed that students more often refer to their motivation and emotions rather than the content or environment used in their learning [5] confirming the importance of social relations in engineering education [2].

Tayebi et al. [6] noted that having a poor relationship with professors is one of the major reasons that students drop out in engineering. The top two reasons were the difficulty of engineering studies and poor grades. Their study revealed that 46% of students have thought about abandoning their engineering studies. This is most likely related to the commonly recognised difficulty of undertaking engineering studies (identified as the first cause of students' dropout). Salas-Morera et al. [7], report that several pedagogical and organisational factors increase the likelihood of students abandoning their engineering studies. These include; inadequate class timetables or planning of exams, overloaded and long syllabi with too many targeted activities, the high level starting point of many courses and difficult exams.

It is widely recognized that university-industry collaboration is highly beneficial for developing engineering students' industry oriented professional competences. The implementation of PBL practices at the project level through partnership with industry seems to be a well-adapted and efficient way to create an emerging learning environment in engineering education. Surprisingly, based on a recent meta-analysis by Chen et al. [8], there are relatively few studies reported in the academic literature with collaboration between university and industry at the project level.

3 METHODOLOGY

This study has an explorative approach with the aim to explain students' perception of educational and pedagogical approaches applied at various STEM universities in Europe. The work is intended as a feasibility study on students' perceptions, behaviour, and preferences from which concepts and hypotheses can be drawn up for more comprehensive research. It was conducted as part of an Erasmus + research project on the future of engineering education, the A-STEP 2030 [9][10]. The data was collected through an online survey using the software, SurveyXact. It was ethically approved by Aalborg University and disseminated through the Board of European Students of Technology (BEST) network.

The survey was divided into three main parts. The first part focussed on demographic variables which depicted the students. The second part of the survey included two open-ended questions related to students' experiences in the classroom. These two questions are not part of the analysis presented in this paper. The third part contained questions that sought answers to students' perceptions of learning activities and their study structure. There were 351 respondents to the survey, however 303 completed the demographic information only and 108 completed all questions on the survey. It appeared that the 303 students became stuck in the open-ended question part of the survey and did not move on. However, 108 responses were determined to be valid for the analysis.

In total there were a vast range of Universities represented in the survey from 31 identified countries in Europe (11 from Other). Twenty four European nationalities were identified with 80 (26%) respondents indicating "Other" which denotes non-European nationality. Although the survey was circulated around students within the BEST (Board of European Students of Technology) groups, 56% of respondents identified as female, which is not representative of the gender split within STEM programmes in general. The age of respondents ranged from under 18 to over 34, but 75% of the respondents were included within the 20-24 (inclusive) age bracket. A range of disciplines of study were included, made up of 25% from computer science, 25% other and the remainder from the main branches of engineering disciplines, maths and science. Students were quite evenly spread from first year to sixth year, with the majority of respondents in third or fourth year.

As this study has a quantitative approach the data will be analysed using statistical methods such as percentages, averages, and correlations to show the diversity of students' perceptions of educational and pedagogical approaches.

4 RESULTS

4.1 Teaching Approaches

In the survey students evaluated the proportion of different teaching approaches used in their degree programme. The four teaching approaches offered for selection included: (1) the proportion of lectures in large groups, (2) small group teaching, (3) laboratory work and (4) project work.

In the survey, the response options were presented as %-categories, divided into 11 response options. In the analysis, the response options were re-coded into new categories to indicate more clearly the students' evaluations. The responses in the categories 70-80% and above were combined. The results of this category is presented in the Table 1.

Although in the survey, students were able to select the proportions within 10% graduations, for simplicity, the responses are presented here by considering how many students reported the percentage of their studies in each of these teaching approaches as 70-80% or more. So, for example, responses were counted where a student indicated that at least 70% of their programme was made up of lecturing in large groups, or teaching in small groups, or so on.

Table 1. Percentage of respondents indicating that at least 70% of their studies use each teaching approach (Response categories 70-80% and above combined).

Teaching approach	Number of respondents (n)	%
Lectures in large groups	26	23.0
Teaching in small groups	8	7.1
Lab exercises	3	2.7
Project work	8	7.1

23.0% (n=26) of the respondents indicated that they have 70% or more of their studies as lectures in large groups. This can be considered as a large amount especially as the majority of the respondents were 3rd and 4th year students. At the end phase of an engineering programme, learning should happen mainly in real learning environments instead of lectures in large groups.

7.1% (n=8) of the respondents indicated that 70% or more of their study programme is teaching in small groups. Again, this is a small number especially considering the study phase of the respondents. This is also aligned with the responses connected to lectures in large groups.

2.7% (n=3) of the respondents said they have 70% or more of their study programme as laboratory exercises. Conversely, 9.7% (n=11) said they do not have laboratory exercises at all in their studies. This is an alarming result in a STEM discipline where it is well known that students benefit from laboratory work in applying theory into practice.

7.1% (n=8) of the respondents indicated that project work made up 70% or more of their studies, which is a surprisingly small number again, considering STEM as the discipline and especially when project work is understood to be a good pedagogical choice and the main teaching approach of some universities. 4.4% (n=5) said they do not have project work at all in their studies. STEM professionals work typically in projects in industry which attests that students should have project work learning environments and experiences in their studies.

Overall, in relation to teaching approaches, the respondents typically had lectures in large groups compared with small group teaching, laboratory work and project work as indicated in Figure 1.

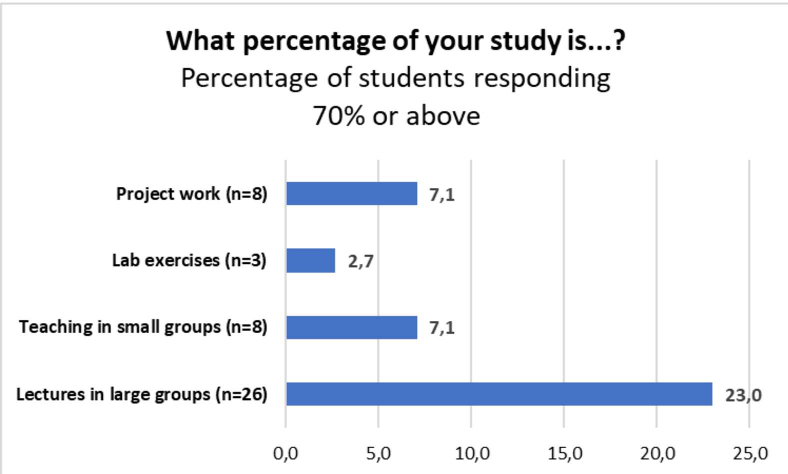

Fig. 1. Percentage of students responding that at least 70% of their studies is in each mode of learning

4.2 Study Projects

In relation to study projects, the time frame of a study project typically lasted for 1-3 weeks (mode). This category represented 25.9% (n=29) of the respondents. This can be considered as a short time period from the perspective of the development of expertise. The short time period then requires that separate projects in different modules are pedagogically aligned to support the overall learning objectives and development of expertise of the students.

The survey also collected information in relation to the percentage of projects undertaken in collaboration with industry. 48.1% (n=52) of the respondents indicated that they do not have projects in collaboration with industry/business at all (Fig. 2). This is a confounding finding for a STEM survey, especially considering engineering as a discipline. It is evident from prior research, contemporary theories of learning and their pedagogical implications that STEM and engineering education benefit from a close connection to real learning environments in the form of industry collaboration.

4.3 Impact of Teaching Approaches

The final question asked students about attendance and how often they skip a class because of the way it is taught. Overall, 90.7% (n=92) of the respondents indicated that they skip at least some learning activities because of the way they are taught (Fig. 3). In fact, 65.7% (n=71) respondents indicated that they skip up to 40% of classes as a result of the way they were taught.

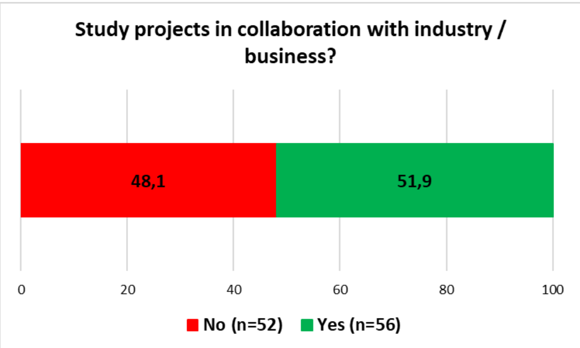

Fig. 2. Extent of Collaboration with industry

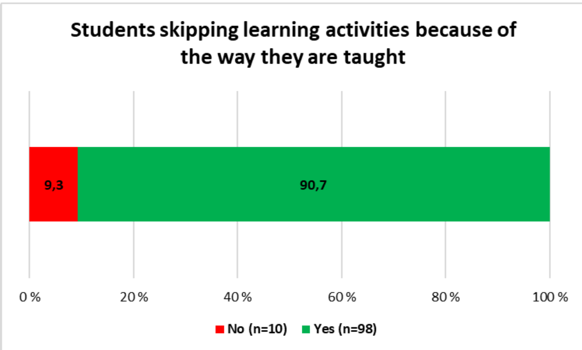

Fig. 3. Percentage of students who skip class

5 DISCUSSION AND CONCLUSION

This study sought to investigate students' perceptions of the different teaching structures and teaching practices and their resulting impact. It is clear that there is a diverse range of practices across Universities in Europe, but what is surprising is that although it is well known that small group and laboratory work are effective teaching practices, 23% of respondents still noted that they have at least 70% of their teaching in lectures in large groups. This is particularly concerning as the majority of respondents were in the latter years of their programmes (3rd and 4th year).

Perhaps more concerning still is that despite an acknowledgement in the education literature about the importance of real life projects and industry collaboration, 48.1% of respondents have no industry project collaboration at all.

However, the most illuminating aspect of this study was the finding that 90.7% of respondents indicated that they choose to skip a particular class because of the way is it taught. This is a wake up call to engineering and STEM educators to show the direct impact that their teaching approach has on student engagement not only in the classroom, but in bringing the students to the classroom in the first place.

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A European vs Australasian Comparison of Engineering Laboratory Learning Objectives Rankings

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ABSTRACT

Learning objectives are important as they provide direction to teaching staff towards what content should be taught, what activities should be undertaken and what assessments are to be used to confirm understanding. Two decades ago, the evolution of new learning modes such as recorded, remote, and simulation/virtual started the research process to define and better understand learning objectives in the teaching laboratory. Much is still to be learnt about laboratory learning objectives including which are most important, and if what is deemed important is universal. For example, do academics in Europe and Australasia align in which objectives are most important and which are not? To answer this question, European and Australasian engineering academics were asked to rank laboratory objectives across the cognitive, psychomotor, and affective domain using a predefined tool called Laboratory Learning Objectives Measurement. A total of 113 academics from Australasia and 25 from Europe responded to the survey. A statistical analysis was conducted to compare the rankings. The findings from this survey show that substantial alignment occurs across the cognitive and psychomotor domains but differs across the affective domain.

1 INTRODUCTION

1.1 Background

The engineering laboratory has always played an important role in preparing engineering graduates for their careers. Advancements in technology and industrial requirements continue to drive its importance, regardless of its mode of delivery [1, 2]. Systematic literature reviews show that laboratory learning can take place in various modes such as face to face, simulation/virtual and remote; and that learning occurs across the cognitive, psychomotor, and affective domains [3, 4]. COVID19 in particular caused many universities to alter their approaches in how they conducted their laboratory classes [5]. Academic staff did the best they could to make the most of a difficult situation right across the world, accelerating the transition to different laboratory learning modes. With the speed of such change, it is important for academic staff to reflect on the most important laboratory objectives to ensure that the objectives drive the implementation, and not the other way around.

The definition of thirteen key laboratory objectives was established in 2002 [6] and has played an important role in directing the learning outcomes for laboratory research in the last two decades. Researchers have been building upon this foundation to better refine and measure laboratory learning. One such refinement is the Laboratory Learning Objectives Measurement (LLOM) instrument as defined in [7]. The authors have used this instrument to explore if there is a commonality to recognise which are the most important objectives that need to be facilitated in laboratory learning.

This work creates the foundation for a future study being prepared by the authors that will compare objective rankings across disciplines. Due to the overweight of responses from Australasia, an understanding of location differences is necessary. Therefore, the first step is to determine if location altered rankings. For example, there are some major cultural and lifestyle differences between Europeans and Australasians. It would be interesting to know if differences in international location would influence ranking decisions. Therefore, this study explores the LLOM ranking relationships across continents. It seeks to answer the research question '*how do Australasian and European academics rank laboratory objectives compared to the international community?*'.

1.2 The LLOM instrument

Learning in the laboratory can be connected across the cognitive, psychomotor and affective domains [7]. This is because when thinking of a traditional laboratory, students must undertake activities like applying, analysing, and evaluating information (cognitive); imitate, manipulate, and articulate with their hands (psychomotor); and attend, respond and value with their presence (affective). The LLOM instrument combines the 13 objectives listed in [6] with the Blooms Taxonomy level descriptors to provide a holistic list as provided in Table 1.

It is important to note that while a separation exists, learning domains cannot be isolated from each other because almost all learning activities involve more than one domain. The objectives used allow universal application across different engineering courses and disciplines. Key words within the text of an objective have been written in italics that allow modification to match the required context or discipline. Any related word can be used, not just the sample words given for context. For example, the objective P1 written as 'Correctly conduct an experiment on [*course equipment/ software name- e.g. power systems*]?' Could be modified to be 'Correctly conduct an experiment on control systems' or 'Correctly conduct an experiment on hydraulics'.

The instrument was explained to participants taking part in the research. Examples such as the one above, were used to demonstrate how the objectives could be tailored to any particular course by swapping out the italicised words. It was the responsibility of each participant to consider each statement within the context of the course/s they teach.

Table 1. Laboratory Learning Objectives Measurement Items

Domain	Item	LLOM Objective
Cognitive	C1	Understand the operation of *equipment/software* used within the laboratory
Cognitive	C2	Design *experiments/models* (physical or simulation) to verify course concepts
Cognitive	C3	Use engineering tools (e.g. [*name of hardware/software used*]) to solve problems
Cognitive	C4	Read and understand *datasheets/circuit-diagrams/ procedures/user-manuals/help-menus*
Cognitive	C5	Draw & interpret relevant charts, graphs, tables & signals
Cognitive	C6	Recognize safety issues associated with laboratory experimentation
Cognitive	C7	Analyse the results from an experiment
Cognitive	C8	Write a conclusion summarizing your findings from an experiment
Cognitive	C9	Write a *laboratory report/entry into a logbook* in a professional manner
Psychomotor	P1	Correctly conduct an experiment on [course *equipment/ software name- e.g. power systems*]
Psychomotor	P2H	Select and use appropriate instruments for the input, output and measurement of your *circuit/system*
Psychomotor	P2S	Select appropriate commands and navigate interface to *simulate/program* a *model*
Psychomotor	P3	Plan and execute experimental work related to this course
Psychomotor	P4	*Construct/code* a working *circuit/simulation/program*
Psychomotor	P5	Interpret sounds, temperature, smells and visual cues to diagnose faults/errors
Psychomotor	P6H	Operate instruments (e.g. [*equipment name*]) required for experimentation
Psychomotor	P6S	Operate software packages (e.g. [*software name*]) required for *coding/simulation*
Psychomotor	P7	Take the reading of the output from *circuits/ instruments*
Affective	A1	Work in a team to conduct experiments, diagnose problems and analyse results
Affective	A2	Communicate laboratory setup, fault diagnosis, readings and findings with others
Affective	A3	Work independently to conduct experiments, diagnose problems and analyse results
Affective	A4	Consider ethical issues in laboratory experimentation and communication of discoveries
Affective	A5	Creatively use *software/hardware* to design or modify an experiment to solve a problem
Affective	A6	Learn from failure (when *experiment/simulation/code* fails or results are unexpected)
Affective	A7	Motivate yourself to complete experiments and learn from the laboratory activities

2 METHODOLOGY

A multi-institution and multi-disciplinary research team was assembled to investigate the research question. Members of the team reached out via direct email and social media in 2021 to their university, research and professional contacts within the field of engineering to answer a survey created in Qualtrics. The survey required participants to rank in order of importance (1 = highest ranked) the multi-domain objectives as listed in the Laboratory Learning Objectives Measurement (LLOM) instrument as outlined in [7]. Participants were required to rank the objectives from most important (ranking = 1) to least important. To determine if any of the rankings remained unchanged, a fixed initial ranking was used based on the order as listed on this page. None of the rankings were left in the default state for the responses analysed.

Approximately 3,000 academics from all continents were invited to participate in the survey with 219 survey commencements and 160 completions. From this, 113 responses came from Australasia and 25 from Europe. While higher number of survey responses were anticipated, as the numbers suggest it was difficult to encourage participation, especially outside of Australasia. European responses came from Finland, France, Germany, Ireland, Portugal, Serbia, Slovakia and Spain. Attempts to gain responses from other European countries were not successful. The sample size for each European country was too small for analysis, but reasonable as a collective to obtain a European perspective. This imbalance creates the need of this research to understand if location-based differences existed.

3 RESULTS

The platform R version 4.05 was used for the statistical analysis with the results shown in Tables 2 (cognitive), 3 (psychomotor) and 4 (affective). The data was analysed in three groups, international (all data from across the world), Australasia and Europe. The sample size for Europe was not high enough to also look at differences between majors. Rankings were determined using averages. The lower the number, the more academics ranked the objective as being more important than objectives with a higher average. In brackets, the 95% confidence interval (CI) is shown. To determine if a statistically significant difference in average values occurs, the 2 confidence intervals must not overlap. Such differences to the international collective are highlighted in green.

In the last column, the one-way analysis of variance (ANOVA) is applied, this examines whether for a particular objective (e.g. C1), the mean responses are different across the groups, i.e. if shown p-value is less than 5%, then responses differ across groups for that question, otherwise not. A multivariate analysis of variance (MANOVA) was applied to determine if there is a statistical difference overall between locations. The p-value for Table 2 is 0.05763, Table 3 is 0.1238 and for Table 4 is 0.4452. This indicates if the overall responses differ across groups.

Each table also provides a visual representation of the objectives in ranking order. Visual representations can help develop a better understanding of statistical data. Colour coding is used to show how the collective ranking, differs across the groupings. For example, in Table 2, C1 is given the colour light blue. The different ranking of C1 for each group can be easily observed in the table by following the colour trend.

3.1 Cognitive Domain

Table 2 showcases the average values and rankings for the cognitive domain. It can be seen that across the three comparison groups there is substantial alignment in ranking order.

Table 2. Learning Objectives Cognitive Domain (Averages With 95% Confidence Interval) And Ranking Order

Obj.	International	Australasia	Europe	ANOVA
C1	3.11 (2.79,3.42)	3.05 (2.68,3.43)	2.80 (2.09,3.51)	0.560476
C2	3.31 (2.92,3.69)	3.38 (2.90,3.86)	3.48 (2.64,4.32)	0.856811
C3	4.06 (3.69,4.43)	4.28 (3.82,4.75)	3.12 (2.34,3.90)	0.029015
C4	5.50 (5.14,5.86)	5.42 (4.99,5.84)	5.60 (4.62,6.58)	0.71859
C5	5.10 (4.84,5.36)	4.86 (4.55,5.17)	6.16 (5.48,6.84)	0.000537
C6	6.23 (5.85,6.61)	6.35 (5.92,6.78)	6.08 (5.06,7.10)	0.596898
C7	3.86 (3.54,4.18)	3.82 (3.43,4.21)	3.92 (3.10,4.74)	0.832927
C8	6.54 (6.22,6.85)	6.57 (6.20,6.93)	6.28 (5.29,7.27)	0.529588
C9	7.29 (6.98,7.61)	7.27 (6.89,7.64)	7.56 (6.76,8.36)	0.504093
Rank				
1	C1	C1	C1	
2	C2	C2	C3	
3	C7	C7	C2	
4	C3	C3	C7	
5	C5	C5	C4	
6	C4	C4	C5	
7	C6	C6	C6	
8	C8	C8	C8	
9	C9	C9	C9	

The most important cognitive objective is C1 '*understand the operation of equipment/software used within the laboratory*' and was consistent across all groups. This result is not surprising as engaging with hardware/software is core to laboratory work.

The least important item is C9 '*Write a laboratory report/entry into a logbook in a professional manner*'. C8, another cognitive writing-based objective was ranked second last. Interestingly, while lab reports and writing are deemed as least important, the work by Nikolic, Ros [4] found that they were one of the most used assessment types. This provides a strong case of the need for further investigation.

The only major difference identified between the three groups is that the Europeans valued the laboratory objective C3 '*Use engineering tools to solve problems*' higher. This difference was found to be statistically significant. They valued solving problems as more important than design (C2) and analysis (C7). This provides a future research opportunity to find out why this is the case. While C4 and C5 were also interchanged, within the overall positioning this can be seen as negligible. Therefore, it is possible to conclude that regardless of location, ranking order across the cognitive domain is mostly aligned.

3.2 Psychomotor Domain

Table 3 showcases the average values and rankings for the psychomotor domain. Across the three comparison groups a complete alignment in ranking order was achieved. Some of the items had statistically significantly greater weight but remained consistent in ranking order. This suggests that regardless of location, there is a strong consensus of which objectives in the psychomotor domain are most and least important.

The most important objective being (P1) '*Correctly conduct an experiment on [course equipment/ software name]*' and the least important being (P5) '*interpret sounds, temperature, smells and visual cues to diagnose faults/errors*'. The importance of P1 appears self-explanatory, success comes from carrying out an activity correctly. This is a core outcome of laboratory work.

However, the lack of importance given for troubleshooting is a curious observation. P5 has substantial overlap with cognitive skills and is complementary to items C1-C4. It extends beyond the cognitive by considering the actual practice of using the tools to undertake the fault finding. For example, using and reading the display or hearing a beep of a multimeter on an electrical circuit, or moving a hand over an item to feel that it is heating up.

Much engineering practice revolves around knowing how to fix things. If one knows how to fix things, that demonstrates a full/deep understanding of the operation of equipment/software (highest ranked in the cognitive domain). Previous work [8] has highlighted the importance of fault-finding ability on the student experience and understanding, therefore it is possible to assume that the relationship between the two items should be stronger. This is another avenue for further investigation.

Table 3. Learning Objectives Psychomotor Domain (Averages With 95% Confidence Interval) And Ranking Order

Obj.	International	Australasia	Europe	ANOVA
P1	2.46 (2.19,2.73)	2.52 (2.17,2.88)	2.28 (1.77,2.79)	0.5432
P2H	4.13 (3.78,4.48)	4.04 (3.63,4.44)	4.04 (3.04,5.04)	0.9925
P2S	5.24 (4.93,5.56)	5.21 (4.84,5.59)	5.52 (4.70,6.34)	0.4873
P3	3.02 (2.72,3.33)	2.89 (2.53,3.26)	3.88 (3.02,4.74)	0.0253
P4	5.23 (4.87,5.60)	5.35 (4.90,5.79)	5.04 (4.08,6.00)	0.5634
P5	6.86 (6.56,7.16)	6.79 (6.43,7.15)	6.92 (6.12,7.72)	0.7568
P6H	4.90 (4.55,5.25)	4.88 (4.49,5.28)	5.00 (3.92,6.08)	0.8159
P6S	6.50 (6.15,6.85)	6.73 (6.34,7.13)	5.52 (4.42,6.62)	0.0144
P7	6.65 (6.29,7.01)	6.58 (6.15,7.02)	6.80 (5.80,7.80)	0.6775
Rank				
1	P1	P1	P1	
2	P3	P3	P3	
3	P2H	P2H	P2H	
4	P6H	P6H	P6H	
5	P4	P4	P4	
6	P2S	P2S	P2S	
7	P6S	P6S	P6S	
8	P7	P7	P7	
9	P5	P5	P5	

3.3 Affective Domain

Table 4 showcases the average values and rankings for the affective domain. Across the international and European groups much commonality is shown, noting that the first three items for the Europe group have the same average. The Australasia group differs substantially for this domain. It is of substantial interest to understand why such a large variation occurs. Such differences are not surprising though, during the authors submission of previous papers involving LLOM, the greatest reviewer debate has been on the affective items. Could it be that differences in culture are most present in this domain due to the focus of less technical items? With the larger Australian sample, a future study will need to look at the differences across Australian institutions. Should alignment occur across the affective domain in Australia, this would create an interesting research pathway to investigate further.

It can be observed that (A1) '*work in a team to conduct experiments, diagnose problems and analyse results*' is deemed most important, not surprisingly as much work and focus in recent years has been placed on teamwork throughout the world [9, 10]. All groups placed 'C*onsider ethical issues in laboratory experimentation and communication of discoveries*' (A7) as least important. With ethical laboratory practises uniformly positioned last, this can be concerning, and it does suggest engineers need greater reflection on affective skill development. Is it wise for engineers not to value ethical practice as highly important? What negative consequences can result on the engineering profession if data collection and communication is not been completed ethically? As is implied by Gwynne-Evans, Chetty [11], does ethics need repositioning?

Table 4. Learning Objectives Affective Domain (Averages With 95% Confidence Interval) And Ranking Order

Obj.	International	Australasia	Europe	ANOVA
A1	2.49 (2.21,2.77)	3.00 (3.00,3.00)	3.00 (1.15,4.85)	0.514
A2	3.24 (3.01,3.47)	4.50 (1.85,10.85)	3.00 (1.69,4.31)	0.2264
A3	3.58 (3.27,3.88)	2.50 (16.56,21.56)	3.00 (1.23,4.77)	0.5492
A4	5.50 (5.28,5.72)	6.00 (6.71,18.71)	6.14 (5.31,6.97)	0.3953
A5	4.44 (4.13,4.76)	3.50 (28.27,35.27)	3.43 (1.17,5.68)	0.8773
A6	4.23 (3.97,4.49)	4.50 (27.27,36.27)	4.57 (2.90,6.25)	0.0556
A7	4.53 (4.20,4.85)	4.00 (21.41,29.41)	4.86 (3.40,6.31)	0.7761
Rank				
1	A1	A3	A1	
2	A2	A1	A2	
3	A3	A5	A3	
4	A6	A7	A5	
5	A5	A2	A6	
6	A7	A6	A7	
7	A4	A4	A4	

4 SUMMARY

Regarding the research question, *how do Australasian and European academics rank laboratory objectives compared to the international community*, this work has found that substantial commonality exists across the cognitive and psychomotor domains. The greatest differences occur in the affective domain. This is not surprising given the attention to cognitive learning and somewhat psychomotor learning found through assessment [4]. Further research will need to investigate why the greatest differences occurred across the affective items. Do the non-technical items integrate with cultural expectations and differences? With topics such as emotional intelligence largely missing from the engineering curriculum, but highly sought after in the workplace [12], it appears greater research, discussion and reflection on the affective items is needed by the engineering academic community. Future work will look at comparisons across disciplines and laboratory modes.

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TOWARDS A NEW PEDAGOGY FOR ENGINEERING EDUCATION IN THE 21ST CENTURY

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ABSTRACT

There have been many advances over the past four or five decades in understanding brain architecture, and how the process of learning aligns with this architecture. One of the more interesting results has been that of John Sweller [1] and his theory of cognitive load. Sweller identifies the task of learning as effecting change in long-term memory. This long-term memory is, in his view, almost limitless. The problem lies in working, or short-term memory, which has a bottleneck of around five items. Any instructional mode which places too many items into working memory will be, at best, inefficient, and at worse, pointless.

It is interesting to note that over the same decades new instructional modes, such as Problem-Based Learning (PBL) have become popular [2]. Sweller, and others such as Paul Kirschner [3], argue that PBL cannot work as advertised, as the student is faced with too high a cognitive load; they can either learn how to solve the problem, or learn the underlying concepts, but not both.

This paper outlines the theoretical background to this issue, and presents an intervention undertaken over the last decade in TU DUBLIN to devise new instructional modes which take account of cognitive load problems, whilst maintaining some of the advantages and benefits of PBL. This intervention initially followed the ideas of Louis Bucciarelli [4] of MIT on open design in Engineering education but was later adjusted to take into account the ideas of Kirschner on minimizing cognitive load in developing problem-solving skills.

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1 INTRODUCTION

In March 2017, the president of MIT, L. Rafael Reif, launched a new research initiative into learning, asking the question, 'If we don't know how we learn, how on earth do we know how to teach?' [5] Whilst this is undoubtedly a very noble and worthwhile enterprise, it is, at one level, surprising. Surprising because, for the last five decades, great progress has been made by neuroscientists, educational psychologists and others in understanding the architecture of the human brain, and how that architecture affects human learning.

New innovations over the past few decades, such as Problem Based Learning and other minimally guided instruction methods is perplexing when one considers the weight of psychological evidence against it, particularly the 2006 paper by Kirschner et al arguing against all forms of PBL as they conflict with how the human brain learns [6].

A related goal of much modern teaching is the acquisition of critical thinking and problem-solving skills, much in demand by companies, and hence by governments. Unfortunately, as the American psychologist Daniel Willingham points out, no such skill exists. [7]

Finally, there is the work of Nobel Prize winner, Daniel Kahneman, an Israeli psychologist who studies how decisions are taken. His results suggest, somewhat surprisingly that 95% of decisions are taken automatically, based on experience, and only in a very small number of cases do humans sit down and work it out. [8] This he calls Type I thinking, fast, but not necessarily accurate. The quality of most decision making therefore depends on the domain specific knowledge base of the person, not on their problem-solving abilities, which Kahneman calls Type II, slow, deliberate, but costly for humans in terms of time and energy.

What all this diverse work points to is that both expertise, critical thinking and problem-solving skills all depend on a large domain specific knowledge base. Given those facts, it seems reasonable that teaching should concentrate on building a student's knowledge base and helping them use it in problem solving.

As Frederick Reif points out [9], science has acquired a large body of knowledge over many centuries. Is it reasonable to expect the average student to have the same keen analytical mind as Newton, or Einstein, in discovering that knowledge themselves?

This paper outlines the current knowledge about human memory, and how it actively supports learning. It then gives a brief overview of PBL and outlines the problems identified by a number of educational psychologists in this approach. Finally, it presents an intervention in TU DUBLIN, which has been developed over the past 13 years, that attempts to build an instructional design that reflects what psychologists know about learning.

2 THE PSYCHOLOGY OF MEMORY

If there is one major research finding in the psychology of learning in the past twenty years, it is the role of memory. Long regarded as merely a passive store of information, psychologists now see long-term memory as an active and critical component of problem solving.

The modern theory of human memory derives from the work of Atkinson and Shiffrin in the 1960s [10]. They distinguish between sensory memory, a passive recording of incoming sensory data that runs on a continual loop lasting around 3 seconds. That data is lost unless conscious attention transfers it to the working memory. That data too is lost after 30 s unless the brain rehearses it, a process that transfers it to long-term memory. This is shown in Figure 1 below.

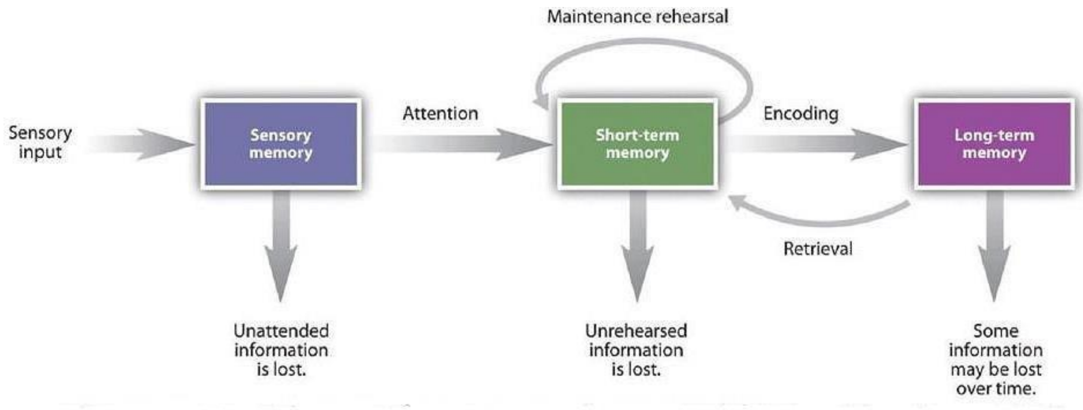

Fig. 1. Atkinson and Shiffer's 1968 Model of Memory [10]

It is clearly crucial that a student pays attention, or else they cannot learn: no transfer occurs from sensory to working memory. This is an area where some misunderstandings can arise. All psychologists studying memory agree that a passive student cannot learn, because attention is an active task. That does not mean that a student cannot learn by listening to a teacher; attentive listening is an active task. It is not necessary for the student to be physically doing something, in order to learn.

The desire to learn comes from humans' innate curiosity about their world. Curiosity is founded upon metacognition, thinking about thinking. The French scientist Stanislaus Dehaene writes: "in order for children to be curious, they must be aware of what they do not yet know. In other words, they must possess metacognitive faculties at an early age. "Metacognition" is cognition over cognition: the set of higher-order cognitive systems that monitor our mental processes." [11]

Sweller develops the theory of how long-term memory acts, by focusing on the work of the Dutch psychologist, de Groot [12] who studied chess grandmasters. "He showed masters and weekend players a board configuration from a real game, removed it after five seconds, and asked them to reproduce the board. Masters could do so with an accuracy rate of about 70% compared with 30% for weekend players."

It is not that chess grandmasters have superior problem-solving skills; rather that they have acquired, over many years (at least ten), a database of chess games, and can recognise the strategic value of a game, whereas the novice cannot. It is the strategic value that they are using to remember the positions of the pieces on the board, not the actual pieces, which are too numerous for short-term memory.

Sweller et al continue: “They tell us that long-term memory, a critical component of human cognitive architecture, is not used to store random, isolated facts but rather to store huge complexes of closely integrated information that results in problem-solving skill. That skill is knowledge domain-specific, not domain-general. An experienced problem solver in any domain has constructed and stored huge numbers of schemas in long-term memory that allow problems in that domain to be categorized according to their solution moves.”

Kirschner, Sweller, Clark in their 2006 paper, ‘Why Minimal Guidance During Instruction Does Not Work’ [13] emphasise the key importance of long-term memory in learning: “It is no longer seen as a passive repository of discrete, isolated fragments of information that permit us to repeat what we have learned. Nor is it seen only as a component of human cognitive architecture that has merely peripheral influence on complex cognitive processes such as thinking and problem solving. Rather, long-term memory is now viewed as the central, dominant structure of human cognition. Everything we see, hear, and think about is critically dependent on and influenced by our long-term memory.

Lord Kelvin famously remarked: “When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind: it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be.” [14]

Kirschner et al define learning as: “The aim of all instruction is to alter long-term memory. If nothing has changed in long-term memory, nothing has been learned.” [15]

This is a critical problem for PBL, which assumes that learning occurs when problems are solved. There is no direct way to measure this, and so by Kelvin’s definition, it is not science.

They then tackle the nub of the problem, which is the limitations of working memory when dealing with new information. Those limitations are temporal and physical. Unless new information is rehearsed, and transferred to long-term memory within 30 s, it is lost. Physically, working memory can handle between 4 and 7 new items, and for items that require intensive processing, this may be as low as 2 or 3. Sweller has published [16] on the extreme load that problem solving places on working memory. Kirschner et al point out that: “The consequences of requiring novice learners to search for problem solutions using a limited working memory or the mechanisms by which unguided or minimally guided instruction might facilitate change in long-term memory appear to be routinely ignored." [17]

There have been many responses to the 2006 paper, but none have really answered the Kelvin question: how is successful learning via the minimally guided problem solving being measured?

3 PROBLEM-BASED LEARNING

Many types of student driven, minimally guided learning developed from the 1960s onwards. Perhaps the best known is Problem Based Learning (PBL), in which students work in small groups (8 to 10) to solve unstructured problems. PBL was first developed in medical schools in the 1970s, to provide medical students with more realistic situations that they would encounter in practising medicine. From an early beginning in McMaster's University in Canada, it spread to other medical schools, such as the new University of Maastricht, which became the first university in the world to apply PBL methods across all faculties [18]. It is interesting to note that the development and adoption of PBL in medical programmes grew out of dissatisfaction with the clinical skills of new graduates.

The 1990s saw PBL being applied to other university disciplines, and even to second-level education (K-12). In his chapter on PBL in the 2007 *Handbook of Research on Educational Communications and Technology*, Woei Hung, stated that a key assumption of PBL is that when we "solve the many problems we face everyday, learning occurs". Educational psychologists such as John Sweller would profoundly disagree. For them, learning occurs only when there is a change in a person's long-term memory. When a problem is solved during PBL, there may be no change in a person's long-term memory, because the students may have hit upon the solution by random chance, as they poured over search engines. [19] Hung goes on to say that, "PBL proponents assume the primacy of problems in learning; that is, learning is initiated by an authentic, ill-structured problem". Notice the crucial word in that sentence: 'assume'. There is no evidence produced for it.

He then goes on to say: "Problem-based learning is based on constructivist assumptions about learning, such as:

- Knowledge is individually constructed and socially co-constructed from interactions with the environment; knowledge cannot be transmitted.
- There are necessarily multiple perspectives related to every phenomenon.
- Meaning and thinking are distributed among the culture and community in which we exist and the tools that we use.
- Knowledge is anchored in and indexed by relevant contexts."

The constructivist perspective, as outlined by Chan et al [20] is that: "Constructivism is a view of learning that knowledge is not a thing that can be simply given by a teacher at the front of the classroom to students at their desks. Rather, knowledge is constructed by learners through an active, mental process of development and learners are the builders and creators of meaning and knowledge. The constructivist conception uses student-centred teaching strategies because this type of learning will help students develop critical thinking and collaboration skills and learning takes place in environments where students are able to participate actively".

The constructivist position that knowledge must be actively constructed by students, or else it doesn't exist, is problematical for scientists and engineers. It may be of limited validity in the social sciences but is simply not appropriate in science and engineering. To return to Reif, science is a highly complex enterprise, created by the best minds of the time; it is not possible for the average student to construct such knowledge ab initio. However, it is easy to see from this definition the appeal of PBL based on constructivist principles in medical education. Knowledge per se is useless for doctors if they cannot apply it in a clinical context.

4 TU DUBLIN INTERVENTION

In 2009, Larry Bucciarelli of MIT [21] spent a semester in TU DUBLIN (or DIT as it then was).

This was the beginning of the attempt to introduce open design problems in the Mechanical Engineering programme. The initial results of this intervention were presented at REES 2015, held in DIT, Dublin. [22] During REES 2015, Professor Ference Marton, of the University of Gothenburg, Sweden, gave valuable feedback, making the suggestion that pre and post tests used to evaluate student learning, should be conceptual, rather than the standard numerical problems then in use. This was done in subsequent years, and the initial results presented at the Portuguese Society for Engineering Education (CISPEE) conference in 2018 [23].

The results from that paper were encouraging:

Over the two sessions, pre and post the open design exercise, the mean scores for the concept questions were 20.61 and 23.98.

There is a significant difference ($p = 0.0402$) between the students' conceptual understanding at the end of the exercise than at the beginning; in other words, the null hypothesis, that the two means are similar, is rejected at the 95% Confidence Interval.

The student t-test results for the 41 pairs involved showed similar results, i.e. at a 1% Confidence Interval and a one-tailed test, the result was significant, with a p-value of 0.006457.

The intervention with a single cohort of TU Dublin Mechanical Engineering students is limited, and with a relatively small number (41), difficult to generalize. None the less, it does show that a modest intervention, not requiring major changes to the curriculum or to the module delivery, can have measurable effects in improving student learning.

In 2020, the Coronavirus pandemic forced teaching to go online in TU DUBLIN, as elsewhere. To help students engage with the material in an active manner, the idea of using Mind Maps as a Continual Assessment (CA) tool was introduced. Mind

Maps are a method to make learning active and to aid retention of knowledge in long-term memory. They were popularized in the 1970s by psychologist Tony Buzan. [24] Mind Maps draw out the relationships between concepts, making the overall structure clear, in a visual manner. They require the student to actively engage with the material, and also to apply judgement as to what things are important (metacognition).

5 SUMMARY

PBL is based on a constructivist philosophy of knowledge, which is not compatible with science. It is also based on a flawed understanding as to what is meant by active v passive in learning. PBL can be passive, if someone is not engaged, traditional lectures can be active, if students are motivated and attentive, and taking notes intelligently.

Changes in long-term memory define learning, not problem solving. Active attention is the only way in which learning can occur, and this relies heavily on a student's intrinsic motivation. Millions of years of evolution have made humans curious, and anxious to learn. This should be exploited by educators.

The clash of scientific instruction with constructivism lies in science's foundation with Aristotle's empiricism. There is another aspect of Aristotle, his ethics, which should also be borne in mind by all educators. In his Nicomachean Ethics [25], Aristotle talks of the importance of the Golden Mean, a position between extremes. Too much courage is recklessness, too little, cowardice. Traditional instruction, where a teacher dispenses knowledge to students, who passively acquire it (or perhaps, not), is not a very effective method of teaching. Neither is its opposite extreme, active learning with no (or very little) guidance.

The Golden Mean for teaching and learning is surely to do both, provide instruction and guidance to the novice to build up expertise, and also to provide open-ended problem-solving opportunities to develop their skills. This is how doctoral programmes work, where students are guided by an expert supervisor. Only as a post-doc, does the successful student can engage in their own unsupervised research. At that point, they have completed the transition from novice to expert.

Constructivism began with the work of the Swiss psychologist, Jean Piaget, whose theories of how children develop centered around the idea of the child construction and testing ideas, mainly through the medium of play in the early years. A century later, the French neuroscientist, Stanislas Dehaene [26] suggests that the child acts much like a scientist, being genetically hard-wired to create and test hypotheses, and having an innate understanding from birth of both numbers and probability. Dehaene prefers to define humans as *homo docens*, as the key difference between humans and the rest of the animal kingdom is the ability to learn. It is an educational tragedy, according to Dehaene, that in the last thirty years research has "elucidated the algorithms that our brain uses; the circuits involved, the factors that modulate their efficacy, and the reasons why they are uniquely efficient in humans", but educators are unaware of this work, and so are not applying it. Dehaene identifies four key components to learning: "focused attention, active engagement, error feedback, and a cycle of daily rehearsal and nightly consolidation" [27]

Memory is critical here: nothing will move from sensory to working memory, or from working to long-term memory unless the learner is paying attention and is actively engaged in the task. It doesn't really matter what kind of instructional design is being used, as students can be using their smartphones to check social media in a traditional lecture or in a PBL group session. 'Active' is in the mind of the student, not in the structure of the lesson.

There is no need for a complete revolution from traditional teaching to PBL or any other radical implementation of active learning. It is possible, as has been done in TU Dublin, of building gradually, reflecting the latest research into learning. This suggests seven steps:

1. Teach students the basic facts, e.g., the gas laws.
2. Take them through worked examples.
3. Get them to tackle traditional closed problems.
4. Get them to create Mind Maps for the topic (metacognition)
5. Give them an open-ended problem to tackle on their own or in groups.
6. Give them conceptual tests on the topic before and after the open exercise to test its effectiveness.
7. Give them good feedback, so they can improve.

Students are results focussed, and that often means a final exam. Daniel Willingham asks his students not to revise by looking over notes [28], but to create new notes from memory, and then compare them to the original notes. It would be even better to get students to draw new Mind Maps as they revise, and then compare them to the originals. This reinforces learning, and as students compare the two, they are made aware of errors. And error correction is, as Dehaene emphasises, one of the keys to successful learning [29].

In fact, he goes as far as saying: "Organisms only learn when events violate their expectations." The learner as scientist continually updates their mental model of the world when outcomes are not as expected. Dehaene believes one of the most important roles of the teacher is to provide good, non-judgemental feedback to the student as quickly as possible.

Education is not about traditional or modern; it is about both. All innovations in teaching and learning must be founded upon research findings, especially neuroscientific and psychological findings into how the brain, and especially the memory, works. New research does not mean throwing away all traditional methods. It is all about the Golden Mean.

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HOW DOES THE EXTENT OF STUDENT-ACTIVE LEARNING IN ENGINEERING PROGRAMMES INFLUENCE STUDENTS' PERCEIVED LEARNING OUTCOMES?

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ABSTRACT

Through the project "Technology Education of the Future" (FTS), NTNU has developed a framework for re-design of its study programmes in technology and engineering. One of the main findings is the need for a broader, more multidimensional view of graduate competence, showcasing the need to fully integrate training of several important non-technical professional skills in future programmes. To enable such integration, student-active pedagogical methods in combination with integrated learning principles are often seen as key tools. This paper quantitatively investigates to what extent study programmes' facilitation of active student participation actually makes a difference to perceived learning outcomes across a variety of competence areas. The research question under consideration is *"How does the extent of student-active learning in engineering programmes influence students' perceived learning outcomes?"* Using statistical analysis of data from a national student survey, correlation was investigated between students' perception of how well active student participation is facilitated by the teaching in their study programmes, and their self-evaluated learning outcomes in 10 different competence areas. Regression analysis was done based directly on individual student responses and on responses averaged over study programmes. The results show statistically significant positive correlation for most competence

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areas. Students' perception of how well their programmes facilitate active student participation is found in good agreement with actual known programme characteristics. The results thus provide quantitative indication that improving facilitation of student-active learning in engineering programmes indeed improves learning outcomes for a broad set of future-relevant competence areas.

1 INTRODUCTION

1.1 Background and context

In August 2019, NTNU launched a project (FTS) for renewal of the university's programme portfolio within engineering and technology, with an ambition to *"promote a new generation of engineering and technology education which is updated in all areas according to international development and society's needs."* Initially FTS reviewed international trends and global best practices in technology and engineering education, as a starting point for SWOT analysis [1] and subsequent quality development in the FTS programme portfolio [2, 3]. This initial phase consisted of an outside-world analysis focusing on future global and national needs, major technology trends, and recent and expected developments in the higher education sector. Insights from this analysis were subsequently "triangulated" with input from faculty and students, advice from Nordic educational experts, and official university statistics, strategies and policies. Based on this foundation FTS subsequently created a set of overarching objectives for the future FTS programme portfolio consisting of a *vision*, a set of *principles,* and *competence profiles.* Finally FTS developed a *roadmap for implementation*, documented in [3, 4].

FTS identified some significant gaps between the status quo and international state-of-the-art in NTNU's engineering and technology portfolio at large, [1], e.g. widespread use of traditional lecture-based pedagogical practices, lack of integrated learning and coordination across courses, and too little emphasis on important '21st century' competences. It is however known that there are significant differences between programmes: Among the 5-year integrated technology master programmes, *Electronic System Design and Engineering (MTELSYS)* and *Industrial Design Engineering (MTDESIG)* in particular stand out positively wrt. student-active and experiential learning: Student-active learning and contextual learning are combined e.g. in an integrated set of courses in the first two MTELSYS years, focusing on conceive-design-implement projects, real-world problems, flipped classroom, campus spaces for student-active learning and peer-learning, and peer assessment and feedback. Peer assessment and team teaching are also prominent elements in MTDESIG, students being taught in dedicated studios and in-house workshops.

1.2 The national portal 'Studiebarometeret'

Among the most important data sources used in FTS' SWOT analysis [1] was *Studiebarometeret*, a national portal initiated by the Norwegian Ministry of Education and Research (KD) in 2014, and conducted by NOKUT (the Norwegian Agency for Quality Assurance in Education), an independent expert body under KD. Each

February, the portal presents results from an annual, extensive *student survey* sent to more than 70 000 2nd and 5th year students in around 1800 programmes nationwide [5]. Students are asked how they perceive many aspects of educational quality in their study programmes, for the purpose of strenghtening quality work in higher education and give education institutions, authorities, students and potential applicants useful information about educational quality and development over time.

Data from Studiebarometeret were used in several ways in FTS' SWOT analysis: For example, to analyze *overall student satisfaction, student workload, facilitation of active student participation, feedback from academic staff and fellow students, and perceived learning outcomes* for different types of programmes in the FTS portfolio.

1.3 Motivation for the present study

The focus of this paper is statistical analysis of data from *Studiebarometeret* to investigate *correlation* between *students' perceived degree of active student participation facilitated by their study programmes*, and their *self-evaluated learning outcome for 10 different competence areas.* The research question under consideration is: *"How does the extent of student-active learning in engineering programmes influence students' perceived learning outcomes?"* This is relevant because student-active pedagogical methods in combination with *integrated learning principles* are often promoted by educational developers and scholars of teaching and learning as key tools to achieve deeper learning and efficient integration of important professional skills into graduates' competence profiles (see e.g. [6]). *The CDIO Community*'s Standard 8, *Teaching and learning based on active and experiential learning methods*, states [7]: "*Active learning methods engage students directly in thinking and problem-solving activities. There is less emphasis on passive transmission of information, and more on engaging students manipulating, analyzing, evaluating and applying ideas.*"

At the same time, one sometimes sees a reluctance or scepticism among university faculty when it comes to making the move from traditional 'one-way' lecture-based pedagogy (often with an emphasis on theoretical aspects) to active and experiential methods as described above. Among the arguments heard against such a move are that it de-emphasizes the importance of theoretical knowledge and thus might threaten students' academic knowledge foundation; it is expensive and difficult to scale up to large classes; faculty are not trained in such methods and therefore do not know how to use them efficiently - thus the change might not work as intended.

The motivation for the investigation is to contribute to the understanding of *what the actual impact of student-active teaching methods is in the current FTS portfolio* - by seeing if it is possible to find a systematic coupling between students' self-assessment of their learning, and their perception of how well their programmes facilitate active student participation. The hypothesis is that a *positive* such coupling exists in a statistical sense, i.e. that *better facilitation of active student participation in study programmes on the average contributes to better learning among students*. If such a statistical coupling can be quantitatively demonstrated to be significant, it might serve as motivation for more programmes and courses to move quicker to a stronger emphasis on student-active learning, and for faculties and departments to invest more in competence development and infrastructure to enable the move.

2 METHODOLOGY

2.1 Student survey questions under consideration

In one section of Studiebarometeret's student survey, students are asked to assess their *Own learning outcome* so far, by answering the following question Q1 for the competence areas C1 – C10 in Table 1: *How satisfied are you with your own learning outcomes so far, concerning …*

Table 1: The 10 graduate competence areas investigated in Studiebarometeret.

C1	Experience with research and development work
C2	Discipline- or profession-specific skills
C3	Knowledge of scientific work methods and research
C4	Oral communication skills
C5	Critical thinking and reflection
C6	Cooperative skills
C7	Ability to work independently
C8	Written communication skills
C9	Innovative thinking
C10	Theoretical knowledge

In the survey's *Teaching* section students are asked how they agree with the following statement S1: *The teaching is organised so as to facilitate active student participation*. Answers are given on a 1 (Do not agree) to 5 (Completely agree) scale.

2.2 Statistical analysis – data and methodology

The data applied in the analysis in this paper are based on "NOKUT National Student Survey 2021, Subject Groups", financed by KD. The data are provided by NOKUT, and prepared and made available by the NSD (Norwegian Centre for Research Data). Neither NOKUT, KD nor NSD are responsible for the analyses/interpretation of the data presented here. Due to space limitations, the focus is only on data from NTNU's 17 5-year integrated Master of Science in Technology (*siv. ing.*) programmes [8]. Student responses are collected from the 2nd and 5th year of study, based on survey data from all years 2018 – 2021. The statistical significance of the relationship between learning outcomes and active student participation is tested by *regression analysis* [9]. Outcome is regressed on reported level of activity, year of survey, and overall satisfaction with study programme and year of study, for 4 underlying data distribution models:

A. Learning outcome is treated as a *cardinal variable* (underlying continuous distribution, discrete levels 1 – 5 uniformly spaced), and separate effects are estimated for different levels of active participation. Such effects are estimated with a reference category, in this case the lowest level of activity.

B. Both learning outcome and the measure of active student participation are modelled as *binary variables*, i.e., the original 5-point scales are quantized to binary scales. Values 4 and 5 are quantized to '1', values 1, 2 and 3 to '0'.
C. The learning outcome responses are modelled as binary as in B, but separate effects are estimated for different levels of active participation.
D. Like B, but the learning outcome variable is in its original ordinal form, estimated by *ordered probit* [9].

3 RESULTS AND DISCUSSION

3.1 Results from data analysis

All regression models A-D above support a statistically significant relationship between students' self-evaluated learning outcomes and their perception of study programmes' facilitation of active student participation. This indicates that the trends and conclusions presented in this section are robust wrt. varying model assumptions.

Initially, results are presented from all 17 study programmes. In Fig. 1 the following competence areas, all important '21st Century Skills', are considered: C6 *Cooperative skills*, C5 *Critical thinking and reflection*, C9 *Innovative thinking*, and C4 *Oral communication skills*. For each of these, individual programme data points are shown, each point averaged over all individual responses to statement S1 (x-coordinate) and answers to question Q1 (y-coordinate) from students within a study programme. *Best linear fits* to these points are also shown. Stronger correlation between x- and y-axis data corresponds to a *larger rate of change* (RoC) in the linear fits (positive RoC for positive correlation, negative for negative correlation). Note that the two programmes scoring highest on facilitation of active student participation are the MTELSYS and MTDESIG programmes (cf. Section 1.1).

Fig. 2 collects the best linear fits to the programme-averaged data points for *all* competence areas C1 – C10 in Table 1, plus a curve for the average over all the areas. For clarity, individual programme data points are excluded in this figure.

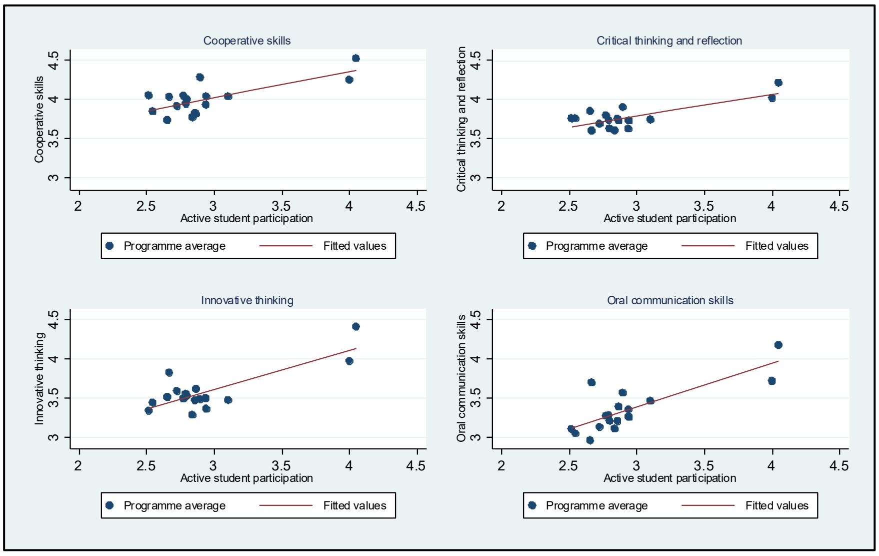

Figure 1: Individual programme data points and linear fits for Cooperative skills, Critical thinking and reflection, Innovative thinking, Oral communication skills. All programmes.

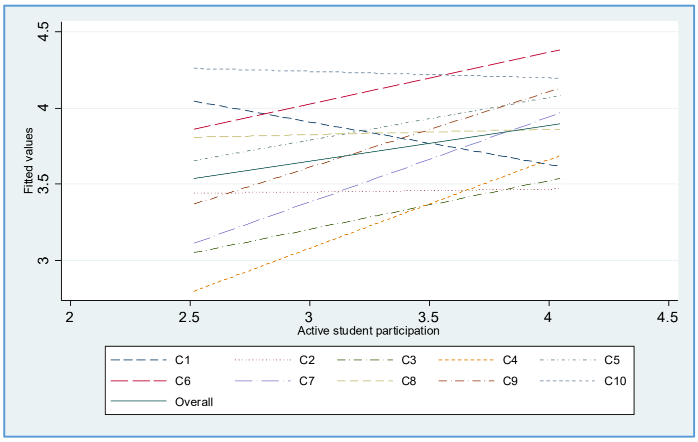

Figure 2 Best linear fits to study programme data for all competence areas. All programmes.

When including data from all 17 master programmes under study as in Fig. 1 and 2, the results show, for most competence areas, a statistically significant positive correlation between students' self-assessed learning outcome and their perception of how well their study programme facilitates active student participation. This is interpreted to indicate the importance of emphasizing student-active learning when designing study programmes with intended learning outcomes reflecting this range of graduate competences. However, the negative trend for competence area C10 Theoretical knowledge in Fig. 2 is potentially worrying: It seems to indicate that strengthening of competence areas C1 – C9 may come at the expense of less deep theoretical knowledge, thus supporting some of the faculty scepticism mentioned in Section 1.3. Upon investigation one however sees that the effect is isolated to only one of the 17 programmes: MTDESIG, whose data point is the lowermost of the two data points with highest x-axis score in Fig. 3 (the other one belongs to MTELSYS).

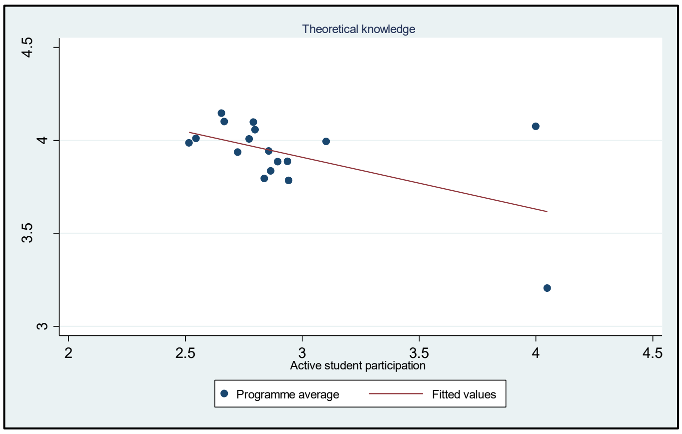

Figure 3 Individual programme data points with linear fit, Theoretical knowledge. All programmes.

Although its students are given a similar theoretical fundament during the first two years as those of the other programmes, MTDESIG as a whole is significantly more oriented towards design and aesthetic aspects, and less towards engineering identity, advanced technology development, and mathematical modeling, than the other programmes. One might therefore argue that a more fair and relevant analysis of 'typical' engineering programmes is actually achieved by excluding MTDESIG data. Fig. 4 present the same results as Fig. 1, but with MTDESIG data excluded.

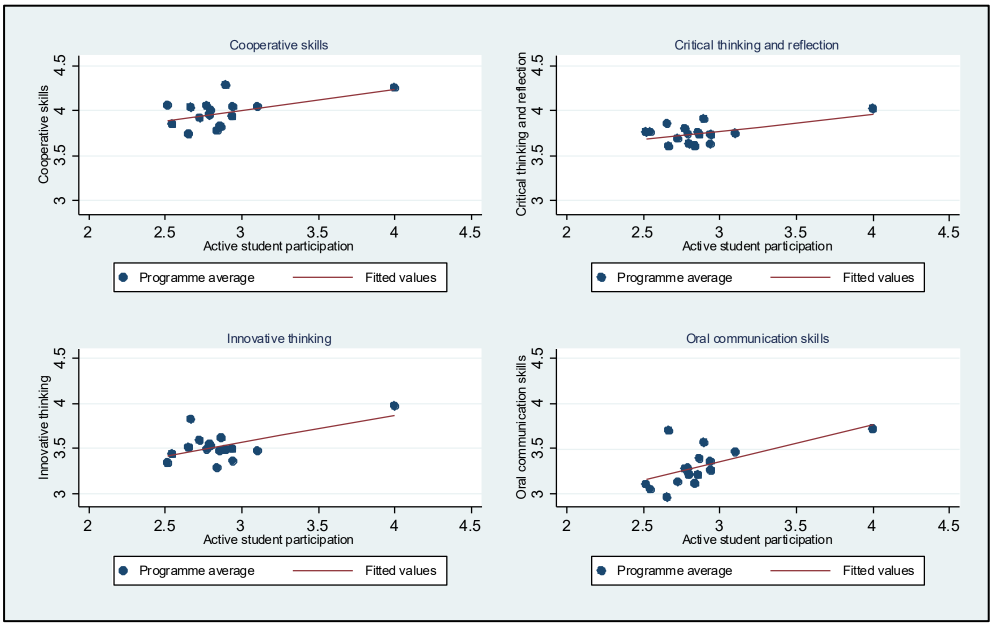

Figure 4: Individual programme data points and linear fits for Cooperative skills, Critical thinking and reflection, Innovative thinking, Oral communication skills. MTDESIG excluded.

When excluding MTDESIG one can no longer see a negative effect on competence area C10: Students' theoretical knowledge now appears not to be influenced at all by the level of active student participation (Fig. 5). The same holds for C1 *Experience with research and development work.* For C2 – C9 correlation is positive (Fig. 6).

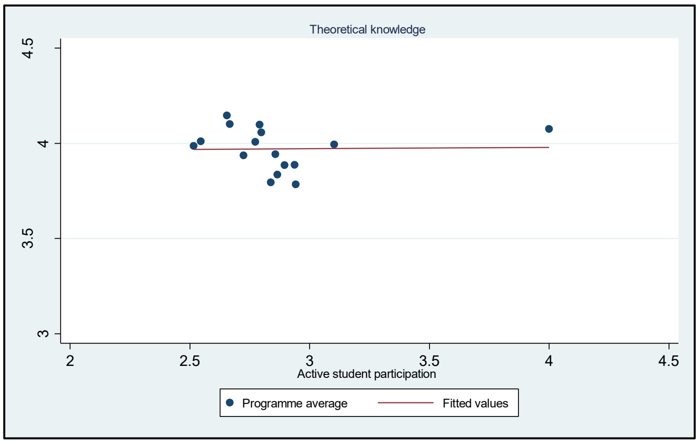

Figure 5 Individual programme data points with linear fit, Theoretical knowledge. MTDESIG excluded.

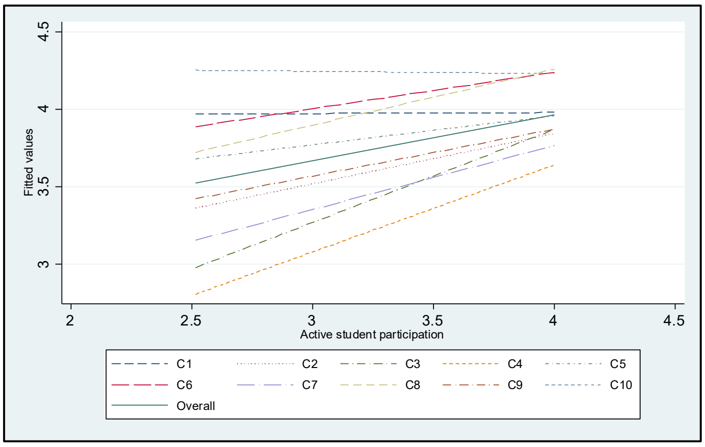

Figure 6 Best linear fits to study programme data for all competence areas. MTDESIG excluded.

3.2 Concluding remarks

One might ask: To what extent can one actually trust students' individual self-evaluation of their learning outcomes, and their perception of how well their study programmes facilitate student participation – i.e., how close are their judgments to actual fact? The answer to this question seems strongly linked to another important engineering competence: *Evaluative judgment* – '*the capability to make decisions about the quality of work of oneself and others*' [9]. The better universities are at developing this competence in students, the more one can probably trust their responses in studies such as this to be in line with actual fact. The authors of this paper acknowledge that as long as there is uncertainty or lack of knowledge about students' evaluative judgment ability, the results should be interpreted with caution, i.e., be treated as indications, not proof, of positive impact of student-active pedagogy in engineering programmes (also, statistical correlation is of course not synonymous with statistical dependency). Nonetheless, results seem to be well in line with recommendations based on state-of-the art research on learning [6].

As mentioned earlier, factual knowledge regarding the characteristics of the programmes under study may be used to gauge how students' perception agree with reality, when it comes to the programmes' facilitation of active student participation. The consistent scoring of the MTELSYS and MTDESIG programmes' teaching as the best in facilitating active student participation is in full agreement with known facts about those two programmes relative to the other 15 programmes under study (again, see Section 1.1). The fact that the other 15 programmes come across as more closely clustered around a narrower range on the x-axis is also in agreement with the fact that these programmes share many similarities in terms of overall structure, common basic and supporting courses, and pedagogical traditions and practice. Thus students' perception of their programmes' facilitation of active student participation seems to be in good agreement with known programme characteristics.

To gauge the reliability of students' *self-assessment of their learning outcomes*, one could e.g. analyse students' grades to check if the systematic differences between programmes are reflected there. However, this has not been done in this study. Also, results from such an analysis might not be so relevant or easy to interpret in practice, since the assessment methods used at present (with final written exams focusing on theoretical knowledge still the most common assessment method) are not necessarily well adapted to evaluation of all competence areas discussed here.

In conclusion, we believe that our results do provide a quantitative indication that

- More emphasis on student-active teaching methods in engineering programmes may indeed improve students' learning of a broad set of future-relevant engineering competences, and that
- it is possible to achieve this without weakening graduates' theoretical knowledge.

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ACTION RESEARCH ON ELECTROCHEMISTRY LEARNING. CONCEPTUAL MODELLING INTERVENTION TO PROMOTE DISCIPLINARY UNDERSTANDING, SCIENTIFIC INQUIRY AND REASONING

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ABSTRACT

Students in engineering-science programmes often struggle with theoretical concepts, while they tend to adopt a surface approach to learning. We suggest that this can be tackled by promoting a specific higher-order thinking skill (HOTS) that enables drawing connections between physical phenomena and theoretical concepts representing them. We designed an intervention to support students in achieving deep insight into electrochemical phenomena, while developing this HOTS. Such intervention aims to scaffold students' learning and development by introducing conceptual modelling as an essential thinking skill of engineering-scientists, and as a strategy to build scientific understanding of natural phenomena. Therefore, conceptual modelling constitutes a main learning objective of this novel course. This paper reports an empirical investigation into how students deal with concepts and complexity, and to what extent the intervention has any measurable effects on the learning outcomes. This phenomenological investigation integrates considerations from various disciplines, and relies on multiple data sources, i.e., students' documents (lab journals and reports), observations of students in action (in discussions with their tutors and while performing lab experiments), and video stimulated-recall interviews. The results show little effect of the intervention, as implemented, suggesting how challenging it is for students (and instructors) to shift from traditional learning-and-teaching approaches, towards an epistemology of knowledge construction for specific problems. The findings are informative for revision of the intervention and generate specific recommendations. Concurrently, our operationalisation of the conceptual framework proves powerful in detecting qualitative differences in HOTS. Plausible implications for research and educational practice in science-engineering education are discussed.

1 INTRODUCTION

1.1 Background, building blocks and overview

Electrochemistry is an essential scientific and practical domain within Chemical Science Engineering (CSE) [1]. Concurrently, students often struggle with conceptual aspects [2] , and many adopt a surface approach to learning [3].

An action research [4] project was conducted to design and implement a pedagogical intervention aiming to support students in achieving deep insight into electrochemical phenomena, while developing higher-order thinking skills [2]. This new 'thinking as a scientific researcher' course[2] taps on inquiry-based learning (IBL) principles [5], while approaching the teaching of thinking in an explicit and content-related fashion, according to a mixed general-infusion approach [6]. Importantly,

[2] The laboratory experience is used as a means of discovery and new theorisation, rather than to confirm given theories empirically (as more traditional lab courses often do). In short, the aim is to promote a different epistemology concerning the role and contribution of science to problem-solving, that is not commonly conveyed in engineering education.

students' learning and development was scaffolded by conceptual modelling [7,8], as a strategy for conducting scientific research that seeks to promote the understanding of natural phenomena. Conceptual modelling is considered an essential reasoning ability of (engineering) scientists and is a chief learning objective of this new course [2]. It is proposed that the conceptual modelling skill can assist students in understanding and theorising (electrochemical) phenomena, so that they will be able to creatively think about such phenomena in new technological problem-solving contexts.

Our empirical educational research witnessed the implementation of this intervention [2]. This phenomenological investigation sought to explore (RQ1) how students learn electrochemistry under the intervention as implemented and in terms of indicators of progress in reasoning, to describe (RQ2) in what ways the student learning is embedded in the learning environment, and to evaluate (RQ3) to what extent the intervention has any measurable effect on the learning outcomes.

This interdisciplinary project, including the instructional design of the course and the educational research design, integrates considerations from Chemical Science, Philosophy of Science in Practice, and Education Sciences. This empirical paper builds on our conceptual work [2], where we elaborate on the relevance of electrochemistry in engineering-science education, and we present an overarching methodological and theoretical framework, as well as a a thorough description of the pedagogical intervention. The present contribution further introduces our analytical framework, which is based on levels of complexity [9] and on recurrent difficulties [10].

1.2 Levels of complexity

In line with our theoretical framework [2], we are interested in qualitative differences in learning; these are best observed in connection to the content, and in both the process and the outcomes of learning [11]. The 'levels of complexity' framework [9] appears appropriate as analytic tool because it takes a situated cognition perspective on learning and cognitive development (which aligns with the IBL approach), and it is developed within a comparable empirical context.

The original framework proposes 8 categories denoting increasing complexity. The first category group refers to 'objects' the students use in the laboratory, their aspects, and their properties[3]. The second category group refers to covariations of aspects and properties of objects and materials[4]. First, we had to grasp in what ways one category is more complex than the preceding one and what it takes to move from one category level to the next. Our reading is that growing complexity means

[3] During the operationalisation of Wenzel's original framework, we broadened 'objects' to include any materials (e.g., electrolytes, salts, buffer solutions) and added a crucial feature, i.e., their purpose. These modifications emerged during our initial data analysis and, therefore, they are part of our research findings (which were engaged in the fine tuning of the analytical tool).

[4] These (co)variations, we add, are not just present or absent. They can be accompanied by a qualifier indicating an effect size and a description of the conditions for the covariation to occur

increasing generalisation, systematisation, acknowledgement of what is contingent and what is stable, connectivity of associations, and covariation (not causality). Finally, we operationalised those categories into an analytic tool that resonates with our particular empirical context. A summary is presented in the methods section.

1.3 Recurrent difficulties

Prior research on teaching and learning Electrochemistry [10] proposes a set of known recurrent difficulties (KRD) experienced by students and teachers. Such KRD are rote application of concepts and algorithms, use of multiple definitions/meanings (from different contexts[5]), use of multiple or hybrid models, wrong interpretations of language, too early connection of labels to meaning, and misleading analogy. To this list, we added 'attribution' to consider groundless or wrong attribution of effect (e.g., causality, mediation, interaction, contribution), as often observed in our experience. These KRD allow one to think about the plausible cause of difficulties, for which knowledge of the disciplinary content involved is required.

2 METHODOLOGY

The research methodology is phenomenological, i.e., interested in the subjects' experiences, next to their performances. Therefore, in seeking methodological consistency [4], we choose to use qualitative methods of data collection and analysis. The project has three educational research purposes (i.e., to explore, to describe, and to evaluate) which were translated into distinctive research questions, as presented in Section 1.1.

2.1 Empirical context

The new lab course consisted of 5 practicums, each to understand a particular electrochemical phenomenon, while addressing an electrochemical question. The students worked in groups of 3 and their learning process was facilitated by learning assistants (LAs). In the preparatory and reflective work around each practicum, the conceptual modelling activity was supported by the B&K method [7], as a cognitive scaffold for the learning and persistent use of conceptual modelling as a conducive scientific way of reasoning. The sustained and effective use of this scaffold was taken as an indicator of the attained level of cognitive skill development [2].

2.2 Data collection

For this study, we selected practicum 2 (about a specific electrochemical cell) and practicum 5 (about cyclic voltammetry) for being particularly challenging, distributed

[5] Based on a historical analysis on 'electrochemical concepts and their meaning in context', i.e., the phenomenological, the particulate, the measurement, and the thermodynamic contexts. This analysis is not to fragmentate what the Conceptual Modelling approach aims to unite (by organising it coherently), but to understand the epistemological difficulty and complexity that electrochemistry represents for students, teachers, and researchers.

in time, and integrative. For additional details on the content and objectives of these practicums, see our conceptual paper [2].

Twenty students (out of 45) consented to participate in this investigation, among whom 8 also accepted to be interviewed. Their data was considered at an individual level. Furthermore, all students had been grouped into 15 work groups of 3. This distribution resulted into 2 full participating groups, whose data was analysed in an aggregated fashion, according to a case study design [12].

The multiple sources of data were (i) documents, i.e., intermediate, and final lab journals, and group reports, (ii) video recordings and transcripts of observed meetings among students and their LAs, (iii) video recordings of students while performing their lab experiments, and (iv) audio recordings and transcripts of video stimulated-recall interviews. The pieces of data were matched to individual students and to groups, allowing for triangulation of the findings.

2.3 Data analysis

In line with the phenomenological approach to research, we were interested in the data that captures subjects' experiences, and further in how various sources of data speak to each other. A case-study logic[6] was used, seeking validity in terms of the depth and robustness of the analytical work [12,13] .

The usable data was prioritised according to availability and richness criteria. The thematic coding[7] relied on the categories in Table 1. After open, axial, and selective coding of the data sources by project group (2 cases), we integrated further pieces by student (8 individual subjects) until we estimated that data saturation had been reached.

Table 1. Summary of the operationalised 'levels of complexity'

Levels	**Description**
Objects	construction of stable figure-ground distinctions
Aspects	links between objects and/or identification of specific features
Properties	construction of classes of objects, based on common/different aspects
Purpose	the intended purpose, function or use of objects and other materials
Variations	changes relating two or more aspects/properties of objects/materials
Operations	systematic variation of objects according to their aspects
Events	links between some stable properties of the same/different classes of

[6] A case-study logic contrasts to a sampling logic, i.e., rather than seeking statistical representativeness, the validity of the conclusions resides in the quality of the analysis, which seek explanatory connections and theoretical replication until data saturation.

[7] To some extent, coding the data according to these categories was interpretative. Often the attribution of a character (e.g., specificity/generality, contingency/stability, concreteness/abstraction, or disorder/organisation) to variations had not been made explicit by the subjects and required a reading of latent meanings (which was supported by the conversational context and/or warrants from the same subject in another data source).

	objects
Programmes	systematic variation of a property according to other stable properties
Principles	construction of stable co-variations of pairs of properties for classes of contexts
Connections	links between several principles with the same/different variable properties
Networks	systematic variation of a principle according to other principles
Systems	construction of stable networks of variable principles

3 RESULTS

3.1 Levels of complexity

Students ’skip’ several levels (e.g., passage from *aspects* to *events*), i.e., rather than 'true discovery', the students appealed to prior knowledge or by-pass the instructional sequence by searching on the Internet. Also, there was much centrality of *objects and materials*, even more than the phenomenon under study (which was often not made explicit). Moreover, students’ reasoning and comprehension seems to benefit when they consider the *purpose* or function of the materials in the experimental setup; they often did this spontaneously, while several difficulties appear to stem from unclear purposes. Furthermore, the students often played attention to *aspects of covariations*, mainly in terms of quality and quantity (e.g., an effect is stronger, a reaction is slower). Causality or directionality were only denoted.

In all, the students seldom went beyond the level of *events*. No measurable[8] growth over time was observed (neither within each experiment, nor between experiments), i.e., students seem to stagnate at a relatively low level.

3.2 Recurrent difficulties

The biggest category is the *rote application of concepts and algorithms*, which seems to give students a false sense of understanding. Indeed, they often used concepts without grasping any meaning, e.g., ‘the salt bridge is used to maintain electroneutrality’. Also, some tended to use algorithms and equations (while neither grasping their basis nor implications) to replace the explanation of a phenomenon, rather than to substantiate it. Their language and reasoning showed a strong tendency to ‘apply’, ‘confirm’, and ‘satisfy’ equations.

We observed quite some use of *hybrid models*, e.g., “the slope is constant and at some point, it starts changing again […] that's where the actual reaction starts happening again”; which denotes an unnoticed mix of explanatory routes. Further, the groundless or wrong *attribution* of effect (e.g., causality, mediation, interaction, contribution) appear to be connected to the rote application of equations, e.g.,

[8] Alternative research methods could be more sensitive and reveal some measurable growth that escaped from this investigation.

"increasing the concentration of reductor results in a lower voltage *because* the concentration is in the denominator of the Nernst equation".

Instances of *too early labelling* (i.e., too early connection of labels to meaning) were observed a few times. E.g., using the terms 'cathode' and 'anode' without understanding what happens at each electrode, as if the very name would convey some meaning. Instances of *misinterpreted language* were infrequent, though observable, e.g.., 'scanning' was understood as 'monitoring, measuring, reading', while 'scanning' in voltammetry is used to denote the deliberate variation of a potential difference at a constant rate. Such misinterpretation has significant consequences on the students' interpretation of the kind of variables, the objective of the experiment, and their very role as engineering-scientists.

Few instances of *mixed meanings* (i.e., simultaneous use of multiple definitions) were observed. No instances of *misleading analogy* were identified.

3.3 Other qualitative differences in terms of content

We captured (evolving) conceptions of the task, as students acknowledged aspects of the task in conversation with the LAs. On the one hand, the students seemed initially concerned about not grasping what was expected from them and about the complexity of the task; on the other hand, they tended to reduce complexity in some (inappropriate) way.

3.4 Use of conceptual modelling

The B&K method was insufficiently used (either implicitely or explicitly). Basically, we found lack of identification of the phenomenon of interest, and vagueness about the epistemic purpose of the conceptual model. In general, there is lack of prediction or hypothesis. Moreover, variables are often mentioned, but (almost) invariably in terms of their measurability (i.e., at the expense of the distinction between manipulated and controlled variables). These findings are likely to be connected to each other. The students often behaved as passive observers of variables that can only be measured, without acknowledging the possibilities to 'play', intervene, manipulate, so to produce a change that they may wish to predict, test, and describe or explain.

4 DISCUSSION AND CONCLUSIONS

To address RQ1 is to explore how students learn electrochemistry under the intervention as implemented and in terms of indicators of progress in reasoning. Although the implementation of the conceptual modelling approach [7,8] seems not to have reached its full power, the findings are certainly informative. They suggest that students (and instructors) still struggle with shifts from traditional epistemologies, and from traditional learning-and-teaching approaches. On the other hand, students do not necessarily have to comply with the 'levels of complexity' [9] framework, i.e., it is desirable that they reach higher levels regardless of the path they follow. Rather than attempting to force the students into certain steps, instructional designers and educational researchers could analyse the shortcuts students take and plausibly adopt them (i.e., capitalise on them) with appropriate guidance and in a way that is consistent with the overall pedagogical approach. This may contribute to students' embracing complexity and adopting deep learning strategies [3]. Finally, our findings on KRD are line with and add specificity to the existing knowledge [10]. These insights call for micro-interventions aiming to prevent such 'known recurrent difficulties' in learning and teaching from re-occurring. Such micro-interventions might not be easy to realise and should attack the underlying reasons for those difficulties to remain recurrent, despite being well-known.

Addressing RQ2 is to describe in what ways the student learning is embedded in the learning environment. A 'thick description' [4] is available, integrating behavioural aspects of learning (e.g., indicators of progress in reasoning) to contextual conditions of the learning environment (e.g., sequencing of the learning activities). This aims at a generalisation to non-observed cases [13] , so our claims can be extended beyond the empirical context. The analytical description of the context, next to the connections to relevant theoretical frameworks[9], allow us to suggest that our conclusions are tenable and valuable in other engineering-sciences disciplines, as students also struggle with theoretical concepts and with epistemological shifts.

In its turn, RQ3 seeks to evaluate to what extent the intervention has any measurable effect on the learning outcomes and needs to be addressed in a further investigation, as soon as the intervention has been re-implemented (as much as feasible) as designed, or with modifications.

Our findings are informative for revision of the pedagogical intervention and generate some recommendations which can be grouped in three areas. First, about students' conception of the task and believes about their roles: (i) help students to embrace complexity rather than reducing it, (ii) request the thorough use of the B&K method, (iii) distinguish 'manipulated' variables from 'controlled' variables. Second, concerning building on previous for further growing: (i) consider reducing the number of 'different' practicums to allow for a second lab experience around the same topic, (ii) emphasise the connections between 'different' practicums. And third, on collaborative learning: (i) introduce peer review of intermediate/final products, (ii) continue investing in the professionalisation of the LAs.

To conclude, this investigation may be expected to contribute directly to the learning and professional development of those involved, which is consistent with the spirit of action research. The plausible implications on engineering-science educational practice regard new insights and recommendations likely to raise awareness among instructional designers and teachers, thus motivating them to reconsider their own practices, be it in line with an epistemological shift towards scientific reasoning in

[9] We propose that the frameworks used in this action research project, as well as our operationalisation of such frameworks, are valuable for engineering-science education in general. We refer to frameworks of conceptual modelling, surface/deep approach to learning, levels of complexity, and known recurrent difficulties. Also, we refer to pedagogical ideas about sequencing of activities (e.g., IBL) and a mixed general-infusion approach to instruction and learning (e.g., deliberate/overt, and both general and content-bound).

and for practice. Concurrently, this contribution advances an operationalised framework of levels of complexity for other educational researchers to study learning in engineering-science education.

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The implications of entrepreneurs' previous experiences on using a scientific approach to decision making: Evidence from a randomized control trial

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ABSTRACT

This study aims to investigate if previous managerial or entrepreneurial experiences of entrepreneurs could moderate the use of a scientific approach to decision-making. To test this, we embedded a field experiment involving 132 real start-ups from Italy. We collected data on performances using phone calls for 64 weeks. Using econometrics analysis, we find that previous managerial or entrepreneurial experiences moderate the effect of this entrepreneurial decision-making approach on start-up performances, such as whether they decided to terminate their entrepreneurial idea, the number of pivots and the amount of revenue gained. The moderating effects differ according to the experiences possessed by entrepreneurs.

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1 INTRODUCTION

Entrepreneurs face several issues when starting and developing their entrepreneurial ideas, especially in the early-stage phase, which involves several critical decisions (Gans et al., 2019).

These critical decisions range from deciding to hit the market, changing core parts of their business or whether or not to give up on their entrepreneurial idea (Camuffo et al., 2020; Gimeno et al., 1997). According to previous literature, entrepreneurs can take these decisions using different approaches to decision-making, ranging from more structured approaches to less structured (Dencker et al., 2009; Sarasvathy, 2001; Camuffo et al., 2019). Focusing on critical decisions, previous studies have shown how using a scientific approach to decision-making can influence decisions regarding whether or not to hit the market, to pivot or to terminate an entrepreneurial idea. Entrepreneurs using a scientific approach to entrepreneurial decision-making act like scientists do in developing and testing their hypotheses in labs. More precisely, entrepreneurs using this approach ground their decisions on hypotheses carefully elicited from a theory they build (Felin et al. 2019) and on thoroughly built evidence, thus mitigating the risk of incurring false positive and false negative decisions (Camuffo et al. 2019). Building on this, entrepreneurs using this approach seem to terminate more their entrepreneurial idea, pivot less – i.e. change a core part of their business model - and gain much more revenue than other entrepreneurs (Camuffo et al., 2020, Camuffo et al., 2019).

On the other hand, these critical decisions could also be influenced by human capital of entrepreneurs (Ott et al., 2017). Previous studies show how previous managerial experience can increase the likelihood of carrying on with an entrepreneurial idea compared to other entrepreneurs (Gimeno et al., 1997). In the same vein, previous entrepreneurial experience seems to lead entrepreneurs to gain higher performances and survive more. (Cooper et al., 1994).

Despite the previous knowledge on approaches to entrepreneurial decision-making and entrepreneur's human capital, we have few pieces of evidence on how human capital – like previous managerial or entrepreneurial experience - might influence the use of an approach to entrepreneurial decision making, such as scientific approach to decision making. Entrepreneurs usually rely on their previous experiences to develop strategies and make critical decisions when operating in an unknown market (Hashai and Zahra, 2021). Similarly, they can leverage an approach to decision-making to gain critical information about the value of their entrepreneurial idea and their customers. Despite this, we still do not have evidence on whether these previous knowledge gained during their experiences might moderate the adoption of an entrepreneurial decision-making approach, improving or not the performances of the entrepreneurs using it. Building on this, this research aims to understand if entrepreneurs' previous managerial or entrepreneurial experience could moderate the adoption of a scientific approach to decision-making and impact start-up performance, such as termination of the start-up, number of pivots, and revenues.

RQ: Do previous managerial experiences or entrepreneurial experiences moderate the use of a scientific approach to entrepreneurial decision making?

This study aims to offer several contributions. Firstly, we aim to shed a first light on how entrepreneurial decision-making approaches – like scientific approach to decision-making – could lead to different outcomes according to entrepreneur’s previous managerial or entrepreneurial experience. Secondly, we aim to offer contributions to the entrepreneurial education field. This work shows how both novice and experienced entrepreneur can benefit from learning and using an entrepreneurial decision-making approach. Furthermore, we show how the benefits differ depending on whether entrepreneurs have previous experience or not. Finally, this study might offer governments, policy-makers, and universities interesting results on the impacts of entrepreneurship courses on early-stage start-up’s performances. Moreover, it shed light on how teaching the same approach to different entrepreneurs could lead to different outcomes. In this vein, we hope to provide governments, policy-makers, and universities with useful evidence on the effects of the entrepreneurial programs.

2 METHODOLOGY

2.1 Empirical Setting

To study the moderation effect between previous managerial or entrepreneurial experience and the use of a scientific approach to decision making, we replicate the experimental settings presented in Camuffo et al. (2019) and Camuffo et al. (2020).

Accordingly, we embed a field experiment in a pre-accelerator program by randomly assigning entrepreneurs to either a treatment (being taught how to use a scientific approach when developing a business idea) or a control group (being taught how to develop a business idea). This pre-accelerator program provides training to early-stage entrepreneurs for a short period of time (three months). Inspired by these previous works, we targeted early-stage entrepreneurs. We launched a call for applications at a national level involving both online and offline channels. The call for applications lasted two months and resulted in 149 applications. After the call for application, we excluded seven applicants as they were already in a later stage of the development of their start-up. Our initial sample thus included 142 start-ups admitted to the program. Using STATA software, each start-up was randomly assigned to either a treatment or a control group through simple randomization. We checked using t-tests that treatment (71 start-ups) and control groups (71 start-ups) were balanced on several key covariates, such as previous experience level at both team and leader level, that might affect the absorption of the treatment and subsequent outcomes. Just before the beginning of the program, 10 start-ups decided not to take part in the training. We checked for the balance check and the randomization was still robust on the covariates. The final sample was composed of 132 start-ups, 67 in the treated group and 65 in the control group.

Treated and control teams were trained during seven sessions from October 2018 to February 2019 (21 hours of training for each group). Our pre-accelerator program focused on market validation, a series of activities aimed at testing the desirability of a product or service concept against a potential target market. The content and length of each session were the same for both groups, but start-ups in the treatment group were taught how to take entrepreneurial decisions according to the scientific approach. In each class of the treatment group, start-ups were taught to elaborate a theory behind their choices, articulate hypotheses and test them rigorously. The control group, instead, did not learn about the scientific approach but followed the traditional approach to decision-making used by entrepreneurs. We avoid contamination and other threats to internal validity by following the same approach as Camuffo et al. (2019).

Data collected refers to 132 real early-stage start-ups operating in Italy. We performed a two steps data collection. The first step began before the training, during the call for application. Before enrolling in the program, we asked to the leader of the start-up to fill a pre-survey concerning information about her start-up and the founding team. The information refers to the demographic and human capital of the founding team - such as the years of entrepreneurial experience of each member of the team - and information about the start-up, such as industry, when its development was started and if it has already gained revenue. These data were used to randomize the start-ups between treatment and control groups and create the variables for the econometrics analysis.

As far as post-training data are concerned, data collection lasted approximately one year, involving 18 points of observations. Data were gathered through phone interviews led by the research assistants (RAs). Data collection involved data referred to start-up performances, such as the amount of revenue gained, wherever they had quitted their entrepreneurial idea or they have changed a core part of their business model. Phone interviews were lead using a semi structured approach. The interviews started after six weeks from the beginning of the program. The first four interviews were lead every two weeks, while the remains were performed every four weeks.

2.2 Variables

We use three main categories of dependent variables to test our hypothesis. The three categories of dependent variables refer to the decision of terminating a start-up, the number of pivots – i.e. if they have changed some key components of their value proposition or their target customers- and the amount of revenue gained. Table 2.2.1 reports the descriptions of the three dependent variables.

Table 2.2.1 : Dependent Variables

Variable	Description
Quit	Binary variable equal to 0 until entrepreneurs quit their idea (they abandon the program and cease their start-up), 1 when entrepreneurs decide to exit. Missing after they quit

Number of pivots	Binary variable equal to 1 when an entrepreneur makes a pivot, 0 elsewhere
Revenue Flow	Amount of revenue earned by the start-up

We developed the econometric analysis using four explanatory variables, one related to the use of the scientific approach to decision-making and the remains related to the human capital of the leader of the start-up. The first explanatory variable is the *Intervention*. *Intervention* was used to discriminate between treatment and control group. This is a binary variable which takes the value 1 when a start-up has been taught how to use a scientific approach to decision making, and 0 elsewhere. As far as human capital is concerned, we defined two independent variables to assess whether a leader of a start-up had previous managerial or entrepreneurial experiences. We define these two variables using data related to the experiences of the leader gained in the pre-surveys. The first dummy variable, *No Managerial Experience*, is equal to 1 if the leader of the start-up has no managerial experience and 0 elsewhere. In the same vein, *No Entrepreneurial Experience* is equal to 1 if the leader of the start-up has no entrepreneurial experience and 0 elsewhere. Table 2.2.2 shows the independent variables used in the econometrics analysis.

Table 2.2.2 : Independent Variables

Variable	Description
Intervention	This is a binary variable equal to 1 for start-ups in the treatment group, and 0 otherwise.
No Managerial Experience	This is a binary variable taking the value 1 if the leader of the founding team has no managerial experience, 0 elsewhere
No Entrepreneurial Experience	This is a binary variable taking the value 1 if the leader of the founding team has no entrepreneurial experience, 0 elsewhere

3 RESULTS

All the regressions include control for time and instructors and errors are clustered by firms.

Table 3.1: Regression Analysis, Dependent Variable = Quit, Number of pivots, Revenue

	(1)	(2)	(3)	(4)	(5)	(6)
	DV = Quit	**DV = Quit**	**DV = Number of pivots**	**DV = Number of pivots**	**DV = Revenue**	**DV = Revenue**
VARIABLES	Linear Probability Panel	Linear Probability Panel	Linear Probability Panel	Linear Probability Panel	Linear Probability Panel	Linear Probability Panel
No Intervention X Has Managerial Experience	-0.024		-0.043		118.213	
	(0.296)		(0.139)		(0.238)	
Intervention X Has Managerial Experience	-0.018		-0.046		469.840**	
	(0.354)		(0.113)		(0.042)	
Intervention X No Managerial Experience	0.053*		-0.053**		174.153	
	(0.094)		(0.029)		(0.327)	
No Intervention X Has Entrepreneurial Experience		-0.018		0.026		21.430
		(0.368)		(0.408)		(0.802)
Intervention X Has Entrepreneurial Experience		-0.018		-0.018		513.186**
		(0.345)		(0.477)		(0.036)
Intervention X No Entrepreneurial Experience		0.052*		-0.017		95.816
		(0.078)		(0.413)		(0.504)
Constant	-0.014	-0.019	0.447***	0.420***	224.132	268.194
	(0.482)	(0.277)	(0.000)	(0.000)	(0.428)	(0.356)
Observations	1,817	1,817	1,817	1,817	1,817	1,817
Number of id	132	132	132	132	132	132
Dummies for mentors	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	-	-	-	-	-	-
Dummies for interviews	Yes	Yes	Yes	Yes	Yes	Yes
Clustered Errors	Firms	Firms	Firms	Firms	Firms	Firms

Robust pval in parentheses *** p<0.01, ** p<0.05, * p<0.1

Model (1) and Model (2) show the results for the likelihood of terminating a start-up. As far as managerial experience is concerned, it seems that the intervention is more efficacy on start-ups which are led by a leader without previous experience as a manager. Moreover, the moderating effect between intervention and not having previous experience as a manager has a positive and significant effect on the decision of terminating the start-up. In a similar vein, start-ups led by a leader without previous experience as entrepreneurs and using a scientific approach to entrepreneurial decision-making are more likely to terminate their start-up than the other entrepreneurs in the sample.

Model (3) and Model (4) show the results on number of pivots made by entrepreneurs. Model (3) shows a negative and significant effect of the moderation between not having previous experiences as manager and the intervention. Thus, it seems that entrepreneurs without previous experiences as manager benefit more from using a scientific approach to decision-making, making fewer pivots than other entrepreneurs. On the other hand, the moderation effect among intervention and previous experiences as entrepreneur seems not to affect the number of pivots made by an entrepreneur.

Model (5) and Model (6) show the results concerning the moderating effect of being treated and previous managerial or entrepreneurial experience. As we can observe from Model (6), it seems that treated start-ups with a leader with previous experiences as an entrepreneur benefit more from using a scientific approach to decision making. The moderation between the intervention and previous entrepreneurial experience has a positive and significant effect on the amount of revenue gained by the start-up. As far as leaders without previous entrepreneurial experience are concerned, the moderation shows a positive but non-significant effect on revenue. In the same vein, there is a positive moderation effect between previous managerial experience and intervention. Entrepreneurs with previous managerial experience who use a scientific approach to decision-making seem to gain more revenue than other entrepreneurs in the 18 point of observation.

4 CONCLUSION

Our study shows the results of a field experiment involving 132 early-stage start-ups from Italy. We find evidence that the use of a scientific approach to decision-making is moderate by the previous managerial and entrepreneurial experiences of an entrepreneur.

This study offers contributions to academics, practitioners and policy-makers. At first, this paper gives contributions to the literature regarding the scientific approach to decision-making. Our results provide insights on the use of this approach to decision-making, suggesting that its outcomes are moderated by the human capital of the entrepreneurs. On the one hand, entrepreneurs without previous managerial or entrepreneurial experiences using a scientific approach to decision-making seem to terminate more their entrepreneurial idea. On the other hand, entrepreneurs with previous managerial or entrepreneurial experience seem to benefit more from an economic point of view when using a scientific approach to decision making, gaining more revenue.

Secondly, this work gives insides to the entrepreneurial education field. This work shows how both entrepreneurs with previous experience or without experience can benefit from learning a specific approach to decision making. Moreover, entrepreneurs using a scientific approach to decision-making seem to gain superior performances than entrepreneurs who use a more classical approach to take their decisions. These results give a further understanding on how entrepreneurial education can be effective for entrepreneurs with or without previous experiences and which approach can be more beneficial for them. In the same vein, this work shows that teaching the same entrepreneurial approach could lead to different results based on the human capital of entrepreneurs. Finally, this work gives interesting insights to policy-makers and universities. Entrepreneurs seem to gain different benefits when using a scientific approach to decision making according to their previous experiences. Entrepreneurs without previous managerial or entrepreneurial experience seem to terminate more their entrepreneurial idea when they use this approach, while entrepreneurs with these experience seem to gain a superior amount of revenue. These results might be important evidence for policy-makers and universities involved in creating entrepreneurial education programs. Based on their own goals, universities and policy-makers could set up course on scientific approach to decision making focused on novel or more experienced entrepreneurs to boost the outcomes related to this approach.

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Profile of the participants in a STEAM Lecturer-Training Program Based on Competencies. Lessons for the future.

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ABSTRACT

This paper presents the results of a research study on the profile of the participants in a postgraduate lecturer training program (15 ECTS) based on competencies in a STEAM (Science, Technology, Engineering, Arts and Mathematics) University. The study research questions are: (1) "In which competences do the participants perceive a personal improvement during the programme?", and (2) "Can we identify a profile of the candidates most suited to take better advantage of the training?" . The study includes current participants and students who have completed the program in the last 5 years. A mixed research methodology was used including both quantitative and qualitative analysis. Data from the program alumni and current candidates have been quantitatively analysed to identify common personal and background features among them. Structured interviews and focus groups have been conducted to find out how their initial expectations matched with their perception of what was offered in the program. The qualitative interviews include a discussion about their experiences along the programme and their ambitions for their further professional development, and put in context with their specific background. This research has important implications for the future, such as the need for increased training in digital skills. The majority of the teachers surveyed have a positive impression of the training and are in the middle of their careers. However, because of the pressure to satisfy other Academia requirements, many potential applicants in their early career stages do not complete or even contemplate participating in the program.

1 INTRODUCTION

Teacher’s training is particularly challenging in the particular context of engineering studies, which traditionally have one of the highest dropout rates in higher education. Patricia Cross [1] stated that teaching will not acquire status until teachers do consider their classes as laboratories for research and innovation. The problem probably comes from the fact that the innovation and research that are conducted at our technical universities do not use the same methods as those traditionally used in the social sciences, which are precisely the ones that would apply to education. Thus, it is necessary for a faculty also to acquire competencies related to these issues.

Hence, we focus our work on the pedagogical training of university teachers in higher education, in a technical university. Lecturers’ opinions of their day-to-day teaching practice usually arise from their culture or previous background as former students, and mainly on their own beliefs, which induce them work as if these beliefs were true. Such beliefs are usually very resistant to change, as well as being consistent with the teaching style of each lecturer [2].

Competency-Based Education (CBE) is increasing its role in Higher Education worldwide. The *KoKoHs* project in Germany, for instance [3], has revealed significant deficits in student competencies, proposing different ways to address them, among others, to promote lecturers’ training in pedagogical competencies. However, few studies can be found about teachers’ competencies. A positive effect was found, for instance, by Muzenda [4] who has described how lecturers' competencies improved students' academic performance. Some authors have proposed CBE programs for training lecturer's competencies in particular fields: Schina et al. [5] outlined some lecturers' training programs in robotics education, while Ulubey and Basaran [6] have reviewed existing lecturers' initial training programs in Turkey. However, which competencies should be trained in a STEAM university is still a matter of discussion, and as far as these authors know no similar programs as the one introduced herein have been analysed in European Universities.

In order to tackle these points which are common to many European STEAM universities, we herein introduce and analyse a teachers' training program designed at our university,(*Universitat Politècnica de Catalunya – BarcelonaTech*) and promoted by its *Institut de Ciències de l'Educació*, to which the authors of this work belong. This training is non-mandatory for the participants, because, no specific pedagogical background is required for teaching at our universities, other than knowledge of the subject to be taught. Since the training programme is voluntary, lecturer enrolment in the program is usually rather low when compared to the total number of lecturers in the university. A matter of concern is how this participation in teacher training programs in higher education can be raised.

The University in which this program is proposed is a technical one, specialized in technology, mathematics, architecture, science and engineering (STEAM). There are no schools and departments of psychology or education within our institution, or any tradition of using social science methods aside from the Economics department. Moreover, our lecturers have the technical competencies required for teaching, but it cannot be taken from granted that they have the professional competencies required for conducting this teaching.

Our previous training programme followed the pre-Bologna pattern: it measured on-site hours and was based on course content rather than on the competencies to be acquired by the teachers participating in the training activities. Degrees have moved from content-based learning to competencies-based learning, the focus being on learning rather than on teaching [7]. Many authors [8 - 12] have discussed the relevance of teachers training in the quality of the teaching received by higher education students, particularly in challenging studies such as those related to STEAM studies. Hence we proposed a training program whose objectives were:

- To design a training itinerary for lecturers based on the competencies they must acquire as teachers, as well as providing a qualification certifying to that fact. This training should also cover lecturer evaluation and promotion.
- To increase the number of lecturers enrolling in our training programme.
- To use this training programme to promote a scholarship in engineering education research, a field of scientific inquiry that has usually been ignored by our teaching staff.

The following six competencies were identified as part of the curriculum training: 1) Interpersonal; 2) Methodological; 3) Communicative, 4) Planning and Management; 5) Teamwork; and 6) Innovation. A final 7) "Digital Training" competency was added in the year 2020/21 as it was perceived that there was an important need for this training during the outbreak of the pandemic.

- Interpersonal: to be able to help participants to develop critical thinking, motivation, confidence and diversity recognitions; by creating a framework of empathy and that includes ethics in their professional practice as well as interacting with other individuals.
- Methodological: to be capable of applying appropriate strategies and evaluation tools in accordance with each educational context.
- Communicative: to be able to conduct appropriate and efficient communication processes in the teaching context which means reception, performance, production and transmission of messages through various media channels. These channels include face-to-face or online interactions as well.
- Planning and management: to know how to design, guide and develop content, training and evaluation so that the results are measured and suggestions for improvement are made.
- Teamwork: this skill is not about teachers leading a group of students working together, but rather about teachers being able to collaborate among themselves. It deals with the topic of taking responsibilities and commitments according to the common objectives, agreed procedures and considering the educational resources available.
- Innovation: to be able to create and apply new knowledge, perspectives, methodologies and resources in the different dimensions of their teaching.
- Digital Training: to be able to use telematics tools, new technologies and software tools to conduct semi-presential or online teaching.

The program has a total of 15 ECTS to be conducted in different courses and workshops including training in all the previous competences. All the courses include, as a general framework a general introduction and an overview of the pedagogical principles. However, a practical approach is enforced. Active methodologies are proposed by the trainers of the courses and workshops which specifically aim to make the participants reflect on their own teaching. Individual and group practical work is proposed in order to discuss whether their teaching day-to-day duties include the principles which motivate good practice teaching in higher education. For example, in the course of Interpersonal training, participants learn to develop an electronic teacher's portfolio which is aimed to reflect and discuss their day-to-day practice and interactions with both students in class and their staff colleagues.

A final project is mandatory to complete the degree with a real innovation being conducted in the class by the participant in the program [13]. Active methodologies and student engagement are intended to be implemented by participants during this training [14]. The final project includes a final memo and is finally presented and discussed after an evaluator board of experts.

2 METHODOLOGY

2.1 Description of the participants sample

Two focus groups were included for this research. Group A was specifically organized for this work with only alumni of the program, while Group B was added as conducted before in 2021 but with the same aim as the first one. Focus Group A included only alumni from the program, and Group B included only participant candidates.

Regarding Group A, five former participants from different departments who have finished their degree in the last five years were interviewed with a structured script. One of the participants was in the initial stage of his career when he was a participant of the STEAM program, aged 27 years old. The other four belonged to a middle stage (Associate professor) aged between 32 and 43 years old. None of the subjects who could be interviewed belonged to the advanced stage (Professor). Three were male and two female. Two belonged to the Management department, 1 to the Physics department and 2 to the Information Technologies (IT) area.

Focus group B was held in 2021, with the aim of answering this Research Question 1. One of the teachers in the training program was in charge of moderating the focus group, and the participants were lecturers chosen from among those who had attended a workshop taught by the moderator. Eight men and eight women were randomly chosen to achieve gender parity, and of the sixteen people invited to participate in the focus group, fourteen accepted (8 female, 6 male). Finally, for practical reasons they were grouped into three subgroups, one of 4 and two of 5 people. The participants in Focus Group B had a wide range of teaching experience from between one and a half and 33 years. Five participants were at the beginning of their academic career, with 5 years of teaching experience or less (many of them were teaching assistants while doing their doctorate) and an age range of between 20 and 30. Four people were in their thirties, and four people were over 40 years old, all of them with over 15 years of teaching experience. The distribution in areas of knowledge in Focus Group B covered all groups at the university: lecturers from the science area (3), industrial engineering (5), architecture (2), civil engineering (2) and IT (2).

With respect of the whole group of participants in the STEAM program, 68% of the students enrolled belong to the middle-stage career teachers (associate professor), with less than 5% of Professorships and a remaining 27% are on the initial-stage teaching career. Lecturers enrolled in the program belong to a wide variety of departments and knowledge areas. The most represented areas are Management, Architecture and Computer Science. This data was used for quantitative and qualitative analysis as described in section 2.3.

2.2 Improvement as perceived by the participants

We used a qualitative approach to answer to this research question ("In which competences do the participants perceive a personal improvement during the programme?") with semi-structured interviews and focus groups.

All five participants have successfully finished their degree with excellent marks and they all found that their involvement in this training program had a significant positive impact in their careers. The semi-structured interview was focused on finding what specific part of training had a real impact on their teaching, how their training was influential in their advancement (if any) in their professional careers, and specifically, which particular competences were perceived by the participants as having improved because of their training. Computer Assisted Qualitative Data Analysis Software (CAQDAS) such as NVivo 11 was used for text analysis.

2.3 Profile of the candidates

A mixed methodology, both quantitative and qualitative was used in order to find out the answer to the second research question ("Can we identify a profile of the candidates most suited to take better advantage of the training?").

Regarding the quantitative analysis, data from the program alumni and current candidates have been quantitatively analysed to identify common personal and background features among them. Previous background, current stage of their professional career, age and gender, as well as time to complete the degree (or credits remaining to obtain it) were taken into account. A multifactorial analysis was performed using SPSS version 25. Correlations between the independent variables and indicators of their success when completing the program were computed.

Qualitative analysis was used to find clues on which are the best indicators from the professional practice of the participants that best correlate with their success, and in which specific parts of the training have they focused on. Again, both the aforementioned structured interviews and focus groups were used.

3 RESULTS

3.1 Research question 1

The participants in the semi-structured interviews all were very satisfied with their participation of the program. Regarding its specific impact on their professional career the results were mixed. Four of them showed that they perceived that their day-to-day teaching was improved, while the remaining participant, the one in his initial stage of his career argued that, while little impact could he perceive on the quality of his teaching, the awarded degree was something valuable that added to other merits to achieve a promotion in his academic status. Four of them noted that the final project was meaningful for their reflection skills on their teaching. Regarding the question on which specific competences the program can be accounted as a booster for them, 3 of them mentioned "Innovation", 2 of them mentioned "Communicative" and "Methodology" and only one included "Teamwork" in their comments in the interview.

The text analysis showed that "Innovation" or "research" was the most frequently mentioned theme, with "active methods" leading the second place and "qualifications" being third. The results may reflect the impact of their training on the perceived new innovation capabilities as well as the importance of the active methodologies being introduced in their day-to-day teaching and their related impact on the qualifications obtained by their students.

Participants in the focus groups believed that the workshops offered were both interesting and useful. The opportunity to include these workshops, and especially the postgraduate degree in the education section of their CVs, is advantageous for young teachers seeking to obtain a `promotion. It is also interesting for teachers in a more advanced stage of their academic career to hold a postgraduate degree when applying for positions as a senior reader or Professor. However, for promotion and recruitment, research experience prevails over teaching and training experience. A consensus exists about the advantages of completing these workshops as a means of distinguishing oneself from other applicants, although it is believed that universities do not value these workshops to the extent that they should. This is the reason why participants think that most teachers do not sign up to these workshops (in a normal situation), since it is more profitable for their academic careers to spend this time publishing papers or securing a project than devoting it to workshops on education. Lecturers found themselves overnight in a pressing situation requiring an accelerated and in-depth course of training in new educational tools and methodologies, to which end they enrolled in the workshops provided. Even so, participants are of the opinion that many lecturers have tried new ways of doing things and have become aware of their own limitations as teachers, so it is likely that a considerable number of newcomers will continue in the program.

3.2 Research question 2

After a multifactorial analysis of the data from the participants in the program and alumni in the last five years was performed, some interesting results can be noted.

Regarding knowledge background areas, 38% belong to Foundation Sciences (Mathematics, Statistics, Physics, Chemistry, Biology, Economics), 18% belong to Industrial Engineering, 21% to IT (Information Technologies), 18% to Architecture and 5% to Civil Engineering. Some of the knowledge areas are overrepresented in the program, such as Economics (usually linked to Engineering and Applied Management topics) and Civil Engineering, which is due to the existence in their departments of a tradition and interest groups on innovation and teaching topics. Most participants and alumni were in their middle stage of the program (62%), many of them were in their initial stage (35%) and very few in the upper stage as Professors (3%). The differences in gender (63% male and 37% female) may reflect the presence of more men than women in STEAM universities staff such as the one herein analysed. Most of the participants (73%) had more than 10 years of experience as university teachers while less than 13% had less than 3 years of experience with only 14% between 3 and 10 years of teaching experience in higher education. Only the combination of Middle-stage career with an Economics ($r=0.85$, $p<0.05$) or Civil Engineering ($r= 0.78$, $p<0.05$) background was positively correlated with finishing the degree.

In the semi-structured interviews it was interesting to find out that all five participants in the interview mentioned their vocational interest in pursuing a training for their teaching. They unanimously perceived, even in strong terms, that their promotion in Academia will not be the result of this training but rather, from their research results in their specific fields of knowledge. This impression was also found in the focus groups. Another significant finding was that during and after the pandemic, they realized that a better training in digital tools and skills was needed to better serve their students.

4. CONCLUSIONS

All participants having been surveyed had a positive perception of the training they had received during the program. The inclusion of active methodologies in their day-to-day practice as teachers, and innovation skills was the competence that stands out to be the best improvement in their teaching practice they could mention after completing this postgraduate program. We could not find a particular background that was most suitable for completing this degree as most teachers did not come from a pedagogical or social sciences undergraduate training. There was a positive correlation with Economics and Civil Engineering backgrounds for a positive completion of the degree, but this fact could be probably due to more tradition in teaching, learning and innovation in their departments in this particular University. Both participants and alumni were particularly satisfied with the practical approach of the program. Some of them reflected that the tools and methodologies proposed to them had a turning point effect on the effectiveness of their teaching. However, organizational restrictions were also often noted as a strong limitation for change. These conclusions can be easily generalized to other STEAM Higher Education institutions in Europe.

This research has important implications for the future. As it has been outlined, no similar studies specific to teacher's training in competencies in Engineering Faculties had been proposed. Among our findings, we remark the need for increased training in digital skills. There is also a significant lack of initial stage participants, who are the teachers who might most likely benefit from such a teaching training program. This is probably due to a small number of full-time professors being hired by this STEAM university (due to economic lack of funds for new hiring) and also to the pressure they are facing to meet research requirements to be promoted. Although economic constraints may vary throughout European Institutions, the problem of being promoted mostly because of research merits and not competencies training is fairly common. Many potential applicants in their early career stages do not complete or even contemplate participating in this program, therefore we suggest that universities may contemplate this teaching training as a merit, or even as a requisite in order to be further promoted in their careers. The potential for improving students' effective learning is of paramount importance.

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ASSESSMENT OF COMPETENCY DEVELOPMENT IN A CHALLENGE-BASED LEARNING COURSE: CAN COACHES BE OBJECTIVE ASSESSORS?

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ABSTRACT

Higher education institutions aim to incorporate competency development into their engineering curricula, which can help engineering students become independent critical thinkers with entrepreneurial mindsets. However, no solid methods exist to evaluate the acquisition of these competencies. Such assessments' objectivities are often ensured by distinguishing between who supervises a student group and who grades its project. The assessor's active involvement in the learning process is essential for assessing competency development during the learning process, but such involvement may lead to assessor bias. This study aims to investigate whether and under what conditions coaches can be objective assessors. An intraclass correlation coefficient (ICC) was used to measure the level of agreement between assessors and coaches when using the same rubric to assess students' deliverables. Four assessors and seven coaches from the University of Twente assessed 24 students' individual learning processes based on individual reflection deliverables. The coaches assessed the students they supervised during a challenge-based learning (CBL) course, while

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the assessors were without participating in the learning process assigned randomly to students. The means were compared using SPSS, which indicated, among other things, that coaches generally awarded higher scores than assessors. This may indicate that coaches are biased because of their involvement in the learning process. Despite this, the results also indicate that coach assessment was in line with assessors when the coach was an appointed and experienced examiner.

1. INTRODUCTION

Higher education institutions aim to better prepare their students for the labour market by facilitating their development of transferable skills and lifelong learning competencies [1], [2]. The inclusion of competency development in higher education calls for new assessment methods, and one of the most promising and innovative approaches that can support such a transition to futureproof higher education is challenge-based learning (CBL) [3]. Challenge-based learning builds on experiential learning theories that view the learning process as being more important than the learning outcomes. Furthermore, these theories argue that skills are learned best in environments that resemble real-life situations [4].

This research was conducted on the Autumn Challenge programme, which is an extracurricular, international CBL programme organised by the University of Twente between October 2021 and January 2022. In this online programme, students from four ECIU[2] member universities worked on seven different challenges that resembled real-life situations and were under the theme of UN SDG 11. The programme was open to second- and third-year bachelor's and master's students from all ECIU universities.

1.1 Assessing competency development

Higher education institutions are increasingly exploring whether students can learn pass tests but also to gain a deeper understanding of the knowledge. The difference between knowledge assessments and assessments that focus on the learning process is that the latter also enables students to develop further after examination. Even though certain difficulties exist when assessing competency development, benefits exist as well. For instance, assessment drives learners to develop transferable skills [5], but also generates a higher level of commitment [6], thereby leading to more motivated students. Feedback also plays a key role, as does the active role that students play in their learning processes. To be able to assess students' learning processes, assessors should play an active role in these processes as well.

An important requirement for competency assessment is objectivity, which is often ensured by distinguishing between those who supervise students and those who assess their final outcomes [7]. In a CBL course, this means that those who coach students should not play a role in assessing the students' deliverables and vice versa [8]. However, due to the focus on the learning process in CBL, the assessor's active involvement during the learning process may provide valuable insights in addition to the deliverables on which the students can be assessed [7], [9]. Thus, combining the assessor and coach roles may provide additional insights into students' learning processes, but also can elicit assessor bias. Such a bias, whether positive or negative,

[2] https://www.utwente.nl/en/eciu/

can cause errors in assessor judgements, eliciting the potential to negatively impact an assessment's objectivity and quality [10].

1.2 On (perceived) biases in the case of the Autumn Challenge programme

An objective assessor is one who assesses the students' deliverables based solely on the criteria of the relevant assessment rubrics and the weighing thereof. However, when subjective factors (partially) influence an assessment, the assessment is 'biased'. Subjective factors can surface in many forms, e.g. the assessor's impression of a student, considering factors that are not part of the assessment rubric, or focusing too much on parts of the assessment rubric that are closest to the assessor's interest(s) or perspective(s) [8]. Various types of grading biases are recognised in the literature [8] and are summarised in Table 1. Due to the coaches' involvement in the learning process in the Autumn Challenge programme, there were five types of bias with increased potential: the contamination effect*,* halo effect, horn effect, norm shift and signal effect.

Table 1: Overview of the most common types of grading biases [8]

Type of bias	Information
Contamination effect	The contamination effect is the effect that occurs in grading when the freedom in grading, involuntary or random, is used for purposes other than those of an uninhibited, unbiased assessment. This is the case, for example, when assessors give lower scores to show that their subject is difficult.
Halo effect	The halo effect occurs when assessors allow their judgement to be influenced by other performances of the student than those expressed in the performance to be assessed. In this case, assessors tend to judge a 'good' student's performance as somewhat higher than warranted by the student's performance. The performance is overvalued.
Horn effect	The horn effect is the opposite of the halo effect. The Horn effect occurs when assessors allow their judgement to be influenced by the student's performance other than expressed in the performance to be assessed. In that case the assessors tend to assess a 'bad' student at a somewhat higher performance level than the performance of the student justifies. The performance is undervalued.
Norm shift	The norm shift is the effect that occurs when an assessor adjusts to the performance of students. For example, an appraiser may become less harsh if after a number of assessments, it is found that most students answer the same question incorrectly.
Restriction of range	Restriction-of-range is caused by the freedom in the assessment task that willy-nilly leads to certain distributions of the ratings that express general human or personal tendencies. For example, one appraiser may use all scale values (scores from 1 to 10), while another will always assign values near the middle.
Sequence effect	The sequence effect occurs when an assessor incorrectly allows the assessment to be guided by one or more previous assessments. For example, assessors review test questions in a certain order. A large number of bad answers followed by a correct answer may then lead to the correct answer being graded disproportionately.
Signal effect	The signal effect occurs when assessors pay attention to different aspects, or when they weigh the aspects differently in their judgement. This effect occurs, for example, when assessors evaluate writing products. One assessor pays attention to grammatical (in)correctness and the other to structure or content.

1.3 Problem statement

In this paper, we use the term 'grading bias' to refer to unintentional grading bias. There is a considerable body of literature on how to prevent this, but these solutions are mainly aimed at eliminating situations where bias can be stirred up, such as intensive collaboration between lecturers and students. Is a certain degree of bias a real issue?

Research has shown that, when students have the feeling that they are not being judged for their work but, for example, for their personality or their past performance, both the student and their peers may feel that they have no influence on the outcome, no matter their efforts.

2. METHODOLOGY

This section of the paper outlines the methodology used to answer the following research question: Can coaches be objective assessors, and, if so, under which conditions?

2.1 Subjects

Student population

In total, 24 second- and third-year bachelor's and master's students participated in the programme in teams of three to five members each based on multidisciplinary, intercultural diversity and their preference for an overarching project. The teams' progress were monitored at weekly team coaching sessions as well as during three programme milestone moments.

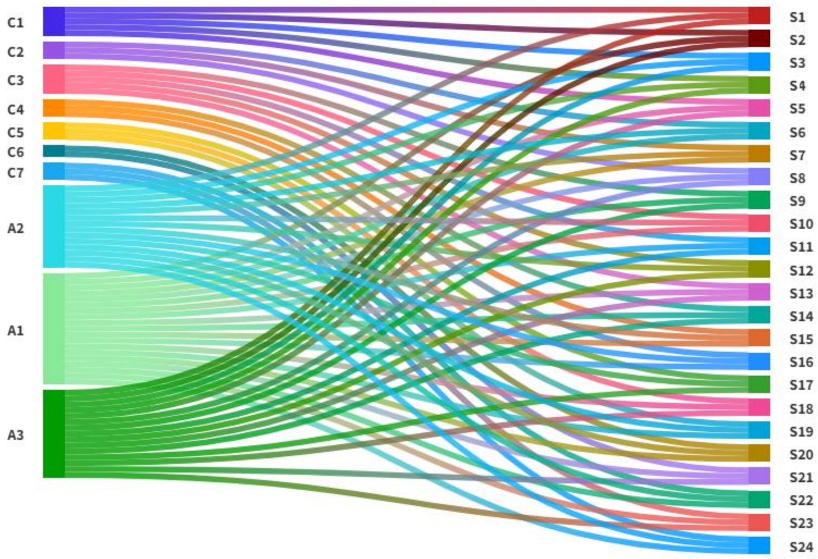
Challenge-based learning coaches

The seven student teams were each supported by their own team coaches. The coach's role in the learning process was to provide proper, flexible, and personal support to the students in their teams in order to enhance the learning process and team dynamics [11]. Two of these coaches were experienced academics and trainers with a University Teaching Qualification (UTQ) and experienced with CBL. All seven coaches received training on coaching in a CBL prior to the start of the programme. The coaches have been actively involved in the students' learning processes throughout the course, unlike the assessors.

Assessors

Just like the coaches, there were also four assessors that evaluated the students' final learning outcomes. Unlike the coaches, the assessors have not been involved in the students' learning processes. Each student has been assessed by his own coach and by two assessors. Details on who assessed the students can be found in Figure 1.

Figure 1: Distribution of the individual deliverables among coaches and assessors. A 'C' refers to a 'coach', an 'A' to an 'assessor' and a 'S' to a 'student'.



2.2 Assessment rubric

The assessment rubric for individual reflection was developed to provide students with the freedom to reflect in a way that suits them. Table 2 shows a summary of the assessment rubric (see Appendix A for the full rubric), which consisted of three levels of 'pass' scores (Excellent, Satisfactory, Sufficient) and one 'Insufficient' score for each assessment topic. For this analysis, each assessment scale received a corresponding score as shown in Table 2. Three assessment criteria were used to score and analyse five assessment topics, namely Professional growth, Skill development, Team role, Problem solving and Development of new skills and competencies. The 'report/video length' assessment criterium was excluded from the analysis, as no differences between the raters' assessments would be found.

Table 2: Overview of the assessment criteria used in the analysis

Assessment criteria		**Insufficient**	**Sufficient**	**Satisfactory**	**Excellent**
		2,5	5,5	7,5	9,5
Individual development	Professional growth	Reflects upon their educational and professional growths. Provides examples and reflects upon the BuddyCheck matrix related to individual development and programme components (Skills Labs, Thematic Lectures, Virtual Teams Group Work).			
	Skill development	Reflect upon the development of skills/competencies related to their individual learning goal set prior to the programme.			
Individual role	Team role	Reflects upon their role in the team. Provides examples.			
	Problem solving	Reflects upon their contribution to the problem-solving process. Provides examples.			
Individual effort	Development of new (interdisciplinary) skills and competencies	Reflects upon their effort to develop new skills and obtain new competencies in the programme. Provides examples and reflects upon the BuddyCheck matrix related to individual effort and programme components (Skills Labs, Thematic Lectures, Virtual Teams Group Work).			

2.3 Reliability of agreement

To ensure that the rubric provides sufficient consistency, and therefore any found differences are not likely to be caused by the interpretation of the assessment items but rather by the assessment itself, an intraclass correlation coefficient (ICC) was used. The outcomes were interpreted as follows: < 0.50, poor; between 0.50 and 0.75, fair; between 0.75 and 0.90, good; above 0.90, excellent. The ICC for intra-rater reliability for rater 1 and rater 2 was fair as it was 0.62 (0.25-0.83); for rater 1 and rater 3, was fair as it was 0.58 (0.19-0.81); and for rater 2 and rater 3, was excellent as it was 0.93 (0.82-.0.97). We can thus conclude that the rubric used ensured a high enough level of agreement between the raters to be able to compare the results.

2.4 Measures

In the case of the Autumn Challenge programme, the assessment structure is two-fold, i.e. assessors and student groups' coaches assess reflection deliverables. The assessors are not involved with the students in the course and, thus, can only base their assessments on the students' deliverables. To investigate this phenomenon further, perceived bias was measured.

Two outliers were detected that were more than 1.5 box lengths from the edge of the box in a boxplot. Inspection of their values did not reveal them to be extreme and they were kept in the analysis.

3. RESULTS

3.1 Data preparation

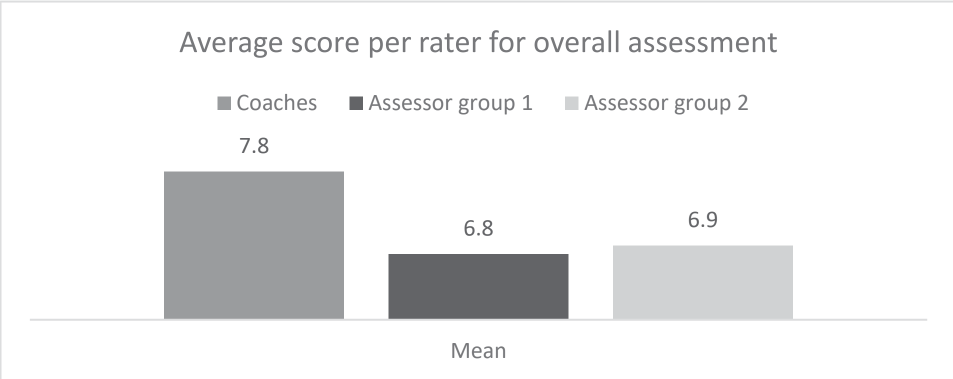
Before comparing the rater groups with one another, the first step was checking for the assumptions of normality and outliers. One outlier was found in the coach group. However, the coach in question is the most experienced teacher in that group, possesses the UTQ, and is very experienced in CBL education. Additionally, the outlier was not more than 1.5 box lengths from the edge of the boxplot. For these reasons, the outlier was not removed. In the first assessor group, outliers were detected, but both of them were no more than 1.5 box lengths from the edge of the box. Inspection of their values did not reveal them to be extreme and they were also kept in the analysis, as both outliers were detected in the overall score and the assessment criteria 'individual development'. In the second assessor group, there were no outliers. Furthermore, six individual cases were excluded from the analysis due to incomplete information, thus 18 cases were used.

3.2 Analysis

Assessment means comparison

The means of the assessment of the students' individual deliverables of the three raters (Coaches, Assessor group 1, Assessor group 2) are firstly compared as a whole as shown in Figure 2, and then on the three assessment criteria as shown in Table 3.

Figure 2: Means comparison of the three groups of raters for individual deliverable



Coaches score, on average (M = 7.8, SD = 1.096), much higher than the assessors, respectively (M = 6.8, SD = 1,535) (M = 6.9, SD = 1.944), who have not worked intensively with the students. Additionally, the average score for the 'individual development' assessment criterium given by the coaches was the highest (M = 7.8) followed by the second assessor group (M = 7.2) and the first assessor group (M = 7.0). Similarly, the highest average score for the 'individual role' assessment criterium was given by the coaches (M = 8.2), followed by the second assessor group (M = 7.2) and the first assessor group (R2 = 7.0). For the assessment criterium, 'individual effort', the highest average score was given by coaches (M = 7.3), which was followed by the second assessor group (M = 6.3) and the first assessor group (M = 6.2).

Looking at the individual assessment criteria, the differences are smallest for development and largest for role and effort. A higher assessment of 'individual role' and 'individual effort' by the coaches may indicate the influence of the halo or signal effects because, in CBL, coaches are part of the team and this may lead to an overvaluation of the students' roles and efforts in the project (*halo effect*). The coaches may also consider the role the students play and the effort they put into the project group to be more important than the students' individual development (*signal effect*).

Table 3: Means comparison of the three groups of raters for different assessment criteria. The highest scores are highlighted in bold.

		Individual Development		Individual Role		Individual Effort	
	N	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Coaches	18	**7.8**	1.331	**8.2**	0.943	**7.3**	1.886
Assessor group 1	18	7.0	1.996	7.0	1.098	6.2	2.346
Assessor group 2	18	7.2	2.211	7.2	1.816	6.3	2.624

T-Test

Overall, the coaches scored statistically significantly higher on the overall assessment score compared to both assessor group 1 ($t(17) = 3.817$, $p < 0.001$) and assessor group 2 ($t(17) = 2.447$, $p < 0.026$). The coaches scored statistically significantly higher on the assessment criterium 'individual role' compared to assessor group 1 ($t(17) = 6.059$, $p < 0.001$) and assessor group 2 ($t(17) = 2.749$, $p < 0.014$). The coaches ($t(17) = 2.247$, $p > 0.38$) did not score statistically significantly higher on the assessment criterium 'individual effort' compared to assessor group 1 ($t(17) = 2.294$, $p > 0.35$). As expected, the assessment criterium 'individual development' was not significant compared to assessor group 1 ($t(17) = 1.750$, $p > 0.98$) and assessor group 2 ($t(17) = 1.225$, $p > 0.24$).

Pass/Fail comparison

As stated in the literature, an assessment that is not only based on visible and expected assessment but where other factors are also taken into account is undesirable [8]. This is the case regardless of whether this leads to a more positive or negative result. Apart from the fact that a grade should reflect the actual performance, there is an even greater risk that students who do not sufficiently master the learning objectives will still receive a 'pass' grade or vice versa. Table 4 shows that, based on the scores of the coaches, 10% of the students would have received a pass score without having objectively achieved the learning objectives.

Table 4: Differences between pass/fail scores given by the three groups of raters.

		Individual Development		**Individual Role**		**Individual Effort**	
	N	Pass	Fail	Pass	Fail	Pass	Fail
Coaches	18	17	1	18	0	17	1
Assessor group 1	18	14	4	18	0	15	3
Assessor group 2	18	14	4	16	2	14	4

It can, therefore, be concluded that coaches are less likely to fail students than assessors. The coaches may overvalue their students' performance (*halo effect*) because they may, to a certain extent, feel responsible for their individual development and the effort they put in.

4. CONCLUSION

Ensuring objectivity in competency assessment is one of the key requirements for valid assessment and future facilitation of transferable and lifelong learning competencies in higher education. The research data indicates that, in the case of the CBL Autumn Challenge programme, coaches were not always objective assessors. Coaches rewarded students whom they have coached with overall higher scores as compared with the assessors who were not involved in these students' learning. Moreover, the coaches gave a fail to fewer students than the assessors did. Based on these outcomes, it can be concluded that bias influenced the coaches' assessments. The coaches either tended to overvalue their students' performances (*halo effect*) or give more weight to the role they played in the group work than to the other assessment criteria (*signal effect*). Nevertheless, our results also indicate that, when a coach was an experienced and trained teacher, disagreement between the assessment of the coach and the assessors was eliminated. This finding is also in line with Sa et al.'s [7] research, which concluded that more rigorous training for coaches in an open-ended project is required in order to assure valid assessment. However, because only two coaches in the Autumn Challenge programme were experienced and trained teachers, further research into the objectivity of experienced and trained coaches as objective assessors is recommended in order to further validate our outcomes.

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APPENDIX A
Assessment rubric: Individual Reflection

Criteria	Pass			Insufficient
	Excellent	Satisfactory	Sufficient	
INDIVIDUAL DEVELOPMENT	Reflects **extensively** upon their educational and professional growth. Provides **specific** examples and **fully** reflects upon the BuddyCheck matrix related to individual development and programme components (Skills Labs, Thematic Lectures, Virtual Teams group work), so **no** additional clarification is needed.	Reflects **adequately** upon their educational and proffesional growth. Provides **some** examples and reflects upon the BuddyCheck matrix related to individual development and programme components (Skills Labs, Thematic Lectures, Virtual Teams group work), so **some** additional clarification is needed.	Reflects **sufficiently** upon their educational and professional growth. Provides **few** examples and briefly reflects upon the BuddyCheck matrix related to individual development and programme components (Skills Labs, Thematic Lectures, Virtual Teams group work), so **substantial** additional clarification is needed.	**Absent** or **very limited** reflection upon their educational and professional growth
	Reflect **extensively** upon development of skills/competencies related to their individual learning goal that they set prior to the programme. Provides **specific** examples, so **no** additional clarification is needed.	Reflects **adequately** upon development of skills related to their individual learning goal that they set prior to the programme. Provides **some** examples, so **some** additional clarification is needed.	Reflect **sufficiently** upon development of skills related to their individual learning goal that they set prior to the programme. Provides **few** examples, so **substantial** additional clarification is needed.	**Absent** or **very limited** reflection upon upon development of skills related to their individual learning goal.
INDIVIDUAL ROLE	Reflects **extensively** upon their role in the team. Provides **specific** examples that support their reflections.	Reflects **adequately** upon their role in the team. Provides **some** examples that support their reflections.	Reflects **sufficiently** upon their role in the team. Provides **few** examples that support their reflections.	**Absent** or **very limited** reflection on their role.
	Reflects **extensively** upon their contribution to the problem solving process. Provides **specific** examples that support their contribution.	Reflects **adequately** upon their contribution to the problem solving process. Provides **some** examples that support their contribution.	Reflects **sufficiently** upon their contribution to the problem solving process. Provides **few** examples that support their contribution.	**Absent** or **very limited** reflection upon their contribution to the problem solving process.
INDIVIDUAL EFFORT	Reflects **extensively** upon their effort to develop new skills and obtain new competencies in the programme. Provides **specific** examples and **fully** reflects upon the BuddyCheck matrix related to individual effort and programme components (Skills Labs, Thematic Lectures, Virtual Teams group work), so **no** additional clarification is needed.	Reflects **adequately** upon their effort to develop new skills and obtain new competencies in the programme. Provides **some** examples and reflects upon the BuddyCheck matrix related to individual effort and programme components (Skills Labs, Thematic Lectures, Virtual Teams group work), so **some** additional clarification is needed.	Reflects **sufficiently** upon their effort to develop new skills and obtain new competencies in the programme. Provides **few** examples and **briefly** reflects upon the BuddyCheck matrix related to individual effort and programme components (Skills Labs, Thematic Lectures, Virtual Teams group work), so **substantial** additional clarification is needed.	**Absent** or **very limited** reflection on their effort.
REPORT/VIDEO LENGHT	Written report: The report lenght is **within** the given word count (600-650 words, excluding references) Video/animation: The video/animation is **within** the given time count (5-10 minutes)	Written report: The report lenght **slightly violates** the given word count (by <75 words, excluding references) Video/animation: The video/animation lenght **slightly violates** the given time (by <2 minutes)	Written report: The report lenght **violates** the given word counts (by >75 but <150 words, excluding references) Video/animation: The video/animation lenght **violates** the given time (by >2 but <5 minutes)	Written report: The report lenght is **largely outside** the given word count (by >150 words, excluding references) Video/animation: The video/animation lenght is **largely outside** the given time (by <5 minutes)

THE EXPERIENCES OF STUDENTS TRANSITIONING BACK TO IN-PERSON LEARNING POST-COVID-19

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ABSTRACT

This paper reports on a preliminary study that was carried out to understand the experiences of engineering students transitioning to on-campus learning following the Covid-19 pandemic. Two cohorts were considered: year 1 students joining the university for the first time after having experienced considerable disruption for the final two years of their schooling and year 2 students who experienced their first year at university almost entirely online. Data was gathered from student surveys which found that the greatest areas of difficulty for students were the academic level of the programme and the workload. A limited comparison was drawn between this finding and some pre-pandemic data which suggests that the difficulty that students had in this area was higher than for students before the pandemic, indicating that two years of disrupted education may have had a negative impact on students' preparedness for higher education. Qualitative open-ended responses by students showed that there was a clear preference for face-to-face teaching, but that students see clear benefits to online resources and lecture recordings, and value having some flexibility in how they learn. Some reduction in student performance was noted.

1 INTRODUCTION

1.1 Background

The onset of the Covid-19 pandemic forced educational establishments across the globe to switch to online and blended modes of delivery, and the impacts of this have been widely reported on. For higher education institutions this has posed a myriad of issues, not only at the time of the emergency responses and rapid online shift, but it is likely that the effects of the pandemic will be felt for many years to come. One of

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the main areas of concern is how to support students on an ongoing basis who have experienced large gaps in their educational experience or who have struggled with transitioning between online and in-person learning.

1.2 School closures and their impact on incoming university students

It has been estimated that 168 million students under the age of 18 in primary and secondary education missed in-person schooling for almost a full year by February 2021 due to the Covid-19 pandemic [1]. The issues faced by school pupils and students during this time are well documented, with many adverse consequences of school closures being identified from lost learning to increasing social disparities and serious welfare issues for vulnerable groups. For school-age children it has been reported that daily learning time was more than halved on average during online delivery, with low-achieving children undertaking even less than this, and receiving less parental engagement with learning activities thus widening the gap between high and low-achieving students [2]. Correlations have been drawn between lower educational level of parents and lower attainment of pupils during this time [3]. School age young people have also been reported to be at higher risk of mental health issues as a result of the pandemic, particularly those who were already more vulnerable, those who were approaching key examinations following the lockdowns, and those who had parents who were keyworkers [4].

Concerns have also been raised about lowering of academic standards due to difficulties in properly assessing students. For example, in the UK, those completing their final year of schooling were awarded calculated A-level grades in both 2020 and 2021 rather than sitting formal examinations, in a process fraught with much difficulty and dispute. Initial studies have reported reduced validity of these calculated grades compared to actual grades, and this is likely to cause difficulties for students when progressing into university, and pose issues for higher education institutes, as they may not accurately reflect student ability [5]. Francis et al highlight a variety of issues for incoming students and their new institutions, including variation due to different educational experiences, lack of experience with examinations and formal assessment, and knowledge and practical skills gaps [6]. This presents specific challenges for engineering subjects which require a combination of theoretical knowledge and practical skills.

1.3 Effects of university closures on existing students

Within higher education in the UK and many other countries, almost all university in-person teaching was halted in favour of online modes of delivery. Within the authors' institution, less than 6 weeks of on-campus teaching took place between the end of March 2020 and September 2021. For those students already at university during the campus closures, problems caused by the switch to online learning were widespread. From an educational perspective these included difficulties accessing appropriate technology and reliable internet connections [7], reduced engagement with course content, limited opportunities to engage with teaching staff, and significant shifts in assessment procedures and practices. From a wellbeing and social point of view, students have reported difficulties in establishing and maintaining social networks and increased mental health issues [8].

1.4 Positive aspects of the online learning experience

Despite the challenges of the online switch, a number of aspects that students find beneficial for learning have emerged. Among these the flexibility afforded by online resources to allow students to access material at a time and place that suits them [9]. This may be particularly beneficial for students with additional learning needs, or who have commitments outside of university such as caring responsibilities. Students have expressed an appreciation for being able to review material, in particular recorded lectures, as this helps with the learning process and is an excellent revision tool. Students have reported increases in self regulation as a result of learning online, and more control over their own time. They have also reported satisfaction with having materials available in advance to allow them to prepare before attending live classes, either online or in-person.[10]

1.5 Rationale

The aim of this study is to evaluate if the prolonged disruption to learning due to the pandemic has had a negative influence on the experience and preparedness of undergraduate students starting on-campus learning in the school of Mechanical and Aerospace Engineering (SMAE) at Queen’s University Belfast. Comparison will be drawn between the experiences of students joining year 1 after over a year of disruption to their schooling, with students joining year 2 after a year of online university teaching. Some limited comparisons will also be drawn with previous data gathered from students transitioning directly into year 2 prior to the pandemic, and outcomes compared with pre-pandemic data.

2 METHODOLOGY

2.1 Selected Cohorts

Analysis was limited to year 1 and 2 undergraduate students in SMAE for several reasons. Firstly, the year 1 students entering in the 2021-22 academic year were the first cohort of students to commence their university studies on a fully on-campus basis since the Covid-19 pandemic. It was of interest to assess whether the disruption to their secondary school education over the previous two years had a discernible impact on their experience, and on the ease with which they transitioned into university. The year 2 students were selected as they had completed most of their first year online, and had virtually no on-campus experience prior to 2021-22.

2.2 Learning environment

The students in this study returned to full on-campus teaching in September 2021. Classes were held in the same manner as they had been pre-Covid, but with additional safety measures in place, such as a requirement of students to wear masks, and a 2m exclusion zone between staff and students, to allow staff to remove masks for teaching. In addition to the traditional lectures and tutorials, a number of the beneficial aspects of online learning that had been identified during the pandemic were retained, such as providing recordings of the live lectures and providing digital resources on the virtual learning platform (VLE) well in advance of live classes.

2.3 Survey

A survey was sent to the students around one month after the first semester started, asking them to rank the difficulty of the following areas on a 5 -point Likert scale:

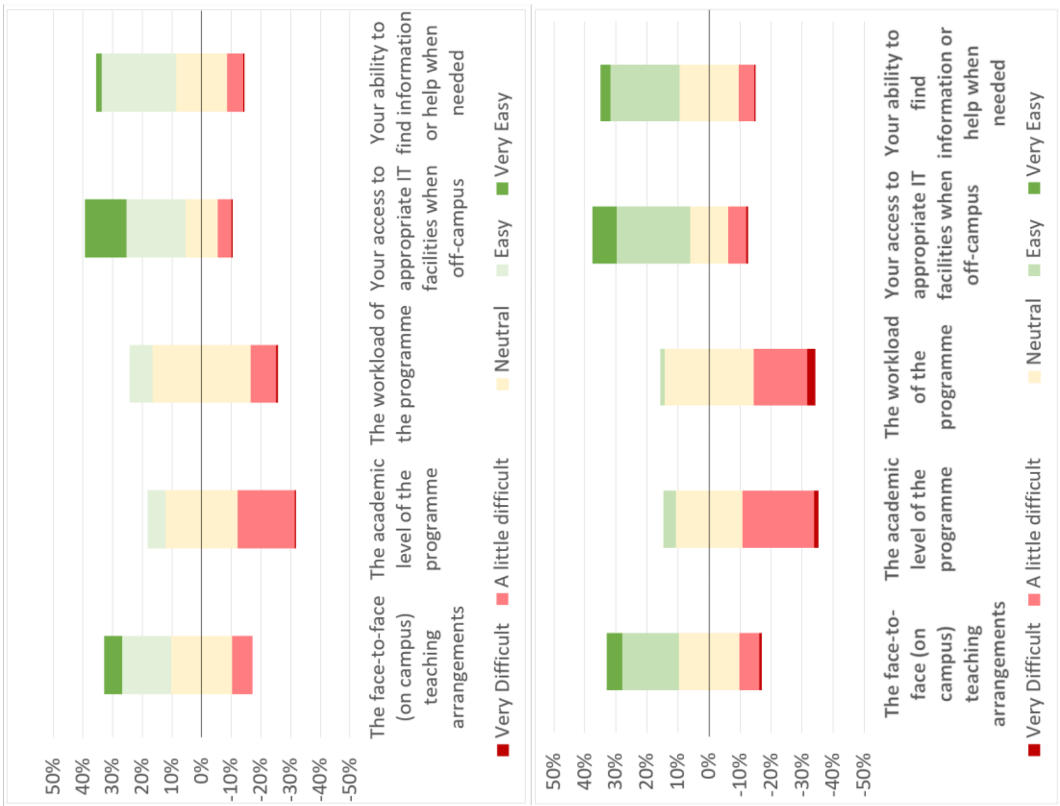
1. The face-to-face (on campus) teaching arrangements
2. The academic level of the programme
3. The workload of the programme
4. The accessibility of appropriate IT facilities when off-campus
5. The ease of finding information and help when needed

A further section of the survey consisted of a number of freeform comment boxes to allow further detail on the five areas above, or any other comments, to be provided.

3 RESULTS

3.1 Survey data

The survey received 109 responses from year 1 students (62%) and 110 responses from year 2 students (64%). Responses to the Likert scale questions on the perceived difficulty of various areas are presented in figure 1 as a percentage of students choosing each option from “very easy” to “very difficult”.



(a) Year 1 Students (b) Year 2 students

Fig 1: Responses to question “How challenging were the following issues?”

Responses were also weighted from (1-5), from “very easy” to “very difficult” and these are presented as mean scores in table 1, along with the median and mode responses for each question. A T-test was also carried out to determine if the responses from the year 1 and year 2 students were significantly different.

It can be seen that students found the academic level and the workload of the programme the most difficult aspects, and this was true for both year 1 and year 2 students, although year 2 students found these more challenging than year 1. This could be simply a reflection of the higher academic level in year 2. No significant differences were seen between the two groups on any of the other questions.

Table 1: Weighted scores from survey responses

	Weighted means - level of difficulty from 1-5 (from very easy to very difficult) [median] {mode}		**Significantly different? P Value**
	year 1	year 2	
The face-to-face (on campus) teaching arrangements	2.57 [3] {3}	2.60 [3] {3}	no p=0.706
The academic level of the programme	3.28 [3] {3}	3.44 [3] {4}	yes p=0.038
The workload of the programme	3.04 [3] {3}	3.43 [3] {3}	yes P<<0.001
Your access to appropriate IT facilities when off-campus	2.15 [2] {2}	2.35 [2] {2}	no p=0.101
Your ability to find information or help when needed	2.55 [2] {2}	2.55 [3] {2}	no p=0.932

3.2 Comparision with pre-pandemic data

It was desirable to determine whether the issues that the students reported with academic level and workload were unique to these post-pandemic cohorts. The only somewhat comparable data that exists from pre-Covid was a survey carried out on two groups of students who entered the same degree programmes at year 2 from two different foundation programmes [11]. One of the groups consisted of international students, mainly from China, and the other cohort was a group of students mainly from the Northern Ireland region, where the university is located. These students had been asked if they felt prepared for the academic level of the programmme, and ranked from “strongly disagree” to “strongly agree”. The responses have been weighted with the same weighting system used in this study, where 5 is “strongly disagree” and 1 is “strongly agree” and presented in table 2.

It can be seen that the students entering the university in 2021 showed clearly more negative responses than those entering pre-Covid. Caution should be drawn in making definite comparisons between these two as the questions were not asked in exactly the same way under the same context, but may give some indication that the disruption to learning over the course of the pandemic has had a negative influence on student preparedness for university level study.

Table 2: Comparison of perception of level of difficulty pre- and post-Covid

	Weighted means - level of difficulty from 1-5 (from very easy to very difficult) [median] {mode}			
	2021 year 1	2021 year 2	Pre-Covid International students	Pre-Covid "local" students
The academic level of the programme	3.28 [3] {3}	3.44 [3] {4}	2.42 [2] {2,3}	2 [2] {2}

3.3 Student comments

Open-ended responses were collated for each of the five areas surveyed. When asked for comments on the mode of delivery, a clear majority expressed preference for face-to-face teaching, with 42 different comments explicitly expressing this opinion and 21 generally positive comments about the current on-campus arrangements out of a total of 104 comments on the teaching arrangements (table 3). Among the year 2 students there were two students who stated they had preferred the online teaching the previous year, and six students who expressed a wish for more options where they could choose to attend online or in-person flexibly.

Both sets of students expressed some difficulty in following face-to-face lectures, however, several students stated that they found online resources very helpful, including the lecture recordings (table 4).

Students appeared to be comfortable in the learning environment, and would have preferred less Covid-19 restrictions rather than more. Several year 1 students found the requirement to socially distance from the lecturers to be difficult, while only 4 students expressed any safety concerns about being on campus (table 5).

Table 3: Selected comments on face-to-face teaching, online learning and flexible delivery

Year 1 students	"*Much better than my previous two years of online teaching.*" *"It's really good and helpful that we are able to attend in-person lectures and classes with the Covid pandemic currently."*
Year 2 students	*"I am enjoying the face to face arrangements and much prefer it to the online content last year"* *"I find it very helpful to learn from and help my peers as we learn together instead of isolated."* *"I am happy to attend face to face teaching when necessary. It is nice having the option to work from home"* *"I think I prefer a mix of face-to-face teaching and online classes to have a little variety."*

Table 4: Selected comments on note taking and online resources

Year 1 students	*"I am struggling to make the appropriate notes from the board whist listening to my lecturers."* *"The backup of the recordings and live stream is very useful"*
Year 2 students	*"Finding it hard to follow FTF lectures after using pre-recorded video lectures for a whole year."* *"I think the recorded lectures are a helpful resource"*

Table 5: Selected comments Covid-19 restrictions

Year 1 students	*"I find this difficult as students aren't able to be shown how to do something because of the restrictions."* *"Sometimes it's a bit difficult in modules like engineering design when the lecturers can't come up to us to help because they must socially distance."*
Year 2 students	"*Due to the situation of Covid, the face-to-face teaching is still a bit dangerous"*

3.4 Overview of outcomes

At the time of writing, end of year results have just become available. Initial impressions from teaching staff were that student performance through the year on coursework and continuous assessment was comparable to previous years, but that exam performance was much poorer. This view may have been influenced by the fact that performance during the last two years, where a significant amount of assessment was online and open-book, was higher than normal. An initial comparison has been drawn up comparing the averages and failure rates in 2018-19 (pre-Covid) and this year (2021-22), across three engineering science year 1 modules (MEE1001, MEE1004 and MEE1008), and two year two modules (MEE2001 and MEE2007). These modules were chosen as they have have similar assessment types and weightings (40% coursework and 60% exam), and have not had significant changes between the two years.

Table 6: Overview of student outcomes in selected year 1 and 2 modules

	2018-19				**2021-22**			
Module	Overall average	No. of fails (1st attempt)	No. of students	% Fail	Overall Average	No. of fails (1st attempt)	No. of students	% Fail
MEE1001	63%	22	160	13.8%	60%	33	168	19.6%
MEE1004	56%	19	160	11.9%	49%	36	168	21.4%
MEE1008	60%	11	158	7.0%	55%	18	169	10.7%
Year 1 averages	**60%**			**10.9%**	**55%**			**17.2%**
MEE2001	52%	27	145	18.6%	52%	18	111	16.2%
MEE2007	51%	24	134	17.9%	48%	21	97	21.6%
Year 2 averages	**52%**			**18.3%**	**50%**			**18.9%**

The results (table 6) indicate that for year 1, there has been a notable drop in averages for the modules in 2021/22 compared to 2018/19, and a clear increase in the percentage of students failing the modules on their first attempt. This would agree with the high perceived difficulty that the students reported, and indicate that students joining university directly from school in 2021/22 were not as well prepared for university as students joining pre-pandemic. For year 2, there was a modest drop in module average and increase in failure rate for one of the modules, but not for the other, which had the same average and a decrease in failure rate compared to 2018/19. This would suggest that while the second year students perceived the difficulty level to be higher than year 1 students at the beginning of the year, this may simply be due to the higher academic level in year 2, and that a previous year of online university study may still have prepared them adequately for in-person learning in year 2. This data compares only two years, and does not give a full picture at module or programme level and more in-depth analysis will be completed in due course.

4 SUMMARY AND ACKNOWLEDGMENTS

A survey of students returning to in-person learning after the pandemic has shown that both year 1 and year 2 students expressed difficulty in dealing with the academic level of the programme and the workload, and this was seen to a greater extent in the year 2 students. The level of difficulty experienced by students appears to be more pronounced than for students who joined the programme as direct entry into year 2 before the pandemic based on some limited historical data that is available. Comments made by students show a clear preference for face-to-face learning over online learning, however students see great benefits in supplementary online resources and in retaining innovations that were introduced during the pandemic such as the provision of lecture recordings as standard, and use of advanced features in the VLE. This correlates well with student feedback during online learning which expressed clear satisfaction with asynchronous elements including lecture videos, and other content on the VLE. Students appear to appreciate the opportunity to access content at a time and a pace that suits them, and to be able to revise content with the full lectures available to watch and review as many times as needed. It is hoped that the availability of this additional content will support the students as they develop their skills in independent study, providing additional opportunities for note-taking and revision as they become accustomed to the lecture environment. Initial data on student outcomes indicates some drop in performance, with notable increases in the percentage of students failing modules on their first attempt. The next steps in this study will be to assess attendance data, engagement with online resources and student outcomes in detail, and to determine if the indications of an increase in perceived difficulty level has had a significant effect. It will be important to continue to monitor the experiences and performance of these groups of students, and to design appropriate interventions where necessary to ensure that they are not disadvantaged by the disruption to their education in the long term.

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EXPLORING ENGINEERING STUDENTS' ENGAGEMENT WITH PROOF WITHOUT WORDS: THE CASE OF CALCULUS

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ABSTRACT

Previous studies have reported that many engineering students struggle to develop a conceptual understanding of mathematics in university calculus courses. Engaging with mathematical proofs is one of the approaches to developing a conceptual understanding of mathematics; however, it is not always easy to use standard proofs for this purpose. In the present study, we focus on a type of mathematical proof known as Proof Without Words (PWW). A PWW typically consists of pictures or diagrams that help readers understand why a mathematical statement is true without

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providing verbal justifications. This study investigates how engineering students engage with PWW tasks related to calculus and also how they perceive its usefulness for teaching and learning calculus. Twenty undergraduate engineering students participated in semi-structured group interviews (in groups of two students), engaging with three PWW tasks related to calculus. Afterwards, students' perceptions of PWW tasks were explored using several open-ended questions. The findings indicate that many students engaged well with this type of activity. Furthermore, all students perceived that PWW tasks could positively impact their mathematical understanding, and many believed they could be used for teaching and learning calculus. Furthermore, several students highlighted that PWWs could also help with comprehending standards proofs and make mathematics learning more enjoyable.

1 INTRODUCTION

Engaging students with mathematical proofs could help students develop a conceptual understanding of mathematics [1]. However, past research has shown that students often have difficulties with constructing and comprehending formal proofs [2]. Therefore, mathematics educators focus on ways to improve the teaching and learning of mathematical proofs [2-3]. On the other hand, improving engineering students' conceptual understanding of mathematics has been the focus of several studies, and previous studies have reported that many engineering students struggle to develop a conceptual understanding of mathematics in calculus courses [4]. In this study, we focus on exploring how a proof type, proof without words, could be used to improve the teaching and learning of calculus to engineering students.

2 PROOF WITHOUT WORDS

There are different classifications for mathematical proofs. For example, Sigler et al. [5] have classified mathematical proofs into *standard proof*, *elegant proof*, and *proof without words (PWW)*. The focus of this paper, PWW, could be defined as "pictures or diagrams that help the reader see why a particular mathematical statement may be true, and also see how one might begin to go about proving it true" [6, p. 118]. Mathematics educators have provided several reasons why PWWs could be used in teaching and learning mathematics. For example, Bell [7] highlighted that using PWWs could help students understand the proof process, develop reasoning skills, and learn how to begin to construct a formal mathematical proof. PWWs could be a supplement for formal proofs and help students understand why a mathematical theorem is true in a more interesting way than some of the formal proofs [6]. Nelsen [8] highlighted this by quoting Martin Garnder, a famous mathematician, at the beginning of his third collection of PWWs: "A dull proof can be supplemented by a geometric analogue so simple and beautiful that the truth of a theorem is almost seen at a glance" (p. vii). More recently, Kristiyajati & Wijaya [9] pointed out that many mathematics teachers also perceived that PWW tasks are interesting activities for students to engage with.

PWW tasks could be used in mathematics classrooms to develop visual thinking in all levels of schooling, from primary to tertiary levels [6]. Many PWWs have been constructed to prove theorems in different mathematical domains such as geometry, algebra, inequalities, and calculus (see, for example, [8]). The majority of previous research that explored the teaching and learning of PWW focused on school mathematics (e.g., [10]). Only a very few studies (e.g., [11]) have explored university students' understanding of PWW tasks and how PWW tasks could be used at the tertiary level. Our literature search indicates that such studies have not been conducted within the context of teaching and learning calculus, particularly for engineering students. Therefore, the present study explores how engineering students engage with PWW tasks and how they perceive its usefulness for teaching and learning calculus to explore the possibility of using such tasks in teaching and learning calculus to engineering students. We considered the following research questions to address this matter:

RQ1: *How do engineering students engage with calculus-related PWW tasks?*

RQ2: *How do engineering students perceive engagement with calculus-related PWW tasks?*

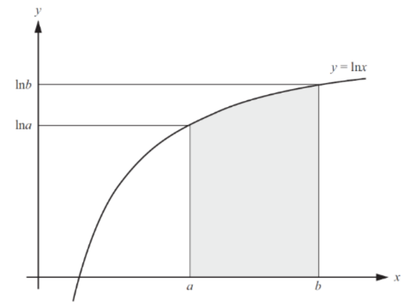
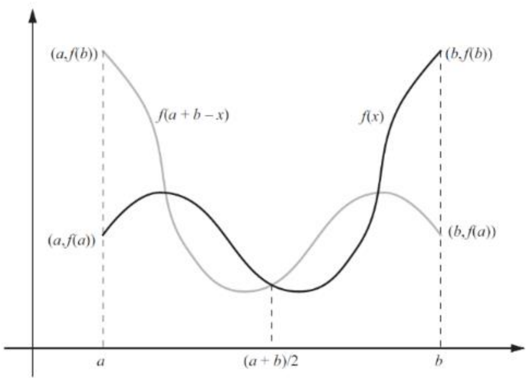
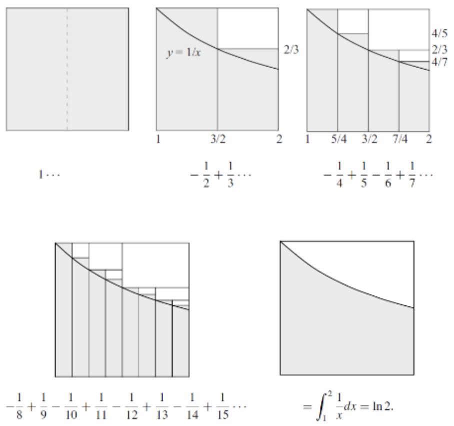
3 METHODOLOGY

In this qualitative study, we take a phenomenological approach where we describe "the lived experiences of individuals about a phenomenon as described by participants" ([12], p.14). The participants were 20 undergraduate engineering students from a major university in eastern Iran who participated in semi-structured group interviews in groups of two. Based on their calculus grades, the students are labelled as S1 to S20 from high to low performance to help readers identify any possible association between students' perception of PWW tasks and their achievement in response to RQ2. The interviews were conducted in Adobe Connect because of Covid 19 pandemic, and they were video recorded and transcribed. Students first engaged with three PWW tasks related to calculus, and then their perceptions of PWW tasks were explored individually using four open-ended questions (e.g., what are your opinions about using PWW tasks for teaching calculus?). The PWW tasks were adapted from Nelson (2015) and were related to (a) the integral area relationships in the context of the natural logarithm, (b) an integral transform, and (c) the relationship between harmonic series and integral. Each task has three parts, and students were given each part separately. In part A, students were asked to respond to the following question: *What mathematical concepts or procedures do you think the figure refers to?* In part B, they were asked to prove the given formula or equalities using the given figure(s). In part C, students were asked to prove the formula/equalities formally. These figures and formula/equalities are provided in Table 1. A correct solution to the tasks was discussed with students before they responded to the four opened-ended questions.

4 RESULTS

We first describe how engineering students engaged with the three PWW tasks in response to RQ1. Then, we discuss students' perceptions of PWW tasks to respond to RQ2.

Table 1. The figures and formulas/equalities in the three PWW tasks

Figure	Formula/equalities
	$\int_a^b ln(x)\,dx$ $= b\ lnb - a\ lna - \int_{ln\,a}^{ln\,b} e^y\,dy$ $= x\ lnx\|_a^b - (b-a) = (\ x\ lnx - x\ )\|_a^b$
	$\int_a^b f(x)\,dx$ $= \int_a^b f(a+b-x)\,dx$ $= \int_a^{\frac{a+b}{2}} [f(a+b-x)+f(x)]dx$ $= \int_{\frac{a+b}{2}}^b [f(a+b-x)+f(x)]dx$
	$\sum_{n=0}^{\infty}(-1)^n \frac{1}{n+1} = ln\ 2$

4.1 Students' engagement with the PWW tasks

Overall, students engaged relatively well with the first two tasks. In response to Task 1, Part A, 90% of groups referred to the concept of integral and mentioned that the shaded area is $\int_a^b \ln x dx$ when the figure was presented to them. For Task 2, Part A, similarly, 90% of groups referred to the concept of integral when the figure was presented to them. These groups also identified that $\int_a^b f(x)\,dx = \int_a^b f(a+b-x)\,dx$. Furthermore, 80% of groups stated that $f(x)$ and $f(a+b-x)$ are symmetric with respect to the line $x = \frac{a+b}{2}$. Regarding Task 3, Part A, all groups mentioned that the figure is related to the concept of integral and series. Moreover, 80% of groups referred also to the integral-area relationship and how a series could be used to calculate the area of rectangles. Thirty percent referred explicitly to the concept of Riemann integral. One group (10%) was also able to construct $\sum_{n=0}^{\infty} (-1)^n \frac{1}{n+1}$ based on the given series under the figures.

The overall success rate of groups for Parts B and C are summarised in Table 2. The findings indicate that many groups were able to prove the formulas using the given figures for Tasks 1 and 2. However, Task 3 was more challenging for students, and even with the interviewer's help, only 60% were able to prove the formula using the figures successfully. Furthermore, the success rate for formally proving the formulas in Part C of Tasks 2 and 3 was much lower compared to Part B. The provided help for Task 1, Part B was that $blnb$ is the area of the largest rectangle in the Figure and in Part C was what could be considered as U and dv in the integration by parts. Regarding Task 2, Part B, the interviewer help some groups to amend their drawing for $f(a+b-x)+f(x)$ in $[a,b]$. For Part C, the provided help was related to students' calculations; some students made a mistake when using the integration by substitution. They incorrectly calculated $dx = dt$ when they considered $a+b-x=t$, and the interviewer told them their mistake. Regarding Part B of Task 3, students realised that the given series under the figures are related to shaded areas; however, they struggled with justifying how the shaded area is exactly calculated with the given series. The interviewer helped them with that. Finally, for Part C, the help was that they could use geometric series to formally prove the given formula.

Table 2. *The overall success rate of groups for Parts B and C across the three PWW tasks*

	Part B			Part C		
	Without help	With the help of the interviewer	Total success rate	Without help	With the help of the interviewer	Total success rate
Task 1	7 (70%)	2 (20%)	9 (90%)	8 (80%)	1 (10%)	9 (90%)
Task 2	5 (50%)	5 (50%)	10 (100%)	2 (20%)	3 (30%)	5 (50%)
Task 3	0 (0%)	6 (60%)	6 (60%)	0 (0%)	3 (30%)	3 (30%)

4.2 Students' perceptions of PWW tasks

All students agreed that PWW tasks could help them with learning calculus. They also pointed out several benefits of using PWW tasks for learning calculus, such as helping comprehend mathematical proofs and learn mathematical concepts (Table

3). Some students also enjoyed engaging with PWW tasks, and a few found it helpful for keeping mathematical concepts longer in mind.

Table 3. The benefits of using proof without words

Themes	N	%	Sample responses
Helping students comprehend mathematical proofs	17 (S1-12, 15-19)	85	"PWWs are more interesting and attract students' attention more than standard proofs. They are presented with figures, whereas standards proofs have only a few symbols or parameters. One can understand the processes in the proof by looking at the figure; they are more understandable than standard proofs" (S4)
Helping students to prove standard proofs	12 (S1-4, 6, 7, 9, 10, 13, 15, 17, 18)	60	"When learning a standard proof, if we have seen a PWW of it, the figure helps us identify its relationship with the standard proof, and consequently a better understanding of the standard proof." (S9)
Improving students' attitudes towards mathematical proofs	12 (S1, 5, 6-10, 12, 14, 16, 19, 20)	60	"In general, PWWs are more interesting to follow, and therefore, it helps us to have a more positive attitude towards mathematical proofs." (S5)
Helping students to learn mathematical concepts	10 (S3, 5-7, 10, 11, 13, 16, 17, 19)	50	"In fact, it makes learning the main concepts easier for us. If we encounter an integral formula without a visual illustration, we would have to memorise formulas and not understand their applications. But in PWWs, using figures makes learning better." (S11)
Enjoyable activity for students	9 (S2, 4, 5, 9, 12, 14, 15, 17, 20)	45	"PWWs... are fun for me, and I enjoy engaging with them..." (S14)
Helping mathematical concepts last longer in students' minds.	4 (S1, 7, 12, 20)	20	"When I come across this series later, its figure will appear in front of my eyes and will last in my mind longer..." (S1)
More accessible to students that standards proofs and less likely that students make mistakes when engaging with them	2 (S9, 19)	10	"We are not experts in proving mathematical theorems; we may not notice if something goes wrong in standard proofs; however, we have figures in PWWs to help us check our work." (S19)

A few challenges of engaging with PWW tasks were also reported, such as some students perceived that comprehending PWWs could be challenging for learning advanced mathematical concepts such as those found in multivariable calculus (Table 4).

Table 4. *The challenges of using proof without words*

Themes	N	%	Sample responses
Comprehending PWWs could be challenging and require strong visual thinking	7 (S4, 5, 9, 12, 14, 15, 20)	35	"In some mathematical topics, it is easier to use standards proofs because if we want to prove using a figure, we need a multi-dimensional figure and paying attention to details requires good visual thinking skills..." (S15)
Analysing the information provided in PWWs could be challenging	3 (S1, 4, 20)	15	"Information in figures of PWWs could be difficult to analyse, and we might make a mistake when analysing them. For example, surfaces have three variables in multivariable calculus and mostly have complex relationships. If we have not mastered them, we might mistake in distinguishing surfaces in the figures." (S1)
Comprehending PWWs is time-consuming	2 (S12, 14)	10	"The teaching time in university courses is short, and the volume of content to teach is high while PWW requires a lot of time to comprehend." (S14)

5 DISCUSSION AND CONCLUSIONS

Helping students develop a conceptual understanding of calculus concepts is one of the main goals of engineering calculus courses [4]. In this study, we explored to what extent PWW tasks could be used to achieve this goal as previous studies reported that engaging with PWW tasks could be interesting for students and could contribute to improving students' mathematical learning in different ways [6-10]. This study also contributes to the existing literature in mathematics education regarding the affordances and constraints of using PWW tasks in teaching and learning of mathematics at the tertiary level, including for engineering students, as most studies related to using PWW tasks were conducted in the school context (e.g., [7, 9-10]).

The findings suggest that all engineering students perceived that engaging with PWW tasks is useful for learning calculus. The reasons they provided for such perceptions are in line with what is highlighted in the literature about the benefits of using PWW tasks. For instance, students perceived that engaging with PWW tasks could help them to have a better understanding of mathematical proofs and how to construct standard proofs. Similarly, Bell [7] highlighted using PWWs in teaching mathematics "can help students improve their ability to reason when asked to explain an illustration, and this heightened reasoning can lead to understanding how to begin a formal proof." (p. 690). Furthermore, many students enjoyed engaging with PWW tasks, as pointed out in [9]. In terms of their engagement with the PWW tasks, students performed relatively well on the first two tasks; however, they faced more challenges when engaging with the third task as they needed to associate their knowledge of integral with their knowledge of series. In line with the previous studies regarding comprehending and constructing proofs [2], several students faced difficulties constructing standards proofs and were more successful in the PWW tasks. Overall, the study findings suggest that PWW tasks could be used in teaching calculus courses to engineering students to provide more opportunities for students to develop a conceptual understanding of mathematics and contribute to making calculus courses more interesting to engineering students.

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PROMOTING ENGINEERING STUDENTS' LEARNING WITH MATHEMATICAL MODELLING PROJECTS

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ABSTRACT

Mathematics constitutes a key component in engineering education. Engineering students are traditionally offered a number of mathematics courses which provide the knowledge needed at the workplace. Unfortunately, many students perceive mathematics as a discipline that teaches mostly procedures not relevant to their

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future careers and often view it as one of the main obstacles on their way to an engineering degree. In this paper, we discuss how introducing university students in a standard Differential Equations course to mathematical modelling (MM), a powerful strategy for solving real-life problems, contributes to the development of their mathematical competencies, motivates their interest to mathematics, promotes the use of advanced mathematical thinking, methods of applied mathematics, and digital computational tools.

1 INTRODUCTION

1.1 Mathematics in engineering education

Mathematics is an integral part of engineering education; it helps to establish connections between different physical quantities and furnishes powerful tools to model the behaviour of complex engineering and industrial systems. Methods of applied mathematics are efficiently used to develop new technologies and simulate various real-world phenomena. Analysis of mathematical models reduces the costs for setting experiments '*in vivo*', allows us to evaluate different scenarios, explore feasibility of solutions, and make comprehensive decisions.

The increasing computational difficulty of the engineering tasks and wider implementation of technology in teaching and learning inevitably lead to a more extensive use of computer algebra systems (CAS) in mathematics courses for engineering students. Kent and Noss argued that “advances in the use of information technology and computers have transformed engineering analytical techniques, and production and management processes” [3, p. 4]. Nowadays, students are expected to combine the power of theoretical knowledge with that of modern digital technologies, and the efficient use of both requires advanced mathematical thinking. Not all engineering students are prepared to meet high demands set in mathematics courses and often view them as an obstacle - “some see mathematics as the gateway to engineering, paving the way to sound design; others see mathematics as a gatekeeper, denying entry to otherwise talented would-be engineers” [13, p. 305].

Faulkner et al. [2] emphasised that engineering faculty want students to acquire “mathematical maturity” rather than calculus skills as the learning outcome from mathematics courses. Although “any single construct will provide a complete view of mathematical maturity” [2, p. 100], it is often used by mathematics faculty to describe students “who have achieved a certain combination of technical skills, habits of investigation, persistence, and conceptual understanding” [1]. Faulkner et al. argued that “these engineering faculty believed that the mathematically mature student would have strong mathematical modelling skills supported by the ability to extract meaning from symbols and the ability to use computational tools as needed” [2, p. 97] concluding that a successful mathematics course should be situated on the cross-roads between engineering, mathematics, and programming. The reform of engineering mathematics education requires timely adjustment of course curricula to the changing demands set by the employers. According to Niss and Højgaard, the three main components in the curriculum of a mathematics course are: (a) purpose of the teaching, (b) syllabus, that is, mathematical content, and (c) assessment including instruments to estimate the extent to which the students have learned the mathematical content [5, p. 45].

1.2 Current trends in mathematics education of future engineers

In response to new trends in engineering education, several efforts have been recently made to include modelling tasks and promote the use of CAS in mathematics courses [4, 8-10]. However, time limitations make the use of CAS in the classroom quite demanding, many difficulties also arise with the assessment of students' learning in courses heavily relying on digital tools. Finding a suitable form of assessment in a mathematics course has always been challenging for teachers. The traditional form of assessment in service mathematics courses in engineering departments is a graded written final examination after which the grade for the entire course is assigned. Quite often, restrictions on the time allocated for the exam and associated stress negatively affect students' performance also impacting the assessment results. To avoid this unpleasant situation, efforts have been made to develop different assessment forms, including several forms of embedded assessment and continuous assessment [12].

In order to develop students' mathematical maturity, some changes in teaching practices should be made. Schoenfeld explained that "mathematics is an inherently social activity in which a community of trained practitioners (mathematical scientists) engages in the science of patterns – systematic attempts based on observations, study; and experimentation to determine the nature or principles of regularities in systems defined axiomatically or theoretically ("pure mathematics") or models of systems abstracted from real world objects ("applied mathematics")" [11, p. 335]. Engineering students often think about mathematics as a set of formal rules which should be used to solve a problem and may apply them even without attempting to understand the logic behind the actions taken. The important role of mathematics lecturers is to motivate students to learn how to "do mathematics" and how to "think mathematically", thus enculturating students into the world of advanced mathematical thinking. A social component is especially important in the process of the development of abstract mathematical reasoning. Collaborative work in groups develops students' use of mathematical language, helps to improve both the mathematical argumentation and communication skills. The importance of the project work in engineering education was emphasised in the recent evaluation of engineering degree programs in Norway: "Making the teaching more project-based offers a means of exercising and evaluating the students' communication skills, of participating in interdisciplinary collaboration and demonstrating professional and ethical practices" [7, p. 10].

In this paper, we discuss how mathematical modelling (MM) projects were introduced in a Differential Equations course for graduate students in mechatronics. The first author modified the traditional course curriculum including a small group project work with MM tasks offered in the format of graded course projects counting towards the final grade. Engaging students into solving applied problems relevant for engineering, we connect their knowledge gained in mathematics, physics, and engineering courses. Furthermore, our MM projects promote students' conceptual understanding of differential equations and show how abstract mathematical ideas can be efficiently combined with the possibilities offered by the modern computer algebra systems. The organisation of students' work in small groups introduces essential elements of collaborative learning and enhances students' social skills. Last but not least, the use of graded projects in the assessment distributes students' work more evenly through the semester and reduces the exam stress.

The research question we address in this paper is: *How modelling projects in a mathematics course contribute to the development of engineering students' mathematical maturity and integration of mathematics and engineering?*

2 METHODOLOGY

2.1 Mathematical competency framework

For the data analysis, we use the concept of mathematical competency defined by Niss and Højgaard as "a well-informed readiness to act appropriately in situations involving a certain type of mathematical challenge." [5, p. 49]. An overall mathematical competence is composed of eight competencies which are defined separately but may overlap. These are: (1) thinking mathematically, (2) reasoning mathematically, (3) posing and solving mathematical problems, (4) modelling mathematically, (5) representing mathematical entities, (6) handling mathematical symbols and formalism, (7) communicating in, with, and about mathematics, and (8) making use of aids and tools [5, p.14]. Designing the tasks that contribute to the development of all mathematical competencies at the same time is challenging. However, we argue that project-based MM assignments not only provide an opportunity to improve mathematical competencies of engineering students, but also make the assessment in a mathematics course more efficient.

An important learning outcome of a mathematics course for engineers is the ability to transform a physical or, more generally, an engineering problem into a mathematical problem (mathematisation) and then solve it using appropriate mathematical and computational tools. To achieve this goal in our standard course in Differential Equations, changes to parts of the course introducing theory and methods of solving differential equations were made. These modifications had the following objectives: (i) development of conceptual understanding of differential equations, (ii) meaningful application of differential equations in practical problems, (iii) improvement of students' computational and analytical skills, including the use of programming for solution and simulation in modelling problems, (iv) improvement of students' communication skills and acquaintance with main principles of collaborative work in groups typical for practising engineers, (v) improved, fair, and less stressful assessment of students' work more evenly distributed throughout the semester.

2.2 Teaching experiment and data collection

The teaching experiment was organised in a one-semester course “Mathematics for Mechatronics” for the class of senior students in mechatronics. Three project-oriented assignments, accounting for 30% of the total course grade, were distributed to the students. Each assignment was related to one of the main topics in the course: (a) first order linear differential equations, (b) higher order linear differential equations, and (c) systems of linear differential equations. The class was divided into small groups of 2-3 students, according to their own choice. Students' written reports for each of the projects were collected and graded during the course. The data analysis was conducted after the final grades were assigned to all students in the course.

3 DATA ANALYSIS

3.1 Sample modelling task

In one of the tasks students were asked to conduct a small experiment with a falling chain and observe how the physical parameters affect the result exploring, for example, what is needed for the chain to start moving. For the mathematical analysis of the problem, it is necessary to describe physical forces acting on the chain and analyse the impact of friction by considering the type of the surface.

Modelling task. Lay a uniform chain on a horizontal surface (say, a table) with a part of it hanging down the table. Release it so that it starts moving down. Find the time when it slips off the table.

(a) What conditions and parameters affect the experiment outcome?

(b) Consider cases without and with friction. What are the conditions for the chain to start moving (for both cases)?

(c) Give the explanation of the physical problem and set it in mathematical terms (for both cases).

(d) Set the differential equation describing your model (for both cases).

(e) Solve the problem mathematically (for both cases).

(f) Use Maple/MATLAB to solve the problems numerically, plot and analyse the solution (for both cases).

(g) Validate your model in practice: conduct an experiment and present a small video showing the timer. Do the experimental data correspond to your analytic solution? Which of the two solutions describe your experiment better?

(h) Submit your video as a media file and your report in a PDF format.

3.2 Analysis of students’ solution

Students were asked to experiment with the chains and table surfaces of their own choice. The weight of the chain, its initial position, and the smoothness of the surface had an effect on the time required for the chain to fall off the table. In this paper, we discuss the solution produced by one group of students only. Students illustrated the experiment with Figure 1. They used a necklace to make a chain with the length $L = 0.46\ m$ and the mass $m = 22\ g$.

After several experiments, the students concluded that for the chain to start sliding down the initial length h (see Figure 1) has to be about $0.11\ m$. At this stage, they used the competencies to *pose a problem and ask questions*, and to *describe the relations* between various parameters. The possibility of choosing their own experiment settings allowed students to conduct practical tests prior to designing a mathematical model.

Fig. 1. Group's illustration to a model and snapshots from the experiment video

Next, the students considered the distribution of forces for the frictionless case. They modelled the chain representing it as two masses connected with a massless rope and a frictionless pulley. At this stage, students were engaged in the process of *mathematising*, that is translating a physical problem into a mathematical problem. In the modelling process, one does not need to reinvent a wheel. Usually, if we want to model with differential equations, the motion of bodies is described by Newton's laws, in particular, by the second Newton's law. We emphasise that it is important for the students in advanced mathematics courses to synthesise relevant knowledge from different courses and apply it for solving the problem.

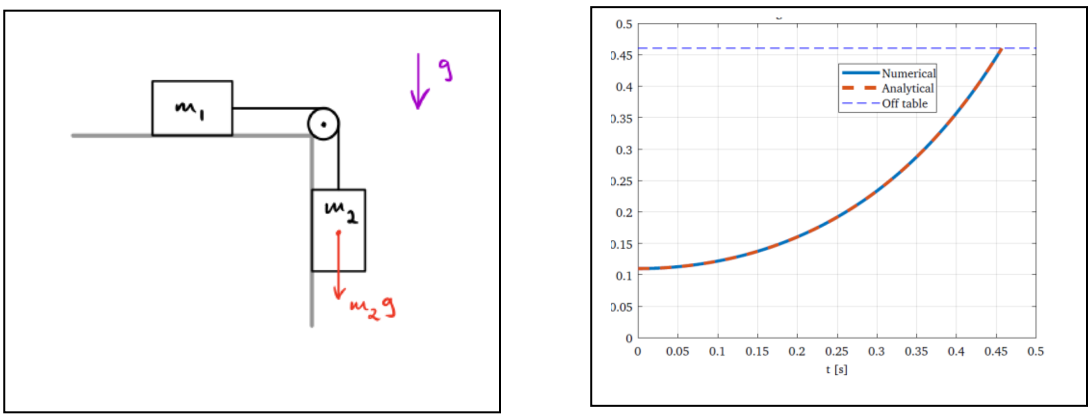


Fig. 2. Illustration of the frictionless model and results of numerical computation

Mathematically the system can be described by the second Newton's law which leads to the differential equation of motion, $m_2\, g = (m_1 + m_2)a$, so the acceleration

$$a = \frac{m_2\, g}{m_1 + m_2}.$$

Using the chain's linear mass density $\frac{m}{L} = \lambda$, we have $m_1 = (L-h)\lambda,\ m_2 = h\lambda$. Then the equation of motion assumes the form

$$a = \ddot{h} = \frac{h\frac{m}{L}g}{(L-h)\frac{m}{L} + h\frac{m}{L}} = \frac{h\frac{m}{L}g}{m} = h\frac{g}{L} \quad \text{or} \quad \ddot{h} - h\frac{g}{L} = 0.$$

The students formulated a mathematical problem by *thinking and reasoning mathematically*, they relied on their previous knowledge in physics for solving the problem. Interestingly, they used the notation "double dot" for the second derivative, as it is used in a physics course, not in mathematics courses. Students identified the differential equation as a second order linear differential equation, and found its general solution in the form

$$h(t) = C_1 e^{\sqrt{\frac{g}{L}}t} + C_2 e^{-\sqrt{\frac{g}{L}}t}.$$

Given that at the initial moment the chain velocity equals zero, the particular solution assumes the form:

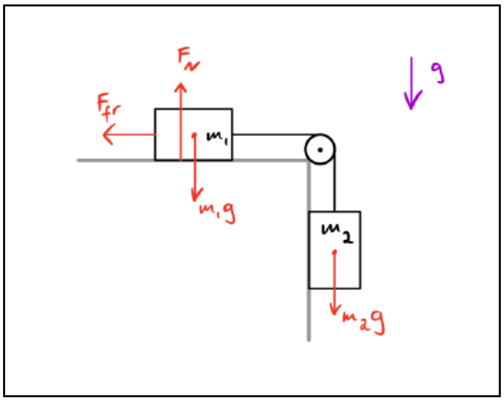
$$h(t) = \frac{h_0}{2} e^{\sqrt{\frac{g}{L}}t} + \frac{h_0}{2} e^{-\sqrt{\frac{g}{L}}t} \quad \text{or} \quad h(t) = h_0 \cosh\left(\sqrt{\frac{g}{L}}\,t\right).$$

In the process of solving the mathematical problem, students demonstrated the *ability to represent mathematical entities* and *handle mathematical symbols and formalism*. Solving the problem numerically, they plotted the graph of the solution with the help of CAS MATLAB demonstrating good skills in using technology.

Finding the time for $h(t) = L$, they obtained $t = \sqrt{\frac{L}{g}}\cosh^{-1}\left(\frac{L}{h_0}\right)$. Using the values of the parameters L, g, h_0, the students concluded that

$$t = \sqrt{\frac{0.46}{9.81}}\cosh^{-1}\left(\frac{0.46}{0.11}\right) \approx 0.457 \text{ sec.}$$

Including additional forces in the diagram, the students discussed the second scenario with the friction. The condition for the chain to start moving should depend on the length of the chain hanging down from the table. Compared to the previous scenario, the start of the motion was only dependent on whether a part of the chain was hanging from the edge of the table or not, regardless of how long it was. The reason for this change in conditions is that now a friction force acts in the direction opposite to that of the chain's motion. The strength of this friction force depends on the mass which is in the contact with the horizontal surface of the table, m_1. As the chain starts moving, m_2 increases, and so does the gravitational force. At the same time, the mass of the chain remaining on the table decreases proportionally and leads to a smaller friction force. This reasoning requires the change in the second Newton's law, $m_2\, g - F_{fr} = (m_1 + m_2)a$.



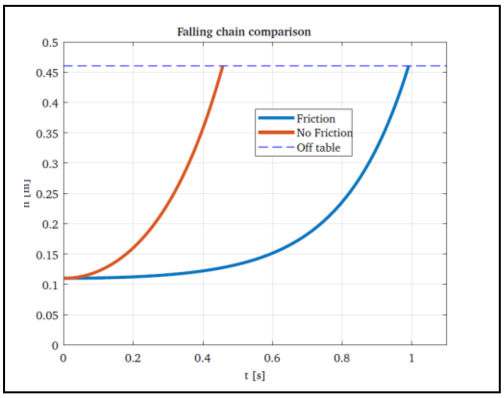


Fig. 3. Illustration of model with friction and results of numerical computation

Then $F_{fr} = \mu F_N$, $F_N = m_1 g$, and $a = \frac{m_2 g - \mu m_1 g}{m_1 + m_2}$. The equation of motion assumes the form

$$a = \ddot{h} = \frac{h\frac{m}{L}g - \mu(L-h)\frac{m}{L}g}{(L-h)\frac{m}{L} + h\frac{m}{L}} = \frac{hg + \mu hg}{L} - \mu g, \quad \text{or} \quad \ddot{h} - h\frac{(\mu+1)g}{L} = -\mu g.$$

Denoting $k_1 = \frac{(\mu+1)g}{L}$, $k_2 = -\mu g$, and solving the equation, students obtained the following solution:

$$h(t) = \frac{1}{2}\left(h_0 + \frac{k_2}{k_1}\right)e^{\sqrt{k_1}t} + \frac{1}{2}\left(h_0 + \frac{k_2}{k_1}\right)e^{-\sqrt{k_1}t} - \frac{k_2}{k_1} = \left(h_0 + \frac{k_2}{k_1}\right)\operatorname{csch}\left(\sqrt{k_1}t\right) \; - \frac{k_2}{k_1}.$$

Substitution of $k_1 = \frac{(\mu+1)g}{L}$ and $k_2 = -\mu g$ yields

$$h(t) = \left(h_0 - \frac{\mu L}{\mu + 1}\right)\cosh\left(\sqrt{\frac{(\mu+1)g}{L}}t\right) + \frac{\mu L}{\mu + 1}.$$

Finding the fall time $t \approx 0.990\ sec$, students compared the two cases in Figure 3.

From the video snapshot in Figure 1, one can see that the fall time in the experiment was 0.925 seconds. After the validation of both models against experimental data, students concluded that the model with friction describes the real system better.

4 DISCUSSION AND CONCLUSIONS

Discussing the role of mathematics in contemporary engineering education, Nethercot and Lloyd-Smith emphasised that it “should be seen as a medium for communicating concepts, ideas, and information in a parallel way to text – and not as the mastery of a series of abstract processes with little or no linkage to physical understanding and application. It should instil disciplined thinking and rigour in the development of arguments based on assumption and simplification in modelling, should teach the importance of controlled approximation, and, above all, impress upon students its value as a tool to be invoked when quantitative evidence is needed to underpin assertion, hypothesis, or sheer physical intuition” [6, p. 14]. We believe that the use of mathematical modelling projects in a standard mathematics course for senior mechatronics students presents mathematics as a medium for communicating ideas and concepts much better.

The research question we asked is *How modelling projects in a mathematics course contribute to the development of engineering students' mathematical maturity and integration of mathematics and engineering?* Using as an example only one of many modelling projects offered to our students, we illustrate how a standard mathematics course can be modified to bring together knowledge and skills from engineering, physics, mathematics, and programming in a meaningful way, cf. [2]. Working on mathematical modelling projects, students combine advanced mathematical thinking with physical intuition, they set experiments, make assumptions, suggest, test, and validate models – all these components contribute to the acquisition of mathematical maturity so much wanted by engineering faculty and employers. At different stages of all projects, eight mathematical competencies [5] are employed and tested without additional exam stress. The work in small groups also provides useful social experience needed for future collaboration in communities of practitioners, cf. [11].

Our experience with the use of modelling projects in a course was positive and encouraging - projects engaged students in collaborative work, contributed to their learning, stimulated exploration, and creativity, and brought positive emotions. Students encountered many practical problems relevant to their engineering specialisation where the theoretical knowledge of linear differential equations and systems of linear differential equations was applicable. Last but not least, students experienced much less stress at the exam since project work contributed to the total grade, and an overall performance in the course improved.

5 ACKNOWLEDGMENTS

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PROMOTING CONCEPTUAL UNDERSTANDING OF DIFFERENTIAL EQUATIONS THROUGH INQUIRY TASKS

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ABSTRACT

Courses in Differential Equations (DEs) have been an important part of engineering education for decades. However, students experience difficulties with the understanding of main concepts including differential equation itself and diverse types of solutions (general, particular, stationary). In this paper, we discuss how the work on non-routine problems on the Existence and Uniqueness Theorems (EUTs) helps students to make sense of DEs and their solutions thus contributing to the development of advanced mathematical thinking.

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1 INTRODUCTION

1.1 Importance of mathematics in engineering curricula

Teaching mathematics to future engineers is challenging; one has to maintain a correct balance between theoretical knowledge and techniques for solving relevant applied problems. On the one hand, "the teaching of 'practical' mathematics is becoming much more focused on the process of modelling of engineering systems - this results in a decrease in the teaching of calculation techniques" [11, p. 9]. Furthermore, due to a rapidly growing use of digital technology in engineering education, "there are significant dangers in losing the teaching of pen-and-paper mathematical techniques to 'button pressing'" [11, p. 10]. On the other hand, Clark [7, p. 149] argued that all structural engineers "should experience a rigorous mathematical education, not necessarily because they will use the mathematics in their future careers, but because of the mode of thinking that such education develops." On a similar note, Devlin stressed that "the main benefit they [software engineers] got from mathematics they learned in academia was the experience of rigorous reasoning with purely abstract objects and structures" [9, p. 22].

Although both educators and students acknowledge the importance of abstract mathematical thinking, educational research often points towards the lack of students' conceptual understanding and the tendency of engineering students to take an instrumental approach to their studies. Many students are surprised by the elevated level of demands set in mathematics courses which are often perceived as obstacles on their path to the engineering degree. One of the difficult but important for engineering curricula courses is that in Differential Equations (DEs).

DEs are used for modelling of a wide spectrum of phenomena including nonlinear oscillations in mechanical systems, complex dynamics of financial markets, currents in electric circuits, and spread of infectious diseases. Students should learn both useful solution techniques and fundamental theoretical results and be prepared for the analysis of applied problems described by DEs using analytical techniques in combination with numerical methods and computer. As Bickley pointed out, "in the end, it is not the number of tricks that the student has learned, but rather the understanding of the concepts and awareness of the relevance of the techniques, which is important – and, finally, his approach to the new learning which an encounter with a new problem may demand" [3, p. 383].

1.2 Research on teaching and learning differential equations

Current research on teaching and learning DEs is rather scarce, there are "fewer than two dozen empirical studies published in top journals" which is surprising "given the centrality of differential equations (DEs) in the undergraduate curriculum" [13, p. 555]. In fact, teaching and learning of DEs at the university level is a quite new area of educational research, and "we need to explore the variety of ways in which content, instruction, and technology can be profitably coordinated to promote student learning" [12, p. 84].

New didactic approaches and modern digital technology have a positive impact on students' understanding of DEs. However, many of them erroneously believe that the success in DEs courses can be achieved by learning only solution routines. Recent empirical research actively explored students' understanding of the concepts of a DE and its solutions [1, 6, 12, 14] revealing many difficulties. Students concentrate attention on specific solution techniques and "often fail to relate them to other concepts or ideas" [6, p. 76]. They experience difficulties with the fundamental concepts including a DE itself, the general and particular solutions [1]. Students "made little or no attempt to place the solution in context, be it a solution to an equation or a DE" [14, p. 48]. Unfortunately, "students were successful in algebraic solutions of DEs, but not in conceptualising DEs and the solution of DEs concepts … algebraic solutions of DEs can be found even without a deep understanding and conceptualization of DEs, which is why students do not feel any need to understand DEs and related concepts" [1, p. 887]. In summary, "research has pointed to the various challenges that students face with this concept" [13, p. 555].

The authors [17] analysed several tasks suggested in the literature for assessing students' conceptual understanding of the general and particular solutions to DEs concluding that only one out of five problems encourages students' inquiry and can contribute to their conceptual understanding of DEs. We argued that the correct formation of the concept as Vygotsky's *scientific concept* can be achieved only through the rigorous explanation of all relevant definitions and theoretical results, including the Existence and Uniqueness Theorems (EUTs), which meaningfully complete the definition of a solution to a DE and link all important notions. We believe that conceptual understanding of DEs can be fostered by the use of inquiry-based pedagogy [12] and non-routine problems [2]; first steps in this direction were recently made by the authors [17-19].

The research question we address in this paper is: *How does the work on non-routine problems impact the conceptual understanding of the notion of a DE and its solutions by senior engineering students?*

2 METHODOLOGY

2.1 Inquiry-based mathematic education

Contemporary trends shift mathematics teaching from instructor-centred to student-centred, and the terms inquiry and inquiry-based mathematics education (IBME) appear increasingly often in research literature and in educational policy documents. Simply put, inquiry-based learning and teaching mean the organisation of students' work similarly to that of professional mathematicians. Rasmussen and Wawro [13] argued that the three important components of inquiry-oriented instruction are (i) student deep engagement in mathematics, (ii) peer-to-peer collaboration, and (iii) instructor inquiry into student thinking. A three-layer inquiry model developed by Jaworski [10] takes this idea further considering the inner layer where students engage into inquiry in a classroom with peers and a lecturer, the middle layer where lecturers engage into professional inquiry aimed at creating new learning opportunities, and the outer layer where education researchers and lecturers extend inquiry further to the developmental research.

The ultimate goal of IBME is to empower students to inquire independently and with confidence. Practical strategies that teach inquiry include rephrasing usual problems as questions, searching for hidden patterns, formulating, and verifying conjectures, designing counterexamples, searching for alternative solutions, etc.

2.2 Conceptual understanding and non-routine problems

Reframing standard textbook tasks into inquiry-oriented ones often turns them into *non-routine problems,* that is, problems “for which students had no algorithm, well-rehearsed procedure or previously demonstrated process to follow” [5, p. 2318]. Such tasks introduce uncertainty and associated risks, their use in teaching is challenging both for lecturers and students, but the benefits are significant – “if more time were spent in classrooms with students engaged in working on cognitively demanding nonroutine tasks, as opposed to exercises in which a known procedure is practised, students’ opportunities for thinking and learning would likely be enhanced” [20, p. 92]. By cognitive demands we understand the form and level of thinking needed by students for successful engagement and solution of the given task. Empirical evidence confirms that “the highest gains on a mathematics-performance assessment were related to the extent to which tasks were set up and implemented in ways that engaged students in high levels of cognitive thinking and reasoning. […] Starting with a good task does, however, appear to be a necessary condition, since low-level tasks almost never result in high-level engagement” [21, p. 344]. The use of high-level tasks in teaching encourages student reflections, facilitates generation and exchange of ideas, fosters creativity, stimulates further inquiry, and contributes to the development of advanced mathematical thinking.

2.3 Teaching experiment and data collection

The teaching experiment was organised in a DEs course for senior mechatronics students in their fourth year of studies. A total of thirty-seven students enrolled in this course based on a popular textbook by Boyce and DiPrima [4]. In the final part of the course, students worked for three weeks on an assessed assignment – a set of non-routine problems on EUTs designed by the authors with the focus on the development of conceptual understanding. Our aim was to explore how non-standard questions can challenge students, develop their analytical skills, and contribute to conceptual understanding of important notions and ideas in an ODE course for engineering students. Furthermore, introducing a small group work in the project, we could explore the extent to which individual work and group discussions contributed to students’ conceptual understanding of EUTs and influenced their individual solutions submitted for final assessment.

Participation in the teaching experiment was voluntary. We expected that by the time of the assessment students acquired necessary theoretical knowledge and developed required computational skills. In the first week, students worked on the problems individually in the tutorial and submitted a copy of their solutions to the lecturer (script #1). Then they worked on the assignment at home and handed in individual solutions in the next tutorial (script #2). During the second week, students discussed their individual solutions in small groups, audio-recorded the discussions and submitted the audio files to the lecturer. In the last, third week, students presented solutions they agreed upon in small groups to their peers during the tutorial. The lecturer was present in the class but did not participate in the discussions and did not comment on students' solutions. In the end of the third week, students submitted individual solutions (script #3) for grading and received lecturer's feedback by email afterwards. During these three weeks, students had no lecturer's feedback on the scripts but had the possibility to reflect (individually or in groups) about their solutions and modify them, if desired, in the next script. We collected students' written work (three scripts), answers to pre- and post- questionnaires, audio recordings of the small group discussions, and the recording of the class presentation of solutions. The audio records were transcribed, and the data were analysed after the course work was completed and the letter grades were assigned.

3 DATA ANALYSIS

3.1 Sample tasks and expected reasoning

The problems on the EUTs that do not require the use of computer in the course textbook fall into the following four categories: (i) determine (without solving the problem) an interval in which the solution of the given initial value problem is certain to exist – six problems; (ii) state where in the ty-plane the hypotheses of the theorem are satisfied – six problems; (iii) solve the given initial value problem and determine how the interval in which the solution exists depends on the initial value y_0 – four problems; (iv) explain why the existence of two solutions of the given problem does not contradict the uniqueness part of the theorem – *one* problem.

Since the nature of sixteen out of seventeen problems on EUTs in the course textbook [4] is procedural, the problems in our assignment were designed to engage students in a deeper reflection about EUTs and related notions. In this paper, we discuss students' approach to the following two problems.

Problem 1. (a) Verify that $y(x) = C_1 + C_2x^2$ is the general solution of a differential equation $xy'' - y' = 0$. **(b)** Explain why there exists no particular solution of the given equation satisfying initial conditions $y(0) = 0,\ y'(0) = 1$. **(c)** Suggest different initial conditions for this differential equation so that there will exist exactly one particular solution of a new initial value problem. Motivate your choice.

Problem 2. The coefficient $p(x) = \frac{2}{x}$ in a linear differential equation $xy' + 2y = 18x^4$ is discontinuous at $x = 0$. **(a)** According to the EUT will a solution satisfying the initial condition $y(0) = 0$ exist or not? **(b)** How does your answer to part (a) agree with the fact that $y = 3x^4$ is the exact solution of the initial value problem $xy' + 2y = 18x^4$, $y(0) = 0$? Explain.

Both problems are non-routine; no similar examples or problems are discussed in the textbook [4]. The tasks encourage exploration and set cognitive demands at the higher levels of using procedures with connections to concepts and meanings and doing mathematics [21]. In Problem 1, we expected that students (i) verify that a given function is *the general solution* and (ii) show that the first initial condition yields $C_1 = 0$ whereas the second one leads to a meaningless equality $2C_2 \cdot 0 = 1$. The exploration in part (c) includes two options: either choose the initial value $x_0 \neq 0$, in which case the EUT always assures local existence of solution to a system of differential equations $y' = u,\ \ u' - \frac{1}{x}u = 0$, (an easier one) or change the second initial condition to $y'(0) = 0$ obtaining a one-parameter family of solutions $y(x) = C_2x^2$ (a more difficult one). In Problem 2, one has to show first that the discontinuity at $x = 0$ of the coefficient in the differential equation written in the standard form $y' + \frac{2}{x}y = 18x^3$ does not allow applying the EUT, and the theorem is inconclusive. However, the existence of an exact solution emphasises the fact that the EUT provides only sufficient conditions and if these are not met, a unique solution to the given initial value problem may or may not exist.

3.2 Analysis of the students' work

We illustrate students' reasoning using the transcripts of small group discussions, group A with students, A1-A4 and group B with students B1-B5. We selected episodes where the discussions are particularly succinct. Although students are not native speakers of English, we did not edit the original text in transcripts.

Episode 1 – Problem 1 (b).

A2. My approach there was just to put in the initial conditions and then see that $C_1 = 0$, that is okay, and then I tried the derivative $y'(0)$, it's supposed to be equal to 1.

A3. 0 is never equal to 1.

A2. So the equation does not compute.

A3. So it is not possible to determine C2. […]

A2. It is 0=1.

A1. I did the same thing as well, but I tried thinking why is it this way, and my sort of conclusion was that it's in the bottom of a parabola, where the derivative always is 0.
A3. It cannot be anything else in a bottom of a parabola which is a minimum point.
A1. So, therefore if you state that the derivative at that point should be anything other than zero it doesn't make any sense because it's the minimum point.

A2. It has to be a minimum or maximum point.

In Episode 1, students employed analytical reasoning pointing to the inconsistency of the system of algebraic equations for determining coefficients of particular solution (A2 and A3) and combined it with a geometrical argument referring to the particular shape of solution curves (parabolas) and the zero value for the slope of a line tangent to these curves at the origin (A1 and A3).

Episode 2 – Problem 1 (c).

B4. For my part, I just made up some initial conditions, I just tried them, so $y(1) = 2$, $y'(1) = 2$. Then we can get $C_1 = 1$ and $C_2 = 1$. So, this will possibly be a suitable initial condition.

B3. I also made up some initial conditions and tested them. I used $y(0) = 1,\ y'(0) = 0$, and I get $C_1 = 1$ and $C_2 = \frac{1}{2}$.

B4. Ok, there will possibly be multiple initial conditions.

B1. You can choose any x-value, and arbitrary … anything except $x = 0$ will work?

B4. Ok.

B5. I did the same, I used the existence and uniqueness theorem because of discontinuity at x=0, so no guarantee there, but for all other x there is a solution guaranteed.

B2. That might be the correct solution. We must be sure that we have a solution by referring it to the theorem. I think you can show it by solving, too.

The developments in Episode 2 perfectly matched our expectations. We observe that students discussed both possible modifications of initial conditions that ensure the uniqueness of solutions. B1, B4 and B5 opted for a different initial point whereas B3 suggested the only possible value for the derivative, $y'(0) = 0$.

Episode 3 – Problem 2 (a).

B4. We have a linear equation, like $xy' + 2y = 18x^4$, and if we put it in the standard form, we have a coefficient like $p(x) = \frac{2}{x}$ and that will be discontinuous at $x = 0$. And according to the existence and uniqueness theorem does a solution satisfying the initial condition $y(0) = 0$ exist or not? As a start, I think that is a tricky question […] trick question. So, my suggestion is, due to the discontinuity, the EUT does not apply. The theorem cannot say anything about the existence and uniqueness of that solution.

B2. I agree.

B4. All of us.

B3. Yes.

Episode 3 demonstrates that students understood the meaning of the EUT. They noticed the discontinuity of the coefficient of a DE at $x = 0$ and unanimously concluded that in this case the theorem is inconclusive.

Episode 4 – Problem 2 (b).

B5. The existence and uniqueness theorem just says that I cannot say anything, I cannot tell you anything whether there is a solution or not because of this discontinuity, so the solution could exist or not exist. It does not violate the theorem in any way if it exists or does not exist. But it exists.

B4. But should someone improve the theorem to make it better?

B5. Maybe. I think in mathematics a lot of the times you have some theorem it cannot tell you everything. There is no universal answer for everything.

In Episode 4, the student B5 explained that the EUT does not provide necessary but only sufficient conditions for the existence of a unique solution. His concise and correct explanation confirms a good understanding of the issues discussed in Episode 4 where he seemingly was less active.

4 DISCUSSION AND CONCLUSIONS

The teaching experiment reported in this paper was designed to explore how the use of non-routine tasks stimulates student inquiry and contributes to the advancement of the conceptual understanding of the notions of a DE, its solutions, and related theoretical results, including EUTs. Preparing the assignment problems, we employed the *inquiry by design technique* where lecturers "design tasks and projects that stimulate to ask questions, pose problems, and set goals" whereas students "must learn to inquire systematically" and "must actively construct their own knowledge" [16, p. 38]. Working with senior students who had previous experience with other mathematics courses, developed appropriate learning strategies and social skills needed for collaborative work, we deliberately provided no lecturer's support because "students operating at the frontiers of their conceptual knowledge have no reason to build new conceptual structures unless their current knowledge results in obstacles, contradictions or surprises" [8, p. 82]. Substantial academic maturity of students facilitated their engagement in unguided inquiry. Four episodes from small group discussions in Section 3 illustrate an overall success of the teaching experiment and positive impact of the use of non-routine tasks on the development of students' conceptual understanding of the EUTs for DEs.

In line with [1, 6, 14], we also acknowledge students' difficulties with the concept of the general solution of a DE introduced as the expression which contains all its possible solutions [4, p. 11] and defined only for linear DEs. Integration of the first order linear DEs always furnishes the general solution although the fact that no other solutions are available is not emphasised. Furthermore, the concept of the general solution is used in [4] primarily to develop the theory of higher order linear DEs with constant coefficients. For nonlinear DEs, the situation may be much more complex, and the textbook prompts that "the existence of "additional" solutions is not uncommon for nonlinear equations" [4, p. 11]. However, in attempt to facilitate students' learning, many textbooks use the term "general solution" only to discuss linear DEs. This might be one of the main reasons for students' lack of attention to this important concept explaining the difficulties experienced when asked to demonstrate that a given function is the general solution to a DE, especially if the equation is nonlinear. The issue can be resolved if the notion is properly introduced and illustrated with relevant examples where "additional" solutions are produced. We plan to address this important problem in one of our forthcoming papers along with the analysis of changes in the views on teaching of DEs during the last fifty years.

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ESSENTIALITY OF KNOWING TRANSVERSAL COMPETENCIES: TOWARDS ENGINEERING EDUCATION SUSTAINABILITY AND INDUSTRY READINESS OF ENGINEERING STUDENTS

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ABSTRACT

Engineering education is to prepare engineers for real-world challenges and seek novel solutions to cater to society's different needs. There is an increase in the global demand for industry-ready engineers. Engineering education sustainability and industry readiness are mutually inclusive, where the former is the combination of different skills and transversal competencies, while the latter is all about their applicability. Transversal competencies, transferable across disciplines, chisel engineering students to become versatile and practical on the shop floor.

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Sustainability in engineering education is usually discussed only from the ecological/environmental viewpoints. This paper tries to find out the relevance of transversal competencies from the perspectives of engineering students at three levels: the most recurring competencies, the competencies they lack, and the ones that need improvement. Recurring and essential transversal competencies such as problem-solving, creativity and innovation, communication, lifelong learning etc., were identified from different policy frameworks of accreditation agencies, industry reports, organizational reports, and academia. Primary data was collected from final-year engineering students for this exploratory research through semi-structured interviews. These transversal competencies, latent throughout the formative years, have a definite role in the engineer's industry readiness, making engineering education sustainable. The need for industry readiness of the engineering students indicates the sustainability of engineering education, which can bridge the gap between the industry and academia. The paper reveals opportunities for further expansion of the competency frameworks in the policymaking and accreditation procedures.

1 INTRODUCTION

1.1 Background

The role of engineers in the world is significant. The world is developing every day and so is the concept of engineering. The world has successfully entered the phase of Engineering 5.0. The main concept in Engineering Education 5.0 is sustainable engineering, which refers to the implementation of engineering solutions without much hindrance to the environment using fewer resources and materials to enable the engineers to face unforeseen challenges (Lantada, 2020). According to the United Nations sustainable development goal 2030, engineers are the solvers of global challenges. Traditional education, which focuses on knowledge, cognition, and technical skills (Care, 2017), often in a pedagogic model, is not enough to keep pace with this multifaceted transformation in the industry. Hence, to prepare the engineers for sustainability, innovative approaches in the learning are rapidly increasing (Cropley 2015; Payzin, 2017). Engineering education is constantly evolving due to new technology and a changing global context. Therefore, learning needs to be active and learner-centred with the help of problem-based learning, project-based learning, research-based learning, etc. (Care, 2017). The learning process evokes behavioural attributes of the learner which work in combination with domain knowledge in the situated context. These learner-centred experiential processes are more effective than a lecture which does not include the participation of the learner (Crasovan, 2017; Cruz et al., 2019). The development of transversal competencies works through these experience-based learning processes.

1.2 Sustainable engineering education

Sustainability, reaching out to all disciplines and levels of engineering education at the university, is likely to extend into lifelong professional development (Lantada, 2020). The sustainability of engineering education depends upon the industry and competency readiness of the engineer. In the engineering industry, the term industry readiness has different dimensions such as process, technology, and organisation. Industry readiness at the engineering graduate level is dependent on the workforce learning and development, leadership, and transversal competencies (Devika et al., 2020). To address the current changes and future challenges across the engineering industries, there is a call for more explorations in sustainable engineering education.

The level of different competencies and interdisciplinary discourses affects the industry readiness of the graduated engineers (Murugesan et al., 2021). There are many definitions, frameworks, and categorisations of transversal competencies by accreditation agencies, international organisations, academicians, and employers. All these domains have overlapping, recurring, and shifting patterns which are defined by the scope of the respective studies/documents (Devika et al., 2021). The needs and objectives of engineering education are already well defined. But there is a need to integrate and work with other disciplines to form a sustainable engineering education platform which is the current need. In engineering education 5.0, the focus has also shifted to the practical part where both domain and theoretical knowledge rely on/are supported by the sub-skills and competencies to attain the desired result. The key stakeholders in this process are the engineering students. For these reasons, a key element of transformed engineering education is that it addresses the sustainability of its human resources: the engineer individually and the engineering community collectively. Crucial to such a transformed engineering education will be the incorporation of elements to help graduate engineers maintain and enhance their abilities over their careers and to adapt to future times and conditions (Sulej, 2021).

In this paper, the meaning of sustainable engineering education is broadened to include the sustainability of the engineer's lifelong learning. The paper tries to analyse the awareness of final year engineering students about transversal competencies at three levels: the most important competencies, the competencies they lack, and the competencies which need improvements.

2 METHODOLOGY

The study has used qualitative research design. Interview was conducted to collect data using a semi-structured schedule as an instrument. Using relevant literature from academia, accreditation agencies documents, industry reports, and project reports and organisational reports, recurring and important transversal competencies in engineering education were narrowed down to creativity and innovation, communication, teamwork, lifelong learning, problem-solving, ethics and environmental awareness. To identify the importance and use of these six transversal competencies, semi-structured interviews were conducted with thirty-five final year engineering students at BITS, Pilani, India. The questions for the semi-structured schedule were prepared with the help of education experts, research scholars, relevant literature and engineering graduates who have extensive industry experience. The interviews were conducted in two phases. Prior to the interviews, the respondents were properly oriented with specialised guidelines. In the first phase, the use, awareness, and purpose of the selected transversal competencies were asked to the students. In the second phase, they were asked to rank and arrange these competencies at three levels; competencies that are important, lacking, and need improvements. For the data analysis, the interviews were audio and videotaped for better documentation and clarity which were later transcribed word-for-word. Content analysis approach (Krippendorff, 2013) was used for data analysis using MAXQDA software (see Table 1). The inter-rater-reliability of the competencies was 0.95 which is considered as a strong value.

3 RESULTS

Based on the content analysis results from the first phase of the interviews, the six transversal competencies (theme), considered important by the final year students – teamwork, communication, creativity and innovation, problem-solving, ethics and environmental awareness, and life-long learning – were extracted from codes via category. The table 1 shows the absolute and relative coding identified for the use of these transversal competencies by the students.

The students were also asked to rank the competencies to gauze the importance of these competencies as per their knowledge. The students ranked problem solving, required to face the uncertainties, as the most important competency followed by innovation and creativity, communication, teamwork, lifelong learning, and ethics-social and environment awareness. Students thought that they needed improvement in communication, teamwork, and lifelong learning; they were aware but lacked the applicability of ethics and environment awareness. The students had the understanding that problem solving abilities, acquired over the period of graduation, would help them at the workplace. For innovation and creativity, communication, teamwork, lifelong learning, and ethics-social and environment awareness, many of the students acknowledged the importance of practice schools (shop floor visits) and internships which would help them to assess and use the other competencies. The study revealed that although the students were aware about the environment impact and ethics in the engineering fields, the knowledge was only peripheral. Students were aware of the need for the competencies which would make them industry ready. But the students were unaware of the identification and integration of the competencies when they faced a problem.

Table 1. Use of transversal competencies by the final year students

Transversal Competency Domain (Theme)	Category	Codes	Coding absolute: the number of codes identified by students/ the total number of codes extracted from the literature review	Coding relative: %
Problem Solving	Problem Identification	• critical thinking • holistic problem approach • clarity	62/62	100

		• observation		
	Cognition (Application)	• possible outcomes notion • decision making • concepts clarity • differences identification • comprehension	64/70	91.42
	Reflection	• finding similarities/uniqueness • learning from errors	60/60	100
Innovation and Creativity	Motivation	• challenge • freedom • idea support and idea time • motivation • cognitive abilities • thinking style • knowledge	50/59	84.74
	Idea Generation	• intelligence and curiosity • autonomy • hard work and perseverance • technical resources • openness	41/50	82
	Reflection	• flexibility • encouragement and recognition • challenge and pressure • risk taking	39/50	78
Communication	Presentation Skills and Client Interaction	• feedback • ideas sharing	48/67	71.64

	Intercultural Communication	• experience field/area • self-confidence • self-exposure	42/59	71.18
	Team Communication	• listening and reading • cooperation • mutual responsibility • shared field of experiences	40/54	74.07
Teamwork	Leadership	• agreement • authority • accountability • trust • adaptability • decision making methods	60/77	77.92
	Communication	• clarity • direction • shared purpose • individuality	44/57	77.19
	Workflow Procedures	• dedication • working relationship • conflict management	52/73	71.23
Lifelong Learning	Initiation	• engagement • motivation and curiosity to learn • willingness	50/65	76.92
	Learning Process	• self-efficacy beliefs • empowerment • learning (study plan) • intellectual development • information location and scrutinisation	46/62	74.19

	Reflection	• self-reflection, self-monitoring, self-regulation • satisfaction • metacognition	46/62	74.19
Awareness on Ethics and Environment	Environment and Sustainability	• responsibility towards environment • knowledge on health hazards	20/37	54.05
	Awareness on Ethics	• commitment • job value • integrity	17/35	48.57
	Application of the Knowledge	• offer constructive criticism • treat everyone with respect • heed critical reviews	15/35	42.85

4 DISCUSSION

The responses from the interviews revealed that each competency had its relevance at each stage. These competencies work in relation to each other. The domain knowledge is to be strengthened with the process knowledge as well. Exposure to organisation and its working creates the environment to learn the competencies at the scale of real task execution. These transversal competencies are relevant in multiple ways (see Table 1). Competencies are not flat or unidimensional but dynamic and multidimensional. An explicit exposure and experience seems to create an understanding which may help them implement these competencies more effectively. Theoretical understanding about the process gets challenged and fine-tuned by the real work with people from different academic backgrounds, cultural sensibilities, communication ease, etc. The terminologies take different understandings when put in the context of real-life situations/industries/workplace. The learning turns out to be lifelong and life wide.

According to the study, students tend to learn more from errors and try to remember and not repeat the same in a similar problem. By the final year of graduation, the students develop their own ways of problem solving. Problem identification, cognition, and reflection, the components of problem solving, are most sought after by the final year engineering students. To solve the problem, the students are expected to include experiences of other people. Hence, teamwork plays an important role in it. Teamwork includes leadership, communication in the team, workflow procedures. The values reflect that teamwork is one of the areas the students think that they need improvement and many of them think that this can only be achieved when they are in a real team in the industry. The students who had industry internships suggested that they needed more such practice-based learning methods in engineering education. The team can only work in a comprehensive manner if the team members are engaged in active communication. Communication also contributes to other competencies as well, such as teamwork, where the students are concerned about the linguistic capabilities and clarity in the oral presentation of ideas. The data suggests that the intercultural communication competence also needs to be improved while student interaction in the teams is better compared to the other components of communication. Innovation and creativity is one of the competency domains the students are well aware of. In the formative years of graduation, they get the opportunities and freedom for innovation. The students think that the education gives more space for them to think creatively and to come up with novel ideas and solutions. In the process of innovation and creativity, final year students use motivation, idea generation, and reflection. For them, motivation is the most used part of innovation and creativity followed by idea generation and reflection. Most of them think that they need more freedom and flexibility to work innovatively, a concern once they are placed in an industry.

As the industries are expanding their reach in terms of ethics and environment awareness, the least preferred competency domain by the students. The students know the environmental sustainability of a particular product or process, theoretically. But they think many times before applying the knowledge. They are more profit conscious and would consider the economy and profit parameters before thinking about sustainability. Ethical perspectives are yet to be developed for the final year students as they have only some general information on the domain.

Many of the students expect to cover these competencies in the upcoming training programs once they are placed. They are aware but need the exposure to industry to see the application of competencies at the workplace. The learning scope is wide and varied with no-definite and no-fixed notions.

5 SUMMARY

The awareness, use, and integration of transversal competencies from the formative years help the holistic development of the engineers. This sustainability in engineering education can only be achieved only when the transversal competencies are identified and used according to the needs by the students. As a first step, this study identified and classified the transversal competencies according to the perspective of engineering graduates. Following, learning from, and using an integrated framework of transversal competencies may help learners attain industry readiness and engineering education sustainability.

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21st century competencies in engineering education: initiation, evolution, current, and now whither to

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ABSTRACT

The fibre of engineering education has evolved from knowledge to competencies. This is a logical consequence of the technologically advanced and multifaceted learning environment where engineers are expected to be technically acute along with a set of essential non-technical competencies. This change is referred to as a 'paradigm shift' in engineering education. Hence, the vision of learning is to immerse a progressive, learner-centric, and competency-based learning environment to face the uncertainties of the 21st century. There are various ways to improve the performance of learners by implementing the available competency frameworks, but the need is to initiate a set of essential competencies according to their nature and purpose that can endure across disciplines. In this paper, the evolution of competencies from the essential to the necessary is reviewed. Finally, the benefits of these competencies in relation to the performance of the engineers are discussed in detail through semi-structured interviews conducted with the engineers. MAXQDA, a qualitative data analysis tool, is used to analyse the data. The findings will help the engineers in grooming their competencies according to the industries.

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1 INTRODUCTION

There is a paradigmatic change in engineering education - a shift from mere technical knowledge to transversal competencies. The learning has to be more inclusive, multi and interdisciplinary, oriented towards the situated social and political scenarios. Its vision is to create a progressive, learner-centric, and competency-based learning environment. Active learners and executioners need these competence and skills to deal with the ill-defined and unthought-of problems of the 21st century (Sangwan et al., 2022). Most learners today are natural investigators, researchers, and information synthesisers as a result of their continued use of digital and mobile technology. These competencies help learners to groom themselves as lifelong learners capable of acclimatising flexibly of changes, and collaborative learning and working environment (Redecker & Punie, 2013). Hence, development of 21st century competencies has to be more inclusive (Neeley, 2021) in accordance with current workplace advancements (Moczek et al., 2015).

Preparing engineers for work, global citizenship, and life in the 21st century is a challenging task. Globalisation, new technology, relocation, international competitiveness, ever-changing markets, and transnational environmental and political challenges influence engineers' capacity to survive and succeed. These talents are referred to as 21st century competencies, higher-order thinking skills, deeper learning outcomes, complex thinking, communication skills, etc. by educators, education ministries and governments, foundations, employers, and researchers. Engineering students overestimate their understanding and acquisition of competencies, sometimes cherishing even an idealised perception. If engineers want to be a part of this phenomenon, they must have a deep understanding of competencies (Wilson & Mukhopadhyaya, 2022). This study focuses on the indispensability of essential competencies for 21st century engineers. The questions addressed are: what are the crucial talents that 21st century engineers must develop and master today; how these may assist learners in navigating the problems; and which competencies will engineers require to face these tumultuous and unpredictable problems?

2 LITERATURE REVIEW

Personalisation, informal learning, communication, teamwork, productivity, and content formation, kernel aspects of the competencies and skills, are critical to the overall concept of 21st century education (Singh et al., 2019; Redecker & Punie, 2013). The rising use of technology is changing how learners learn and create new social norms, and finally leading to lifelong and life wide learning. Furthermore, personal skills (initiative, resilience, personal accountability, risk-taking, and creativity), social skills (communication and collaboration, networking, empathy, and compassion), and learning skills (managing, organising, metacognitive skills, and failing forward - or changing perceptions of and responses to failure) are critical to peak performance at the 21st century workplace (Raj & Sangwan, 2020, Redecker & Punie, 2013).

Over the previous two decades, international organisations and commissions, governments, commercial consortia, and private institutions have developed frameworks to address the challenges of the 21st century. While there is no one-size-fits-all approach to educating young people for the 21st century, there are a number of competencies available (Sangwan, 2021). The International Commission on Education for the Twenty-First Century’s Delors Report (1996), at the very onset, established the four visions of learning - knowledge, understanding, life skills, and action skills. Several studies (Sangwan et al., 2022; Devika et al., 2020; Griffin, 2012; Partnership for 21st century Abilities (P21), 2005) have highlighted the main skills required to prosper in the globalised world of the 21st century. Creativity and innovation, critical thinking and problem-solving, communication, collaboration, information literacy, technology usage, career/life skills, and personal/social responsibility are found to be dominant 21st century competencies.

Engineers, working in multidisciplinary teams, coordinate multiple competencies to address complex problems (Passow & Passow, 2017) (environment, sustainability, resources depletion, societal living standard, etc.), which call for social competencies as well (Wilson & Mukhopadhyaya, 2022). Service learning (Muñoz-Alcón et al., 2022), active learning (Hernández-de-Menéndez, Marcela), competency-based learning (Henri et al., 2017), learning factories (Devika, 2021), an outcome based and learner-centred pedagogy, may help the engineers groom themselves at personal as well as the citizenship level. Evidence-based competencies have relook at teamwork as coordination, ethics as responsibility taking, lifelong learning as information collection and skill expansion, etc. to exchange information and plans, apply knowledge and skills, and seek problems and solutions (Passow & Passow, 2017).

3 METHODOLOGY

The research approach is categorised as interpretive research with the goal of gaining a deep understanding of the contextual factors and the interviewees’ perceptions about the importance of the competencies in 21st century environment. In this qualitative study, open-ended questions and non-numerical analysis were used. The unit of analysis was the critical incident reported by the participants. A critical incident refers to a work situation. This technique allows the interviewees to express their views in their own terms, helps avoid misunderstandings and can create reliable, comparable qualitative data. We used the Critical Incident Technique (CIT) to derive all critical competencies (Koch, 2009). Interviewees were asked the following subquestions: (1) What were the challenges you faced during the initial period of recruitment? (2) How did you overcome these obstacles and progress? (3) What were the consequences of your actions regarding the concrete work situation? (4) What impact did effective problem-solving have on the work’s future progress? A total of 30 responses (freshly graduated engineers in recent two years) were collected for this study. To determine how many people needed to be sampled, the concept of theoretical saturation (Glaser, 1992) was used.

All the interviews were recorded and transcribed using the software MAXQDA to conduct content analysis. Although we asked the interviewees all the sub-questions (e.g., what led to this work situation?) together with the main question about a critical incident (please recall an important work situation), the interviewees often did not describe the incident in chronological order, and instead skipped back and forth from one stage to another. Similar incidents and phenomena were then compared and contrasted with each other, and correspondingly coded where they were found to be similar. With the newly added data, the iterative reflection of the already coded data was carried out. Several iterations were done to narrow down the level of granularity of work situations (the consequences of the analysts' behaviour). Subsequently, we compared existing competency models with initial codes to select a model that fitted the data well. It consists of eight competencies and 30 components of competencies at the finest level of detail, where no competency is subsumed by any other competency. The framework of the competencies contained detailed definitions, including behavioural indicators, which were adapted to the role of the engineers.

4 RESULTS

Based on the perception of the graduated engineers, the study identified eight competencies (see Table 1) which cover eight high-level competency factors. When the participants were asked about the challenges they faced during the initial period of recruitment, they reflected on various problems, including the transition from the learning environment to the execution environment. Working under pressure (dominated by seniors), taking responsibility (afraid of taking the responsibilities of the task due to their newness in the working environment), working by themselves (working on their own without seeking assistance from experienced people), working with people from different backgrounds, being afraid of failure, dealing with superiors, not knowing enough languages, etc. The second interview question referred to the methods (competencies) of overcoming the challenges used in situated work. The definitions of these competencies garnered against the setup of particular work situations, contextual factors (antecedents) are shown in Table 1. The third interview question dealt with the consequences of the actions taken regarding the concrete work situation. The fourth interview question addressed the stages of the implementation of the competencies at various levels, which can help the engineers in managing and solving the problems.

Table 1. 21st century competencies of the engineers

Competencies	Components	Findings
Creativity and innovation	Fluency of ideas	Generate a variety of ideas about a given issue (the number of ideas is important, not their quality, correctness, or creativity)
	Flexibility (variety of ideas)	Be flexible in developing a wide range of thoughts and reactions across several categories to observe things

		from various perspectives. Also think about and transition between different notions at the same time.
	Originality (uniqueness of ideas)	Originality is frequently related with qualities like imagination, persuasiveness, and creativity.
Critical thinking and problem-solving	Critical thinking	Analyse, interpret, infer, explain, observe, reflect, self-regulate, and self-evolve to solve the problem.
	Application skills	Apply domain knowledge and skills, contribute to the assigned role, and accomplish work tasks smoothly.
	Problem finding	Develop critical thinking to necessitate observation to identify and resolve the problems, based on previous experience, to forecast the problems.
	Information collection	Check the data's origins and credibility to see if the findings are based on facts or merely views.
	Reflective thinking	Develop higher-order thinking skills, relate new knowledge to prior understanding, think in an abstract way, develop questioning attitude, identify areas for improvement, and encourage active engagement.
	Decision making	Take work responsibility, demonstrate commitment to appropriate decisions to ensure work ethics, generate and evaluate alternatives before making a decision, and select the option that balances risk and reward.
Communication	Verbal	Communicate verbally in straight forward and appealing ways especially during discussions where the managers/team take appropriate actions.
	Confidence	Be confident during hostilities to solve and understand the problem and communicate with the higher positions people to state the ideas and intentions clearly.
	Concise	Be concise in communication by sticking to the point, keeping the information brief, constructing sentences carefully, and using grammar properly.
	Feedback	Take and give feedback to evaluate the effectiveness of messages by ensuring no miscommunication.
Collaboration	Negotiation	Exercise general, special, and specific coordination to provide reliable psychophysical readiness and suitability for quick, effective, and successful solutions.
	Cross-cultural sensitivity	Accept and respect other cultures and others' cultural identities. Cultural sensitivity counters ethnocentrism, and involves intercultural communication.

	Organisation	To be organised, prioritise and organise tasks meritoriously, share information equally in a team, create a plan for success, ensure proper training, and conduct regular meetings to get suggestions.
	Open-mindedness	Be open- minded and unbiased to listen to others and reduce interpersonal or intra-team conflicts in the team.
Information literacy	Digital/social media management	Have a great understanding of digital marketing and online based digital technologies such as desktop computers to promote products and services.
	Critical media content evaluation	Access, retrieve, understand, evaluate, create, and share information/media content in all formats through media platforms with regards to the materials available for scrutiny in the different forms of media/information.
	ICT attainment	Be critical in applying logical/critical thinking to evaluate the information. Use computer operating systems to produce common digital information and use internet to update the company's social media accounts.
Technology usage	Technical writing	Express difficult information in writing in a clear and understandable manner about products and services.
	Project management	Develop technical initiatives and project management skills to master complicated systems and programmes.
	Productive software applications	Master productivity in general and customised software such as word processing, spreadsheet, and presentation to complete tasks professionally.
Career/life Skills	Self-awareness	Perceive self-strengths and preferences to recognise effective stress management strategies.
	Coping with stress	Be physically and mentally healthy to deal with stressors in the company. Identify what causes stress, how to cope with them, and how to avoid them.
	Coping with emotions	Understand/manage personal emotions in the company to entail greater knowledge of the conditions that trigger negative feelings and investigate the appropriateness of emotional responses to certain situations.
	Healthy interpersonal relationship	Maintain a healthy interpersonal interaction in the team through compassion, empathy, emotional reciprocity, effectual communication, etc. to create and sustain a healthy relationship in the company.
Personal/social responsibility	Environmental responsibility	Work in an ecologically responsible manner. Reduce pollution, increase reliance on sustainable resources, and offset negative environmental impact to maintain corporate social responsibility.

	Ethical responsibility	Ensure ethical responsibility to certify that the organisation operates in a fair and ethical manner. All stakeholders, including leaders, investors, employees, suppliers, and customers, should be treated fairly by organisations.
	Economic responsibility	Take responsibility for all the economic factors related to the environment to give a positive impact, not just maximise profits.

5 DISCUSSION

On an average, important work situations described by the interviewees required two main competencies to identify the problem (communication and collaboration). When freshly graduated engineers joined industry, they faced challenges in terms of adjusting to and understanding the working environment. In such situations, they are expected to learn from an expert (feedback/suggestions) about their performance. This can only be done if the team members are open-minded and willing to share.

The second stage is to solve the problem, where engineers are to use critical thinking and problem solving, creativity and innovation, information literacy, and media literacy (four competencies). Critical thinking and problem-solving abilities allowed them to apply higher-order thinking to new problems through acceptable reasoning and suitable decisions (for non-routine problem solving). Critical thinking requires an understanding of the surroundings and resources to avoid problems; creativity and innovation assist in inventing new ideas/approaches to look at the problem from a different perspective. In the new technological environment, special emphasis is placed on knowing how to best apply technological knowledge during a crisis. Such technology usage strengthens the ability to find and apply appropriate tools resourcefully, ethically, and successfully. Information literacy and technology go hand in hand, where information literacy provides the capacity to obtain, assess, synthesise, and disseminate information from a variety of disciplines.

When it comes to the third stage of the experiences that are learned from both the stages, two competencies (personal/social responsibility and career/life skills) are important. Personal and social responsibility allow us to collaborate with others by identifying and respecting cultural differences while dealing with people from various cultural and social backgrounds. Career/life skills make engineers self-directed and autonomous learners who can embrace change, manage projects, exhibit ownership of their work, lead others, and generate outcomes.

While conducting the interview, an interesting observation comes in terms of competency knowledge. Barriers seem to be that the competencies are either not widely known by the participants or they tend to avoid the effort of understanding and implementing the learned competencies in the workplace, such as career and life skills, critical thinking, and creativity. Additionally, the criticality of having high technical knowledge and information literacy is not sufficient in conducting the smooth functioning of the work. The interviewees also stated the importance of these skills in getting the job. Individual Competencies assist individuals by (a) summarising the experience and insight of seasoned practitioners; (b) providing a tool that individuals can use for their self-development; and (c) outlining a framework that can be utilised to help select, develop and understand the effectiveness of engineers. Thus, the effectiveness of engineers' jobs often depends upon specific combinations of these competencies.

Engineers should be able to communicate across a wide range of cultures because they work with such a diverse group of people. Collaboration concentrated on the active integration of all the team members into all aspects of the decision-making process. The participants' most common theme was that they needed to improve their communication abilities. They regarded communication essential for successful career advancement. Regular communication, early presentation of concepts, and feedback seeking help in maintaining a healthy and friendly environment at the workplace. However, it was not always sufficient to solely concentrate on creating a friendly environment. In some cases, this even led to unsuccessful project outcomes when teams, for example, wanted to keep doing their work exactly the same way despite possible improvements or when they underestimated the technical complexity of the desired software product. In this situation, the team has to develop innovative ways of working by improving their information literacy and technological knowledge. Blurring the barriers of culture and behaviour leads towards a healthy relationship and a positive outcome of the work. Engineers are required to behave independently, make judgments, and collaborate with peers in real-life situations. As a result, collaboration provides an opportunity to engineers on the periphery to integrate their knowledge and abilities into the core of the engineering community.

6 CONCLUSIONS

The paper elaborates on a 21st century competency model, thus contributing to theory in the critical area of competency evolution. The study sheds light on the specific situations at the workplace for newly recruited engineers. Overall, the paper triggers the need to link competencies with specific situations and stages so that the newly graduated engineers can consciously work on grooming their competencies. Based on the result, it might be possible to connect the identified competency profile with existing standard tests used in HR management. This would enable a better and easy-to-apply recruitment process. It also facilitates better individualised training programmes for engineers. Moreover, this paper shows how other engineering-related job profiles can be analysed and, correspondingly, explored and developed. The main limitation of research refers to the derivation of the model from interviews. However, the participants explained in detail how a specific behaviour had impacted the further advancement of the work.

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A QUANTITATIVE EXPLORATION OF ENGINEERING STUDENTS' PROFESSIONAL IDENTIFICATION (RESEARCH-PAPER)

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ABSTRACT

In today's fast-moving world, we must continuously adapt to changes in all areas of life, and the ability to do so is increasingly highlighted as a key skill particularly for engineering graduates. At the same time, research shows that having a stable professional identity, and identifying with one's field is important for aspects such as job-satisfaction and productivity, in addition to overall well-being. However, research of higher education have been critizised for apparently viewing professional identity and employability as synonymous, and an end 'goal' of education, rather than exploring the continuous processes of professional socialisation that take place in the everyday practices of universities. Accordingly, we ask: what affects engineering students' professional identity constructions *while* they are students?

To explore the proposed research question, a quantitative survey instrument measuring professional identification, as well as previously identified related aspects has been constructed. In the research literature, there is little consensus on how to measure professional identity quantitatively, thus, developing a comprehensive measure that can provide insight into these processes is the focal point of the study. Subsequently, the data material consists of 271 engineering students at the Norwegian University of Science and Technology.

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1 INTRODUCTION

In today's ever changing world, flexibility is highlighted as key competency in both education and the working life. Within the field of engineering education, flexibility is important for teachers and academics when educating the engineers of tomorrow while at the same time handling the fast-paced developments of technology and modes of communication. In addition, educators have to balance between contributing to students constructing clear professional identities, all the while they have to aid them in developing the highly requested flexibility. [1] In this context, engineering education has been subject to various changes and reforms due to the experienced mismatch between the scientific focus of universities, and the multifaceted demands of professional practice, with the links between engineering degrees and the realities of an engineer's working life are often put at the forefront of engineering education. [2]

On a more general level, research literature emphasises how constructing stable senses of selves and being able to separate oneself from others is fundamental for how we lead our lives. [3] For adults, the workplace and one's professional identity therefore becomes perhaps the most influential source for the ongoing negotiations of identities and (self-)perceptions. [4] Consequently, higher education emerges as a significant arena for adults' identity constructions, especially in terms of professional socialisation and identification. [3, 5] From a sociocultural perspective, identity is both social and personal, as well as dynamic and ongoing, embedded in the surrounding contexts, and can be viewed as the result of dynamic mediation and negotiation between individual behaviours, social contexts and cultural structures. [4] 'Professional identity' thus, reflects the sense identification to or with a profession or field, on both a personal and social level. [3] Research on professional identity also shows that a strong sense of belonging to one's field and identification with one's professional 'group' can affect several aspects of life, such as general wellbeing and self-esteem, as well as job-satisfaction and work performance. [5, 6] However, Daniels and Booker argue that higher education research generally puts too much emphasis on professional identity as an end 'goal' rather than exploring the ongoing socialization in the everyday practices of university students. [5]

Keeping the growing interest on students' professional identities in mind, we find it interesting to approach identity construction and negotiation processes from an engineering education research perspective. Based on the previous line of reasoning, there appears to be a need to explore these processes of professional identification through the experiences of students. In accordance with a dialectal pluralistic perspective, one can argue that it would be advantageous to employ both qualitative and quantitative measures to attain a comprehensive understanding of such a complex phenomenon. However, as there appears to be a lack of quantitative instruments examining professional identity, especially within sociocultural theoretical frameworks, the aim of the current paper is to present such a quantitative measure, in addition to exploring students' professional identification the research question: what affects engineering students' professional identity constructions *while* they are students?

2 METHODOLOGY

2.1 Development of the instrument

Informed by a dialectal pluralistic perspective, it is believed that employing a variety of approaches is useful to research complex social phenomena, such as professional identification. The questionnaire is part of a larger mixed methods research project on students' professional identities with a planned sequential explanatory design. Thus, in developing the survey instrument, a key aim was to have an open and broad approach to be able to explore an array of possible connections and relationships to be delved deeper into through later qualitative approaches. In this regard, it was important to establish a clear theoretical understanding of the phenomena at the 'heart' of the project, harmonious with both quantitative and qualitative approaches.

Starting from a sociocultural and discursive perspective on identity, possible quantitative operationalizations were explored. First, we attempted to translate and employ the Professional identity Scale Questionnaire (PISQ-5d) by Mancini et al., however through the pilot study it became apparent that it did not work as intended in our context. [7] The subsequent revision of the instrument and analysis of the results (e.g. factor analysis and correlation matrix) also showed that there were some ill-fitting aspects of the instrument. The further development of the instrument included revising the conceptualisations, operationalisations and measures to better suit the specific context and participants. For instance, changing the main dependent variable from 'professional identity *status'* to a two-folded measure for professional identity through measuring 'professional *identification*' an 'professional *commitment'* with the latter being greatly based on some of the items from PISQ-5d that had consistent results in the pilot study. The former measure is based on an adaption of Mael and Ashforth's scale for Organizational Identification. [8] In addition, a single-item social identification measure (SISI) ('*I identify with engineers'*) has been included as research has highlighted consistent high validity and reliability across a broad range of social groups [9, 10]. It is the SISI that is at the centre of this paper, while the other measures will be analysed later on. However, we believe that the SISI encaptures the previously presented perspective of identification with a social group as a key aspect of professional identity, thus being suitable for the scope of this paper.

In addition, students from academic disciplines found it difficult to relate to and respond to items including 'neutral' term for professional identification such as 'a professional' in the pilot study. Consequently, each questionnaire was adjusted to fit the field and ensure that the participants understood the questions, e.g., '*engineers', 'chemist'* or *'sociologist'.* This also impacted the method of distribution which will be explained in the next section.

2.2 Sample and distribution

The target group of the project as a whole is 'students at the Norwegian University of Science and Technology (NTNU)'. However, as noted in the previous section we were not able to produce a 'general' questionnaire that we could distribute to all students at the university and had to adapt each questionnaire to the given programme. NTNU is also a relatively large university with close to 45 000 students and more than 330 programmes, and thus selecting a number of programs to focus on appeared appropriate.

Additionally, based on the pilot survey we changed the previously intended method of distribution. Before the pilot, the plan was to distribute the survey digitally through informal forums run by the students themselves, i.e., Facebook-groups, group-chats etc. to make the project as participant driven as possible. However, in the pilot, the response rate of the group targeted through this approach was 18,75% (N = 21), while the response rate of the group in which we conducted the focus group who had time during their lecture to respond was 100% (N = 12). Of course, there are most likely other aspects influencing these response rates, nevertheless the main method of distribution was changed from predominantly student-driven, to recruiting lecturers and faculty to aid in the distribution. To ensure the informed consent of the participants, as well as the convenience for all parties, the distributors received an information document, a short information film, a direct link to the survey and a QR-code that was linked to the survey, making it possible to show on a PowerPoint or other presentation devices.

As a result, 522 students from 50 different study programmes have participated in the survey. Due to the nature of the distribution method, in addition to most lectures being non-obligatory and the low attendance after COVID-19, as well as several courses consisting of students from an array of different programmes, it is challenging to make any claims about the response rate. Subsequently the number of students reached might not be equivalent to the number of students enrolled in the programme nor the specific subject of the lecture in which the questionnaire was distributed in. As the focus of this paper and conference is engineering education, the results are based on the 271 engineering students that have participated in the survey so far, and not the remaining 251 students.

2.3 Operationalizations and varibles

To measure students' professional identification, we have employed the SISI to explore wether the students' identify with engineers. As stated, previous studies have highlighted the strong validity and reliability of this measure across samples and contexts. [9, 10] Despite this recognized scientific quality of the measure, we discussed changing from 'I identify *with*' to 'I identify *as*', however, due to the full project including other measures for identification and commitment in addition to the SISI we chose to keep it as is to see whether they would complement oneanother or overlap. Preliminary results show a significant ($p = <.001$) moderate correlation between the single-item measure and the composite measure of identification (.30), indicating that they to some degree are related to oneanother. In addition, using 'with' instead of 'as' is believed to encapture the social aspect of the previously presented understanding of professional identity, while also pointing to it being an internal identification with a social group, thus fitting well with the aim of the paper.

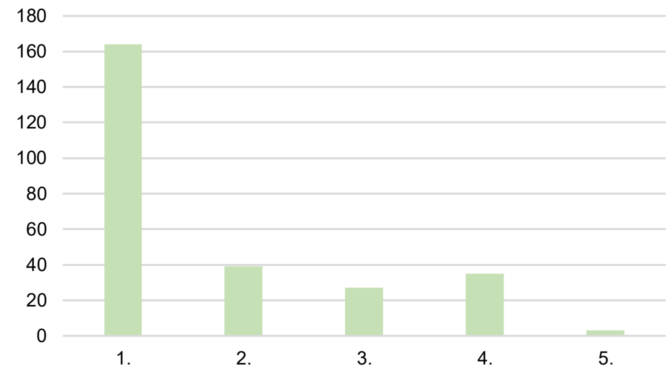
Furthermore, we have included composite variables of intrinsic and extrinsic motivation based on the works of Skatova and Ferguson, and Ryan and Deci. [11, 12] The measures consist of four and three items, with the factor analysis proving a high degree of inner reliability for both variables with factor loadings ranging from .649 to .867, and Cronbach's alfa .741 and .728 respectively. In addition to these composite variables, we asked the students about their previous work and/or volunteer experiences, and whether they found it relevant for their degree, as well as praxis as a part of their programme.

3 RESULTS

3.1 Participants

As mentioned, the data consists of 271 engineering students from 21 of NTNU's 32 engineering programmes. The distribution of participants across programmes is varied, with the larger groups being Bachelor's degree in Civil Engineering (16,3%), Electrical Engineering (10,0%), Mechanical Engineering (11,4%) and Master's degree in Industrial Economics and Technology Management (9,2%). Due to the varied number of participants from each programme, we will not differentiate between programmes in this paper, but rather uncover similarities and important factors for engineering students as one group. However, we also acknowledge that there could be important distinctions between programmes, which we hope to be able to explore further in the future. On the note of the future research, we also intend to perform comparative analyses between engineering programmes and programmes of other professions and disciplines at a later time to gain a more comprehensive understanding into these processes of socialisation and identification.

Figure 1. Year on programme



As can be seen from Figure 1 over half of the participants are first-year students (66,3%), while less than 20% are third to fifth year-students of their current programme. This might to some degree be explained by the method of distribution, as physical lectures and mandatory subjects are typically more prevalent during the first two years of the programmes, while the later years often contain more independent work, i.e., Bachelor's or Master's thesises. There are some limitations to having such a clear majority of students in the beginning of their degrees, as one can argue that the process of socialisation and establishing a sense of identification is dependent on experiences that one can argue students are gradually exposed to throughout their time at university. Furthermore, it could complicate the comparative analyses between students from the different years due to the differences in respondents. However, having a large number of first-year students participating opens for the possibility to perform a longitudinal analysis in the future. In addition, despite the majority of participants being first year-students (61,2%), only 41% state that they are currently doing their first year at university overall. Thus, several of the first-year students have some previous experience in higher education, which might affect the results.

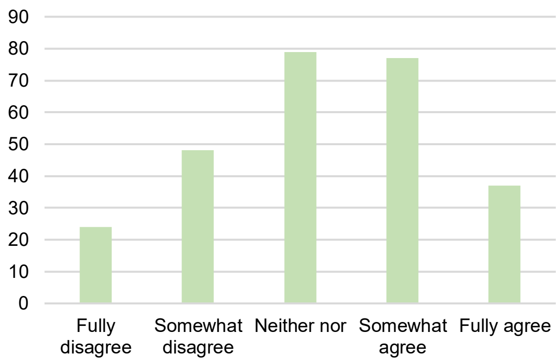
As expected, the majority of engineering students are male (66,4%), with 33,2% female respondents, and 0,4% of respondents identifying with another gender identity. This is in accordance with official numbers from NTNU which shows that the amount of women in three-year engineering programmes were approximately 22% in 2019, while it was closer to 38% in in the five-year programmes. [13] Furthermore, the official statistics have not included a category for other gender identities, and even though the number of respondents is too low to explore analytically we argue that it is important to include the option of a third gender to ensure the inclusion of the entire student body.

In terms of age, most participants are between 20 and 26 years old (94,4%), with the mean age being 22,9 years old (median = 22, mode = 21). This is somewhat low compared to the national average of Norwegian students of approximately 28 years old. [14] However, the latest numbers informing the national averge are from 2016, where it is highlighted that a majority of students take several years off school before beginning higher education. One of the most noticeable effects of the recent pandemic however, have been that less people take one or more gap-years from education after finishing upper secondary school, and that more people enter directly into higher education. Thus, the national average might be lower in 2022 than it was in 2016, making the discrepancy between our participants and the student body in Norway as a whole less extreme than it might appear.

3.2 Distribution of the dependent variable

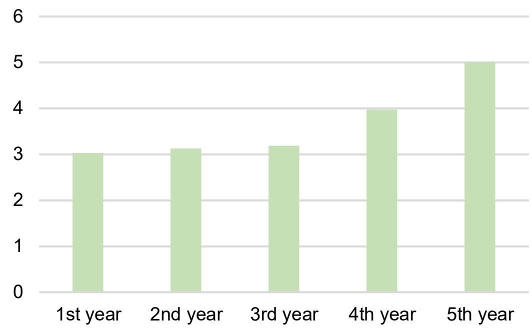
As is visible in Figure 2 the students' responses to whether they identify with engineers are slightly positively skewed, with 40% either somewhat or fully agreeing, and 28,6% either somewhat or fully disagreeing. Whereas, about a third (31,4%) are neutral to the statement, neither agreeing nor disagreeing. This could again indicate that there are some socialisation processes within the enigeneering education programmes at NTNU that contribute to students identifying with engineers.

Figure 2. SISI distribution



Furthermore, Figure 3 highlights the average score of identification dependent on year on programme. We can see that first- to third-year students on average answer neither nor (2,03, 3,13 and 3,19 out of 5 respectively), while the average fourth year student somewhat agrees (3,97) and the average fifth-year student fully agrees (5,0). This could suggest that engineering students identify more and feel a stronger sense of belonging to the field of engineering throughout their time as students, which indicates that the socialisation process does in fact depend on the time spent at their programme. It could also suggest that the way the programmes at NTNU are structured support students' professional identification, and/or provides them with the necessary tools and experiences to feel ready for the professional life. However, it is once again important to note the low number of responses from fourth and fifth year students, and that we have to perform more complex analyses to claim anything about what influences these scores, as well as the statistic significance.

Figure 3. SISI distribution by year



3.3 Findings

The findings presented in the below section is based on a bivariate analysis with Pearson correlation, as well as linear regression analysis of the dependent variable (SISI) and the chosen independent variables.

As can be seen in table 1, there are only six out of the 21 correlations that are significant ($p = <.05$). Not surprisingly, one of these are relevant work experience and relevant volunteer experience, suggesting that if a students have had one, they are more likely to have also experienced the other. Furthermore, for the identification measure, year on programme (.28), extrinsic motivation (.13) and intrinsic motivation (.22) were significantly correlated, however with a correlation coefficient below .3, thus indicating a low correlation. Interestingly, the two strongest correlations in the correlation matrix is between year on programme and relevant work experience (.29) and relevant volunteer work experience (.41). In light of the previously mentioned interconnections between engineering education and demands of the working life, it is not too surprising that more experienced students appear more likely to have relevant work or volunteer experience as well.

Table 1 Correlation Matrix

	1.	2.	3.	4.	5.	6.	7.
1. I identify with engineers	-	.28**	.13*	.22**	.09	.11	.08
2. Year on programme		-	.08	.02	-.04	.29**	.41**
3. Extrinsic Motivation			-	-.11	.09	-.11	-.07
4. Intrinsic Motivation				-	.03	.11	.07
5. Praxis					-	-.05	-.06
6. Relevant work						-	.23**
7. Relevant volunteer work							-

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed)

Furthermore, the regression analysis showed that our model is significant (p = <.001) and explains about 11.8% of the variance in students' identification (.118). Table 2 shows all the coefficients and related significance.

Table 2 Linear Regression Analysis

	B Coefficients	Sig.
Year on programme	.23	.022
Extrinsic Motivation	.17	.023
Intrinsic Motivation	.43	<.001
Praxis	.13	.195
Relevant work	.07	.661
Relevant volunteer work	-.08	.624

Based on the correlation analysis, we expected at least three significant relationships in the regression analysis, which was confirmed, as the only significant variables were year on programme, extrinsic motivation and intrinsic motivation – the same as in the correlation matrix. Unlike in the correlation analysis, intrinsic motivation (.43) appears to have the distinctly strongest influence, with a moderate correlation, and year on programme (.23) and extrinsic motivation (.17) having weak correlation coefficients. These results might change or paint a slightly different picture if we performed a hierarchal regression analysis, but this has not been done as of today. In the context of the proposed research question, we can argue that motivation and years spent at their programme affects students' professional identification. Still, we cannot make any claims based on the presented research about whether the students are intrinsically and/or extrinsically motivated *before* starting their degrees or if the universities provide them with tools or experiences that facilitate and strengthen their motivation which further impacts their professional identification. On the other hand, since year on programme is significant in the regression analysis as well, the university appears to provide *something* that contribute to engineering students identifying with engineers.

However, in line with the dialectal pluralistic perspective established previously, these relationships and the related ‘how’s’ and ‘why’s’ should probably be explored further through e.g., qualitative interviews to gain an even more comprehensive understanding of these processes.

4 SUMMARY AND CONCLUSIONS

To conclude, it appears that the single-item measure of social identification could be a useful tool in measuring students’ professional identification, however more research within this context is probably needed. Furthermore, the analyses show that students motivation, both intrinsic and extrinsic, are influencial when measuring their identification with engineers, in addition to how long they have studied at a programme. Interestingly, work praxis as a part of the study programme, previous relevant work and volunteer experience did not come out as having a significant impact on the students professional identification, despite the engineering programmes at NTNU continuously highlighting the importance of their close-knit relationships with the working life. However, as the regression analysis shows that the engineering students appear to identify more with engineers the further along in the programme they are, there must be something during their time at university which facilitates this gradually increasing identification. What exactly this is, will have to be explored later on.

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THE FUTURE OF WOMEN AEROSPACE ENGINEERS IN ACADEMIA – A NUMBERS GAME

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ABSTRACT

The gender divide for women in the engineering domain in academia is still very large today, even though most institutions are committed to changing this. Although there are slow improvements in the number of women working in academic positions in Engineering, the Netherlands, in particular, is still lagging badly behind the rest of Europe with women making up only 17.6% of all full professors in the engineering domain and for 25.7% in the entire academic domain. This is despite many efforts across the board to improve this situation.

The situation is even worse in the field of Aerospace Engineering and within this field, the lack of progress is not unique to the Netherlands with similar issues being reported in the United States of America and wider afield.

This paper reports on research on the capacity building among women required within the aerospace engineering domain to reach the commonly defined critical mass percentage of 30% of women full professors using metrics on career progress and on as well as labour market data on the career development of Aerospace graduates to show where potential new interventions can be made.

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1 INTRODUCTION

Women Aerospace Engineers to date are still few and far in between, despite the many campaigns worldwide by both industry and governments to change this. This is especially true for women aerospace engineers in academia, which should be seen as a major concern as research has shown that there is a strong correlation in engineering between student diversity and faculty [1].

Although the Faculty of Aerospace Engineering at Delft University of Technology (TU Delft) in the Netherlands is the largest aerospace engineering school in Western Europe with over 2800 BSc and MSc students enrolled in 2021/22, only 14% of its students are women, a number that has only slowly increased over the last decades. Of the 19 full professors in aerospace engineering at TU Delft, only 2 (10.5%) are women, ranking at the lower end of TU Delft's representation of women full professors (17.9% over the whole of TU Delft). TU Delft ranks last in the list of Dutch universities when it comes to the number of women professors in the Netherlands [2], which averages at 25.7%, making the Netherlands one of the worst-performing countries in the EU in this respect. The Dutch Network of Women Professors has therefore set itself a target of reaching a "critical mass" with 30% women professors by 2024 [2].

The critical mass percentage of 30% is widely attributed to the political scientist Dallerup as the threshold when women's participation is no longer tokenism. After reaching this critical mass a qualitative shift will take place in an organization. As she states, however, this idea of a specific absolute turning point of 30% has been found not to exist but the notion that a certain mass of representation has to be build-up to achieve a qualitative shift in an organisation remains [3].

With the number of women in aerospace in academia in the Netherlands still being so low, this paper reports on research into the required capacity building to reach the suggested target of 30%. Is this an achievable number within the next 10 years given TU Delft's capacity for training aerospace engineers also compared with other countries?

2 HISTORIC CONTEXT

To provide some explanation as to why the current numbers are still so low, it is important to take into account the historical context of the academic field of aerospace engineering and the socio-economic context of the Netherlands over the past 100 years.

2.1 Development of the Field of Aerospace Engineering

Aerospace or Aeronautical Engineering as a recognised academic field of study is itself not that old. Initial degrees were named Aeronautical Engineering and from 1958 onwards the term Aerospace Engineering was often adopted to also reflect the Space content of the programmes. Although the discussion still rages on who exactly is the first to start teaching courses in aerospace, the first courses are taught in Europe from 1907-1910 onwards[4] in London and Paris with today's 'ISAE

SUPAERO' now in Toulouse, France the first to establish a formal degree programme. In the USA, the University of Michigan follows suit in 1916 and M.I.T founds its aeronautical engineering programme in 1926. At TU Delft the degree programme in aeronautical engineering was founded in 1940, days before the outbreak of World War II in the Netherlands. Today, aerospace engineering schools are spread all over the world covering every continent apart from Antarctica, and the demand for aerospace engineers in the job market remains high and is expected to continue to increase [5].

2.2 The History of Women in Aerospace Engineering

With the field of aerospace engineering itself still being so young, it will not come as a total surprise that it was not until 1929 that Canadian woman Elsie McGill was the first woman to graduate with a Master's degree in aeronautical engineering from the University of Michigan. This did not mean there were no female aircraft designers before this: Lilian E. Bland (Ireland, 1909) and E Lillian Todd (USA, 1910) designed and build their own aircraft, both of which flew. Like many other early aviators, they schooled themselves in aircraft design. In Europe, not all countries had established degree programmes in aeronautics yet, but this does not mean that women are not interested in studying aeronautics. In Germany, Ilse Essers (nee Kober) in 1926 and Melitta von Stauffenberg (nee Schiller) in 1927 also obtain Master's degrees with aeronautical-related theses in Mechanical Engineering at what is now RWTH Aachen and Applied Physics at what is now TU München, respectively. The first European woman with a master's degree in aeronautics is likely British woman Hilda Lyon, who obtained a Master's in aeronautical engineering at MIT in 1932. However, it was not until 1965 before the first woman graduated in aeronautical engineering from TU Delft, Indonesian national Koo Siu Ling, with the first Dutch woman Hedwig Ritzen graduating in 1969. It would not be until 1996 that the first PhD degree in Aerospace Engineering was awarded to a woman at TU Delft and it took until 2006 before Hester Bijl (now rector at Leiden University) was appointed as the first woman professor in Aerospace Engineering at TU Delft.

2.3 Socio-Economic Development of Women in the Netherlands

To understand why it took so long for the first women to graduate in aeronautical engineering at TU Delft, it is important to understand the socio-economic context in the Netherlands at the time. Until the end of the 19th century, secondary education in the Netherlands was only open to the privileged few. A change in the Dutch education system in 1876 allowed anyone with the national advanced secondary education diplomas *Gymnasium* and *HBS* to gain entry to university, although not all universities were equally happy to admit women.

Admittance policies differed per university but the first woman to graduate from TU Delft was Maria Elizabeth Bes, a chemical engineer, in 1904. This did not mean that women were flocking en mass to universities. Although women were given the right to vote in 1919, married women were deemed legally incapacitated and a marriage ban was in place at all government institutions, often mirrored by industry, under pressure from unions and Christian political parties. They favoured the breadwinner economic model and successfully argued that allowing women to work would take away jobs from men with families and lead to lower wages. Even after the abolishment of these laws in 1957, the lack of childcare facilities or the ability for children to eat lunch at school instead of going home for lunch until well into the 1980s made having a professional career as a woman an uphill battle. In addition, until 1988, a person was not deemed to be of age until they reached the age of 21, meaning that young people needed parental permission to enrol at university. Only from 1990 onwards, the breadwinner model was abandoned and men and women were expected to each be able to earn their own income regardless of their marital status and women were actively encouraged to gain professional qualifications. As a result, the percentage of financially independent women rose from 25% in 1990 to 64% in 2020 - compared to 80% of all men)[6].

3 METHODOLOGY

3.1 Data sources

All data reported and used as input in this paper is publically accessible data from various government sources and international organisations. When comparing different countries the same base year for all countries was used, being 2018 as that was the year the most complete data set could be determined. Relevant international data was found for the United States of America [7], the United Kingdom, and Spain. Next to that, the European Union's *She Figures* report [8] was also consulted. All data for the Netherlands as a whole came from the Universities of the Netherlands, all TU Delft data came from the TU Delft data tableaus.

3.2 Netherlands Academic Career Model

Different countries will have different academic career progression models. In the Netherlands, to enter a PhD programme at a Dutch university a Master's degree is mandatory and as a general rule, a PhD is the minimum requirement for an Assistant Professor position. Although PhDs have been awarded at TU Delft since 1906, only since 1982 have formal PhD programmes been in place at Dutch Universities. The Dutch academic system until recently has largely been a hierarchical system, meaning that full professors were only hired when a vacancy occurred or when a new research group was started. More recently, qualifying associate professors can also be promoted to full professor, but this is not an automatic system and the qualifying conditions can vary greatly.

3.3 Capacity Modelling

The Royal Society [9] reported in 2010 that in the United Kingdom 0.45% of all PhD graduates will become full professors and 3.5% will become permanent research staff. How this number is determined differs from country to country based on methods, different academic career models and definitions of academic positions. It is however important to realize that, especially in the field of engineering, the university system is an open system. It means that people leave academia for other employment, but also that people come back to academia. Research by the Rathenau institute shows that overall the in- and outflux are almost in balance [10]. In the capacity model proposed in this paper, it is therefore assumed that the in- and outflux are in balance.

Equation (1) is proposed to calculate the number of PhD graduates needed to appoint 1 full professor. Divide 100 by the multiplication of the percentage of people progressing from 1 academic rank to the next:

$$N_{PhD\ per\ full\ prof} = \frac{100}{\%(PhD \rightarrow PostDoc) \cdot \%(Postdoc \rightarrow Asst.) \cdot \%(Asst. \rightarrow Assoc.) \cdot \%(Assoc. \rightarrow Full)} \tag{1}$$

Using the reported data by the Rathenau institute over the 2003-2013 period this comes to 333 PhD graduates per full professor appointment or 0.3% of all PhD graduates become full professors. This is slightly lower than the reported 0.45% by the Royal Society for the United Kingdom [9] but is likely more accurate as Dutch universities require a Master's degree before entering a PhD programme whereas in the UK a Bachelor's degree suffices.

It is proposed that Equation (1) can be expanded to calculate the number of graduates with a Master's degree that are needed to appoint one full professor:

$$N_{Mdegree\ per\ full\ prof} = \frac{100 \cdot N_{PhD\ per\ full\ prof}}{\%(Mdegree \rightarrow PhD)} \tag{2}$$

The earlier mentioned *She Figures* report [8] by the EU indicates that 0 - 20% of all women with a Master's degree enter a PhD programme and 0 - 30% of all men. For the Engineering, Manufacturing and Construction domain, this is 10% for women and 13% for men in the Netherlands [8]. To see if this data was representative for TU Delft a further step was taken: To estimate the percentage of Master's graduates that obtain a PhD degree the 5-year average of the number of awarded PhD degrees at TU Delft over the 2017-2021 period, 387, was divided by the number of awarded MSc diplomas over the same period, which averaged at 3496, which comes to 11%.

3.4 Glass Ceiling Index

The Glass Ceiling Index (GCI) is used by both the EU and the Dutch government as a measure of career progression for women. Each has a slightly different definition. The EU definition of GCI is [8]:

$$GCI_{EU} = \frac{\%\ all\ woman\ full, associate\ and\ assistant\ professors}{\%\ all\ women\ full\ professors} \tag{3}$$

The Dutch government defines GCI per academic rank [2]:

$$GCI_{NL} = \frac{\%\ women\ in\ highest\ rank - 1}{\%\ women\ in\ highest\ rank}$$

(4)

In both cases a GCI of 1 means there is no difference between men and women being promoted, a GCI > 1 means there is a Glass Ceiling effect with the higher the value, the more women are underrepresented in higher academic positions, whereas a GCI <1 means women are overrepresented in a higher academic position.

4 RESULTS

4.1 Capacity Building

From a capacity-building point-of-view, it is interesting to see how many woman PhD graduates in AE are needed to reach the "*magic*" number of 30%, which in the case of AE is 6 full professors and compare those numbers to the actual number of women PhD graduates. A similar calculation can then also be made with respect to the number of woman MSc graduates needed to reach 30% full professors.

As was mentioned before, 333 people must have gained a PhD in Aerospace to appoint 1 full professor which means 1,998 women must gain a PhD in Aerospace from TU Delft and subsequently using Eq. 2 and the percentage MSc - PhD of 11% results in a requirement of 3,003 people with an MSc degree in Aerospace in order to appoint 1 full professor. Therefore to reach the number of 6 woman professors at TU Delft without using capacity from outside, some 18,000 women must gain a Master's degree in Aerospace Engineering from TU Delft.

This naturally leads to the following question: How many women have obtained a PhD or MSc degree in AE at TU Delft so far? Based on aggregated TU Delft data, by 31 August 2021, 7,140 MSc diplomas have been awarded in total since 1943 when the first diploma was awarded, of which 576 were awarded to women. The total number of PhD -degrees in AE from TU Delft that have been awarded since the first one in 1947 is 605 of which 75 were women. It is worthwhile noting that only recently, in March 2022, TU Delft awarded its 10,000th PhD degree.

It is safe to say, that based on these numbers AE at TU Delft is not educating sufficient Aerospace Engineers at Master's and PhD levels to even sustain its current total of 19 full professors, let alone women. This probably also goes a long way to explaining why of the current 19 full professors in aerospace engineering only 6 hold a PhD in Aerospace Engineering from TU Delft of which only 1 is a woman and of whom only half hold any aerospace PhD or MSc degree.

Is there perhaps additional capacity for aerospace engineers elsewhere? To find out several international databases and publications on aerospace engineering graduates were consulted, notably in Spain (Educa database), The United Kingdom (HEPA), and the USA [7]. The data shown in table 1 lists the number of MSc and PhD graduates of the 2018/2019 academic year in each country and the total population of the country with the exception of the USA which shows the data for the 2017/2018 academic year.

Table 1. Number of MSc and PhD degrees in Aerospace Engineering awarded in 2018/19 (USA in 2017/2018) in the Netherlands, Spain, the United Kingdom and the United States of America in absolute and normalized by million of population.

	NL		Spain		UK		USA	
Population (mln)	17		47		67		332	
Number	**Abs**	**Norm**	**Abs**	**Norm**	**Abs**	**Norm**	**Abs**	**Norm**
MSc (total)	296	17.4	419	3.9	935	14.0	1,587	4.8
MSc (women)	39	2.3	92	2.0	161	2.4	233	0.7
PhD (total)	37	2.2	N/A	N/A	180	2.7	412	1.2
PhD (women)	7	0.4	N/A	N/A	22	0.3	54	0.2

It is clear from the small selection of countries that capacity is also limited in other countries. If the numbers are normalised per million inhabitants, the Netherlands outperforms all countries when it comes to the number of MSc degrees awarded per year and forms the top 2 with the United Kingdom when it comes to the number of PhD degrees awarded per year per million inhabitants. It also shows the even direr situation in the USA.

*Table 2. Share of Women in Academic staff at TU Delft AE, TU Delft as a whole, the Engineering Domain of the Dutch Research Universities, and All Dutch Research Universities (excluding Healthcare), based on data for Dec 2020. *excludes external PhDs and bursary students. (Sources: WPO Data Universiteiten van Nederland and TU Delft)*

	AE			TU Delft			Eng NL			Uni NL		
Rank	**All**	**W**	**%W**	**All**	**W**	**%W**	**All**	**W**	**%W**	**All**	**W**	**%W**
Full	19	2	10.5	274	49	17.9	545	96	17.6	3,555	889	25
Assoc.	25	4	16	302	66	21.9	543	10	18.8	2,827	886	31.3
Assist.	56	16	28.6	543	171	31.5	1,068	326	30.5	6,383	3,820	44.1
PhD	288	74	25.7	2,911	887	30.4	3,112*	942	30.3	9,721*	4,366	44.9

Table 3. GCI Indexes at TU Delft Aerospace Engineering, TU Delft as a whole, the Engineering Domain of the Dutch Research Universities, and All Dutch Research Universities (excluding Healthcare) based on data for Dec 2020. (Sources: WPO Data Universiteiten van Nederland and TU Delft)

GCI	AE	TU Delft	Eng Domain NL	UNI NL
Assoc.→Full	1.5	1.2	1.1	1.2
Assist.→Assoc.	1.8	1.4	1.6	1.4
PhD→Assis.	0.9	1.0	1.0	1.0
EU	2.1	1.4	1.4	1.4

4.2 Glass Ceiling Index

Using the public data files of the Universities of the Netherlands and the data available from TU Delft data tableaux, the GCI_{NL} indexes were calculated for the Aerospace Engineering (AE), TU Delft, the entire Dutch Research Universities Engineering Domain and all Dutch Research Universities (excluding healthcare). Healthcare is not reported as this domain is reported separately. Also, Dutch universities of applied sciences are not included in this data as they have a different academic structure. The share of women in academia is shown in Table 2. The GCI indexes are presented in Table 3.

It is clear from the GCI_{EU} index that Aerospace has a solid glass ceiling when it comes to women advancing in their academic careers. *T*he GCI of TU Delft, the Dutch Engineering domain, and the Netherlands as a whole *are* all at 1.4 which in itself is also still far away from parity. There may be a slimmer of hope in that GCI for transitioning from PhD to Assistant Professor is smaller than 1, indicative of a better possibility of transitioning for women who have just finished their PhDs.

To give a better idea of how big the problem is, it is important to also compare these numbers to international data. The EU report She figures 2021 [8] reported an EU-average for GCI_{EU} of 1.5 based on 2018 data with the Netherlands also 1.5 which is in line with the EU28 average and based on the 2020 data provided in this data the situation overall in the Netherlands and the engineering domain continues to improve, with AE lagging.

*Table 4. Share of Women in Academic staff in the Engineering Domain of the Dutch Research Universities (Source: WOPI data Dec 2020 – Universiteiten van Nederland), the USA and Canada [7]. * excludes external PhDs and bursary students*

	NL (2020)			**USA (2018)**			**Canada (2018)**
Rank	**All**	**W**	**%W**	**All**	**W**	**%W**	**%W**
Full	545	96	17.6	13,808	1,698	12.3	12.5
Assoc.	543	10	18.8	7,081	1,430	20.1	19.3
Assist.	1,068	326	30.5	7,668	1,894	24.7	24.6
PhD	3,112*	942	30.3	12,156	2,869	23.6	23.4

Table 5. GCI Indexes for the Engineering Domain of the Dutch Research Universities, (Source: WOPI data Dec 2020 – Universiteiten van Nederland), the USA and Canada [7].

GCI - ENG	**NL (2020)**	**USA(2018)**	**Canada (2018)**
Assoc.→Full	1.1	1.7	1.5
Assist.→Assoc.	1.6	1.2	1.3
PhD→Assis.	1.0	1.0	1.0
EU	1.4	1.4	1.3

What about the Aerospace domain? An attempt was made to find staff data for the aerospace domain. Sadly, the EU and ASEE do not report at degree level so no comparison within the aerospace domain could be made when it comes to GCI. It is possible to do so on an engineering domain level with the USA and Canada but for the EU the domain definitions are incomparable and the level of data reported in She Figures [8] has insufficient depth to make good comparisons.

From the data in tables 4 and 5, it can be seen that on the more holistic GCI_{EU} level the Dutch engineering domain scores comparable to the USA and Canada but there are differences in the GCIs between the different academic ranks. It is, however, worth noting that the ASEE's Engineering by the Numbers - report [7] does state that aerospace engineering only has 11.8% female academics (compared to 22% at AE TU Delft) and women only made up 13.1% of all doctoral degrees awarded in aerospace in 2018, against 25.7% at AE TU Delft so *again* the situation may be even direr in the USA.

5 DISCUSSION

More women can indeed go some way to solving the capacity problem in aerospace. As this paper shows women are still woefully underrepresented in academia in engineering and thus should be a welcome pool of available additional capacity that is currently underused. University Leadership will often say that there are not enough women out there to increase the number of women in aerospace in academia. The data presented in this paper goes a long way in proving that point when you look at the current available capacity, not just in the Netherlands, but also elsewhere. It is unlikely that the 30% target will be met in the next 10 years. Combine that with the ever-increasing industry demand for aerospace engineers [5] and the capacity problem will not be solved instantly. At the same time, universities themselves are not without blame either. Many universities have limited capacity in terms of the number of students admitted to study aerospace engineering and as the GCI index shows, it is still very difficult for women to rise to the top in aerospace academia. This lack of ability to progress is also what is holding women back in pursuing an academic career in engineering: lack of progression, unconscious bias in recruitment and promotion processes and finally, structural barriers such as work-life balance. One might argue that those who made it are miracle workers as they defied all odds. Better hiring and recruiting practices and, more importantly, better retention practices are needed and are needed fast.

However, it is too easy to just appropriate all the blame on the universities themselves: Governments are restricting education and research funding is also limited which affects the number of available places for students across the tertiary education spectrum. Almost all aerospace degree intakes are capped and the number of PhD positions is highly dependent on external funding. Access to degrees is becoming more expensive year on year and the quality and offering of STEM teaching in secondary schools are declining due to insufficient capacity of STEM teachers thus unnecessarily limiting the pool of (woman) candidates as well. Industry could also step up and take their responsibility: If the (aerospace) industry continues to insist on lower taxes but yet expects an ever-higher yield from (government-funded) universities and other education sectors, they are frankly delusional. If they want to keep their competitive and innovative edge, both in terms of highly trained human capital and in research-based innovation, they must generously invest in the (aerospace) university sector and improve their often not-so-positive image in the eyes of women to make themselves more attractive. It is after all a basic economics question of supply and demand. If you are short in supply, you can choose whom you want to work for.

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DEVELOPMENT AND APPLICATION OF SIMULATION GAMES TO INTRODUCE MODEL-BASED SYSTEMS ENGINEERING

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ABSTRACT

Model-based Systems Engineering aims at increasing consistency of information in complex engineering processes that involve different engineering domains. A major challenge when introducing Model-based Systems Engineering is to highlight the interactions of different process activities, like requirement definition, specific methods and available tools as well as roles. These interactions have to be demonstrated to members of the engineering team in order to induce awareness for potential hurdles within the implementation process and to increase acceptance for required changes of processes, methods and tools. Simulation games present a promising approach to generate awareness as well as the needed expertise for successful implementation of Model-based Systems Engineering, in both teaching of students and training of experienced engineers. In this contribution a development process and essential aspects for the game design of simulation games are proposed. The structured process and its specific steps are illustrated by the development of the simulation game *MbSys*.

1 INTRODUCTION

Modern products incorporate crucial technical changes, like dynamic behaviours, intensive networking, connection to the Internet of Things or the use of on demand services [1]. Consequently additional requirements, like cyber security, are placed on the

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product and have to be handled within the engineering process. In most cases a more holistic view on the system and its environment is required to handle the complex requirements and interactions. Therefore the use of different system views are key elements of an engineering process that follow the Model-based Systems Engineering (MBSE) methodology. However, application of MBSE results in new processes, methods and tools (PMT) and the adaption of the existing PMT ecosystem [2]. To generate awareness for required adaptions of the PMT ecosystem, we research the design and application of simulation games.

1.1 Value and Benefits of Gamification Approaches

Gamification within education has become a central opportunity to drive behavioural change among individuals and to enable new methods for training within complex systems [3]. Additionally gamification increases the motivation to study or learn new items [4] within an enjoyable format. With regard to MBSE gamification provides various benefits. First, gamification supports harmonizing terms and wording, e.g. what is meant with the term *model* within MBSE? Second, gamification facilitates the definition and design of engineering processes as well the selection and application of appropriate methods and tools. Furthermore, gamification can be a great support by understanding the interactions between processes, methods and tools within an organisation. The understanding of these interactions are essential for the implementation and permanent application of MBSE within an organization. The following section gives an insight into the basic benefits of MBSE and typical challenges that occur. Target of this paper is, to address these challenges with a simulation game in order to improve engineering design education.

1.2 Benefits and Challenges of MBSE

Systems Engineering (SE) is a holistic interdisciplinary approach for successful development and realization of systems [2, 5]. Thereby, SE involves processes, methods and tools which focusses either single aspects, like architecture definition, or overall challenges, like comprehensive system understanding or interdisciplinary communication [2, 6]. MBSE extends SE by capturing engineering information, like interface control and system description documents, within an overall system model [5] in order to ensure data consistency and traceability along the complete product life cycle. Additional benefits which are reported in literature [5, 7] are: better communication and information sharing, improved system understanding and design, improved collaboration, better management of complexity, increased capacity for reuse, better requirements engineering and management. These selection of expected MBSE benefits highlights the support of MBSE when engineering complex products. However, introduction of MBSE frequently faces different barriers, which can be organizational, processual or educational justified [8]. With this paper and the corresponding simulation game mainly processual and educational barriers will be addressed. Key factor as well as big hurdle, due to widely established discipline and component oriented thinking, for successful SE implementation is holistic systems thinking [2, 6]. A second pivotal element for successful implementation of MBSE is an appropriate PMT framework, based on the PMTE paradigm pyramid introduced by Martin [9]. Especially, the relations between processes, methods, tools and their environment needs to be understood and respected while definition of new or adaptation of established PMT.

1.3 Research questions and paper structure

This paper propose the use of simulation games for the implementation of MBSE. Therefore, a structured development approach for simulation games is proposed and preliminary experiences from application are presented. The following research questions will be answered within this paper: (1) Which development steps and elements should be considered for a successful design of simulation games? (2) How can the identified development steps and elements be integrated within a structured development process? The presented paper is structured as follows. Within section 2, different gamification approaches are distinguished and based on established literature typical development steps and elements for the design of simulation games are presented. Section 3 describes the proposed development process focussing on the simulation game *MbSys*. The paper closes with a summary and outlook for future work.

2 STATE OF THE ART

The term gamification is used with different understandings in literature. In Fig. 1 a basic distinction of relevant terms for this contribution is illustrated.

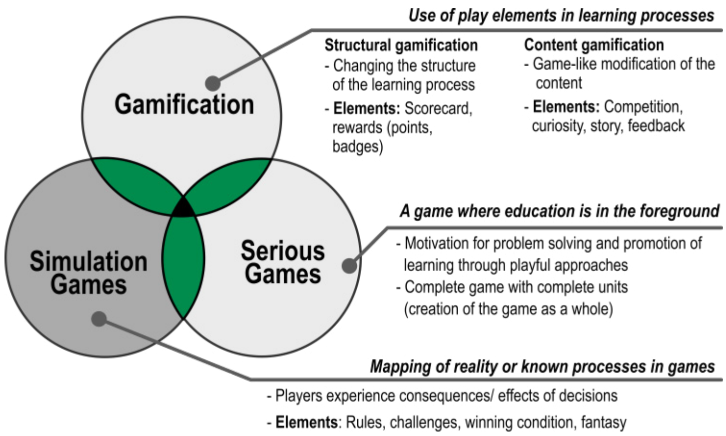

Fig. 1. Differentiation of learning games based on [10, 11, 12, 13]

Thus, different ranges of game-based learning have to be differed, resulting in gamification, simulation games and serious games as basic types. Gamification is the use of game design elements in non-game [10]. As soon as game elements such as fantasy, rules, challenges or winning conditions are added to the simulation, it becomes a simulation game [11]. Here the focus is on the representation of processes and effects known from reality. A third approach are serious game that focus on education rather than entertainment [12]. This paper focus on the development of simulation games and presents therefore a typical development process in the following section.

2.1 Development of Simulation Games

In general the evolution of simulation games can be described as an iterative problem-solving process. Therefore, the identification and the comprehensive understanding of the problem is fundamental. After problem analysis the design evolution, including technical and project management processes, follows. Thereby the use of development cycles including prototypes, which presents the key functions and a previous visualization of the game, is established. Important for successful game development is the addition of an implementation and evaluation phase, which compares the initial problem and the developed solution. Fig. 2 presents a engineering process, which contains the mentioned development steps, for the introduction of a simulation game.

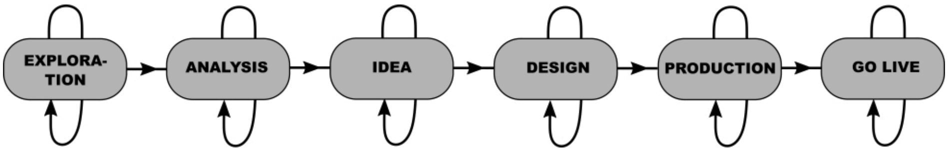

Fig. 2. Development process for simulation games, based on [14]

Especially the exploration phase at the project start, which contains the problem analysis and the definition of contentual and gameplay targets, functions and evaluation criteria, is important. Thereby also first ideas concerning the game content can be considered. Based on different concept sketches within the analysis phase important artefacts, like use cases and context of the game will be described. Methods for requirement definition, like system context analysis or use case scenarios can support these activities. Leveraging on the described concept sketches and artefacts within the idea phase detailed concept papers, including game mechanic, will be elaborated and evaluated. The idea phase closes with the selection of one concept which will be operationalised within the following design phase. Thereby prototypes evolve within an iterative development process. These prototypes will be used for evaluation of the realized game with the initial defined targets and functions. Finally the developed game design needs to be produced and introduced into the defined context. [14]

2.2 Pivotal elements for the development of simulation games

During application of the presented development process (chap. 2.1) we identified that the content of each development phase needs more structure. One possibility for better structuring can be the *Serious Game Design Assessment Framework* [15]. These framework was initially developed to assess games based on essential elements, but can also be a great support for structuring the development phases. Fig. 3 presents the pivotal elements that should be considered while developing a simulation game.

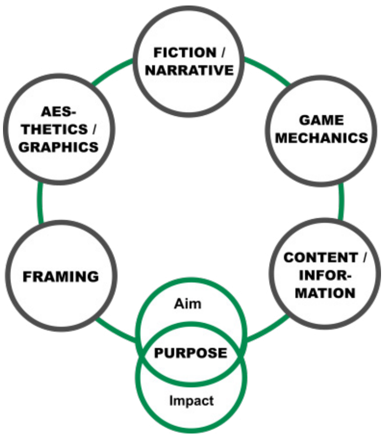

Fig. 3. Essential elements for game design, based on [15]

The *purpose* contains the *aims* of the game and the *impact* on the players, which the game should evoke. These elements are essential and should be reflected in all other elements. The element *content / information* represents all information and data offered and used in the game. The interaction between the players and the game is part of the *game mechanics*. To describe these interactions definition and visualization of actions can be helpful. Typically the *game mechanic* contains basic rules, space for decision making, in-game targets, challenges and events. Therefore often a simulation model is used in the background to define all existing relations. *Fiction / narrative* are needed to give the game mechanics a fictional content. Especially for simulation games the fiction and narrative should illustrate the real-world situations. The *aesthetics* and *graphics* refers to the audio and visual illustration of the game and present the game to the player. All listed elements should consider the target group of the game. Therefore the *framing* of the game has influence on all other elements and should answer at least the following questions: What is a suitable game type? Which prior knowledge attendees require? Are the learning targets easy or difficult to acquire? Which kind of game events can motivate players and affects the game dynamic? [15]

The presented elements should be considered within the development process of a simulation game in order to generate a purposeful game design. In section 3 these elements will be integrated into the presented development phases, see section 2.1.

3 DEVELOPMENT OF SIMULATION GAME MBSYS

Key element of this contribution is the description of the development process for simulation games *MbSys*. For a better structuring we integrated the pivotal elements of a simulation game into the presented development process, see Fig. 4. The production and go-live phases are out of scope within this contribution.

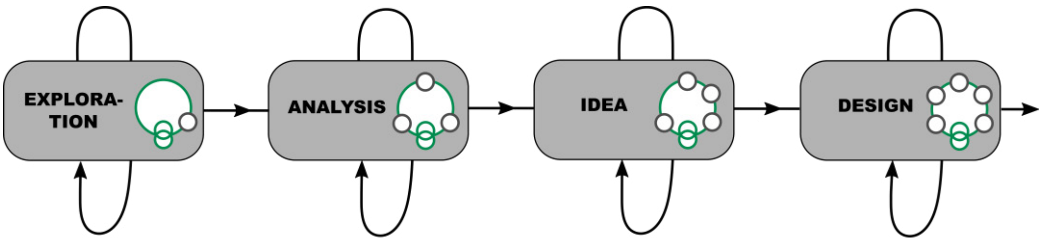

Fig. 4. Integration of essential elements into simulation game development process

While integrating the essential game elements into the development phases we identified that each phase considers different or additional elements. The exploration phase meanly focusses the *purpose* and the fundamental *content* of the game. During the analysis phase additionally the *framing* and *fiction* will be considered by a more detailed use case description. Afterwards an appropriate *game mechanic* needs to be selected, which is the core of the idea phase. Finally, during the design phase all elements based on the previously phases will be operationalised and the *graphical* visualization will be developed. Following the application of the introduced development process will be presented for the simulation game *MbSys.*

Exploration phase

Within the exploration phase we defined the aim of the game and the impact that the game should have on the player. *MbSys* has the aim to make MBSE including essential development processes and artefacts perceptible for the attendees. By knowing important artefacts, engineering decisions and influencing factors within MBSE, the attendees should adjust their functioning to a more model-oriented working behaviour. Additionally, we defined first aspects of the game content. We will use a typical product development process, which includes gates and artefacts, as an established game fundamental. These known fundamental should enable an easy game access, which is one of the game targets. The outcome of the exploration phase was an abstract product development process as the game vision, see Fig. 5.

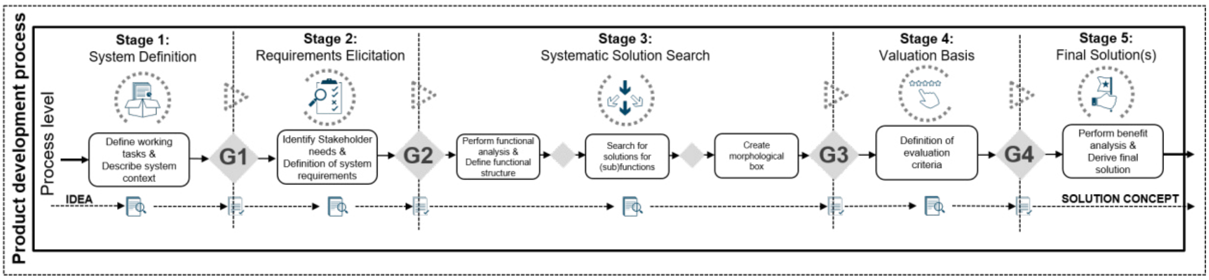

Fig. 5. Product development process as game fundamental

This development process includes different development stages and gates. Within each stage exemplary development activities are included, which are required to provide the needed artefacts at the individual gate.

Analysis phase

Part of the analysis phase is the consideration of the defined game use case (Fig. 5) in more detail and an in-depth understanding of the game attendees in this context. Thereby the initial game content was extended by an appropriate selection of development methods and tools, which are needed for successful MBSE, see Fig. 6.

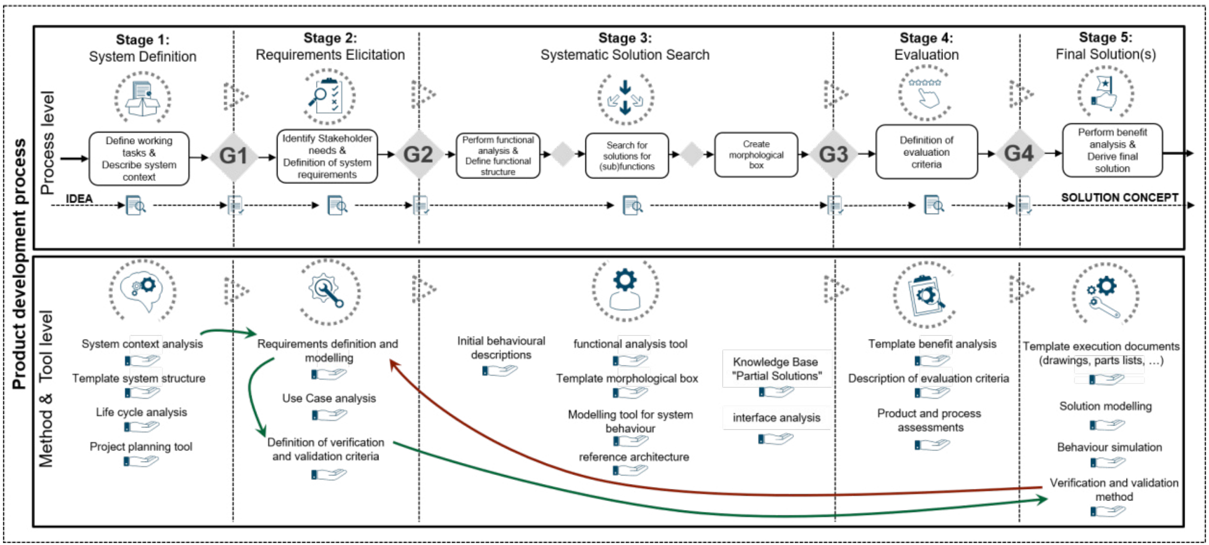

Fig. 6. Product development process including processes, methods and tools

One of the key question in these phase was the game opportunities of the players. Within a simulation game the players require some freedom to act within the defined content. In the case of *MbSys* we determined that the process level in the development process is fixed as a frame for the game and the players should select appropriate methods and tools to provide the needed artefacts at the individual gate. Thereby needs to be considered that typically not one method leads to the needed artefact. The players should understand the relations between different kind of methods and tools. A second aspect that increases the opportunities of the players is the integration of a quality classification for the applied development methods. That means a player has to decide in which quality (poor, medium, best) a method should be applied. While framing the game we identified the need that the game should have a flexible structure, e.g. the amount of gates, the required artefacts or the selected methods and tools should be adjustable. This is causes by individual stakeholder requirements.

Idea phase

Core of the idea phase was the evaluation of different game mechanics concerning the described use case. For *MbSys* we selected a role play oriented game mechanic, because the use case presents a sequence of events (stages, gates) that happened successively and the players can be seen as development team members. This can be compared with a guiding storyline including operating characters. In addition we wanted to simulate events (e.g. test case failed, post freeze requirement changes) that could occur within a development process. Therefore the described mechanic is also suitable. The occurrence of events can happen randomly, e.g. by rolling a dice.

Design phase

During the design phase the game concept and mechanic will be operationalised. The iterative development of prototypes supports evaluating the content and experience-oriented game targets, which were defined during the exploration phase. In case of *MbSys* we identified that additional resources (available development time) for each player increases that game dynamic intensively. Accordingly, each player has a defined amount of development time and has to decide which development methods should be applied and which quality level should be considered. Typically a higher quality level requires more development time. In parallel the aesthetics and graphical appearance of the game was defined and evaluated. *MbSys* uses classical elements for game appearance, e.g. printed game plan, 3D-characters, playing cards and dices. For game introduction and special events announcement the narrator will be support by audio-visual elements.

Presently *MbSys* is in the production phase and it is planned to apply *MbSys* for Model-based Systems Engineering education in the second half of this year.

4 SUMMARY AND FUTURE WORK

MBSE can have various benefits for the development of complex products but different barriers can inhibit a successful implementation. Gamification approaches can support by overcoming these barriers. Therefore this paper presents an appropriate development process, including different phases and essential elements, for simulation games. Furthermore, this paper gives an insight into the development of the simulation game *MbSys*, which follows the evolved development process. The target of future work is the application *MbSys* to support MBSE implementation and the identification of conclusions for the educational success.

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INVESTIGATION OF PROCESSING TEST RESULTS BASED ON KNOWLEDGE SIMILARITY

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ABSTRACT

The traditional scoring is based on the difficulty of the task. However, the same total score can be earned with different knowledge, hence it is difficult to create homogenous groups by only relying on the total score. In our work, we aim to present a new scoring method where such knowledge-based groups can be created, as opposed to the previous point-based method.

For comparison of the test result done by the students, we utilized different distance measures. The main challenge with finding the similarities between the results is the high dimensionality of the data compared to the total number of observations.

First, we used the traditional Minkowski distance with different p values, then we used local similarity hashes and high dimensional embedding techniques designed originally for natural language processing. With these never before used techniques, we were able to identify students with similar skillsets and knowledge. Furthermore, we utilized dimension reduction methods (t-SNE and UMAP) to make a lower dimension representation where we can cluster the data easier. These clusters and pairwise similarities were assessed by oral exam subjective scores.

The teacher's subjective scores correlated more with this new metric-based method of scoring than the total test score itself. The presented procedures can not only be used effectively in research but can also help to get a more complete picture of the students' knowledge we teach in everyday practice.

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1 INTRODUCTION

Testing has several functions in the learning process. However, in many educational contexts, it is still used only to check knowledge: the test is the way in which the student reports on the extent to which he or she has mastered what has been learned. However, recent brain research suggests that tests may have a greater role: testing can be seen as part of the learning process, because rather than repeatedly introducing the knowledge to be learned, recall is a more effective tool for learning. With tests of the right difficulty and taken at the right time, we can acquire long-term knowledge.

The analysis of the results obtained is also an essential element. We can now visualise data in a number of ways, some of which are almost artistic, but they are not all about beauty . A well-done visualisation can also lead to the discovery of new correlations. Assessing the results obtained in different ways can enrich our analysis.

Evaluation as feedback is an important part of the learning process. There is evidence that timely feedback during learning increases the effectiveness of the process [1], [2]. Correct assessment and appropriate feedback also inform the learner whether his/her preparation has been adequate. As well as being fair, good assessment should also be motivating. It should encourage the student to progress to the next level by doing more work.

Good assessment of knowledge and ability is also important for the person doing the assessment, for example, if you want to create smaller, more homogeneous groups in a large, heterogeneous group of students to increase the effectiveness of teaching, it is important to define the groups well.

It is not uncommon for students to come to a course with very different levels of knowledge. Then, when evaluating their tests, it may be important to be able to find errors that result from a lack of knowledge (for example, a student cannot solve a problem because he or she does not know how to calculate scalar multiplication), in order to distinguish them from those that result from, for example, an incorrect algebraic transformation. With this knowledge, we can form groups of students much more effectively.

As the drop-out rate in STEM fields is also high in Europe, many higher education institutions are measuring first-year students to identify those at risk and start catching them up as soon as possible. It is also important to find first-year students with exceptional potential, for whom talent programmes offer the opportunity to develop their skills in a way that is appropriate to their abilities.

For many first-year university courses, it is a prerequisite that the student has passed a test from the secondary school curriculum at the appropriate level. Such tests, which can cover several subjects, are designed to check the knowledge required for entry to studies. It should be borne in mind, however, that if an incoming student fails a few tests in the first week, this may discourage him from starting his studies. It is also not ideal if, after the admission procedure, a lengthy series of tests is used to determine who needs catching up. In addition, there is often insufficient time to complete tests in class, and extra-curricular activities are difficult to organise for large classes. It is important to use the same or very similar assessment tests, but in this case, it is not possible to write at different times.

In the case of voluntary participation, we have found that the very people who do not attend the sessions advertised in this way are those who later have difficulties in progressing according to the curriculum. We therefore consider this solution to be of limited effectiveness.

It can therefore be seen that, while measurement is certainly desirable, it is not so easy to implement. And once we have measurement results, it is worth making the most of them. We now have increasingly efficient algorithms to help us with the evaluation.

In the following, we would like to show examples of what we can learn about a population by evaluating the results of a test using different methods. Often, we are looking for answers to the question of who wrote similar tests, how far apart the students are according to a metric of our choice.

One of the major problems to be solved in online education was to reduce the amount of cheating. The EduBase online education platform that we use has several features that try to reduce the use of illegal devices [3]. For example, the system alerts when the screen is being recorded or when the person completing the test leaves the page. The order in which the test taker progressed through the tasks and the time spent on each task can also be accurately tracked. But there are still plenty of opportunities for cheating. With the analysis we present, we have been able to filter out students who may have been communicating on another device.

Furthermore, we demonstrate a data visualisation procedure using graphs that displays the results of a test in an easy-to-understand format. In all cases, we will try to present our computational results in a visual way.

2 DATA

For our analysis, we use the results of a test we developed at the Budapest University of Technology and Economics, which consists of mathematical and linguistic elements and is used to identify those at risk of dropping out and those who deserve talent support. However, the procedures presented here can be used to analyze the results of any test. Only a handful of parameters are required for the analysis, the most important is the results of each question. This can be a continuous variable, an integer, or a binary value. Other parameters also can be used, for example, the time it takes to answer each question or the background of the student (ie: high school, study group). At our university, we have study groups and in online settings, they tend to work together, even if they should work independently. Previously, we used a single-component test with only mathematics problems to measure the proficiency of first-year students, but we found that the picture is more nuanced when language problems are included [4], [5]. Indeed, the results of the mathematics tests are distorted by the fact that students focus on practising different types of tasks already in preparation for the exam. This proved to be a winning strategy in that situation, the lack of real understanding did not significantly affect the outcome - the grade obtained. We often find that students who come to us are calculating derivatives or doing integration, but they do not have the correct understanding of the meaning of derivation or infinitesimal summation. The greater variability of language tests makes it much more difficult to learn without a deeper understanding, so the use of a complex test has proved more effective.

The maths part of the test consisted of 14 tasks, while the language part consisted of 30 tasks, with 90 minutes to complete. (The larger number of language tasks is due to the more detailed breakdown of the tasks for electronic evaluation, while in mathematics it was not necessary to break down the tasks into smaller parts.) Language questions are similarly varied. The tasks are weighted by difficulty. This provides us with a data set that measures a wide range of knowledge.

The other test on which we present a possible form of evaluation and data visualisation is the results of a test measuring geometric reasoning, compiled by Usiskin based on van Hiele's theory.

The subjects of both our tests were first-year students of mechatronics and energy engineering admitted to the Faculty of Mechanical Engineering of BME in 2020. A total of 153 participants took the test. They are students with high admission scores, high aptitude and the most homogeneous knowledge levels. So, when we define distances, we are actually looking at a population of very similar elements, according to their secondary school results, their matura exam, and trying to find the subtle differences that can be taken into account to create effective groups of students and to identify the gaps that need to be filled for them to succeed in the obstacles.

3 METHODS

Determining the distance between two data points is not always straightforward. Mathematicians have developed several methods to characterise this distance. There are two main directions: one is designed to measure the distance of binary vectors (vectors containing ones and zeros), and the other is for real-valued vectors. An example of the former is the Jaccard distance, which we use, and the latter is the Minkowski distance. The Minkowski distance reproduces several well-known distances with the appropriate choice of parameter, such as the Manhattan distance ($p = 1$) or the Euclidean distance ($p = 2$). There are also much more complex metrics with area-specific properties, but these will not be discussed due to space limitations.

These metrics can also serve as a basis for the construction of a graph. One way to create such a graph is to construct a matrix of pairwise distances, which becomes the adjacency matrix of the graph. On this basis, the weight of the edge between two data points will be proportional to the distance between them. The resulting matrices can now be well studied using graph theory methods but can also be used as a basis for manual studies using, for example, a Force Atlas visualization. In this case, the edge weights act as virtual springs, with samples of similar properties pulled together and outlier points pushed apart.

The best known and frequently used dimensional reduction method is principal component analysis. This allows us to identify the directions with the largest variance, which is useful information in the reduction process because it tries to keep the differences in those directions that allow the data to show distinct groups. This procedure gives a good picture of the distribution of the data globally but is not as detailed locally.

The t-SNE method tries to preserve this local relationship by keeping points that are nearby in the higher dimensions as well as in the lower dimensions. This closeness is mostly controlled by the adjustment of the number of nearest neighbours. The UMAP method similarly focuses on maintaining local similarities but is also more effective at maintaining global similarities. This method is also based on nearest neighbours and builds a graph based on their distances, optimizing the lower dimensional similarity using a stochastic gradient descent method. More modern versions of these latter two methods have appeared (TriMAP, PaCMAP), which are now able to produce good dimensionality reductions without complex parameterization, considering global and local features, but they do not always provide better results. These were also tested but did not give significantly better results.

We used Python for our analysis because it provides easy access to huge amounts of statistical and computational methods. The first step is data ingestion and cleaning. The data comes in XLSX format for the online learning platform. After removing the unnecessary variables and missing values we can compute the distances between the students. Based on these distances we can find the most similar students. A graph can be created based on this distance matrix, the distance matrix is as assigned as the graph's adjacency matrix.

This similarity can be due to knowledge similarity or due to cooperation. Based on the timing of the test and the order of the questions we can sort out the cheaters. Overlapping time and the same order of completion can be telling in this situation. In the last part, we reduce the dimensions of the data with the aforementioned methods. This step is for visualization, manual similarity checking, and clustering.

4 RESULTS

The most common way of evaluating a test is to weight the tasks according to difficulty and then add up the scores for each task to get a final score, which can be used to give the student a grade. Students with the same score will then receive the same mark, but their knowledge may be different. Consider an essay where you want to check a wide range of knowledge. If you have hundreds of students taking a test, online testing is preferable as it is quicker to correct. Another advantage is that the results of the tasks corrected by the machine can be easily retrieved and used immediately for analysis.

Figure 1 illustrates the results obtained using UMAP on the study population. Each dot represents a student, the same colour indicates that part of the maths-language test that was designed to test how the knowledge acquired in high school was applied in situations that they had encountered in high school. (The first third of the math test assessed procedural skills, here were algebraic transformations, and calculations with identities. The second third was the part mentioned above, while the last third was to solve problems for which the students had acquired the necessary knowledge in high school, but the task was unusual, most likely they had not or had only rarely encountered the application of their knowledge in such a setting.) Although the colouring was done according to the scores on the middle block of the mathematics test, the separation, finding students with close knowledge of each other, was done based on the overall test scores. We can see that there are dense clusters of the same colour in the point cloud, marking students who are close to each other in terms of knowledge, but it is also clear that points of the same colour can be very far apart. If we want to create groups with homogeneous knowledge, then students represented by the distinct point clusters in the figure can be placed in a group.

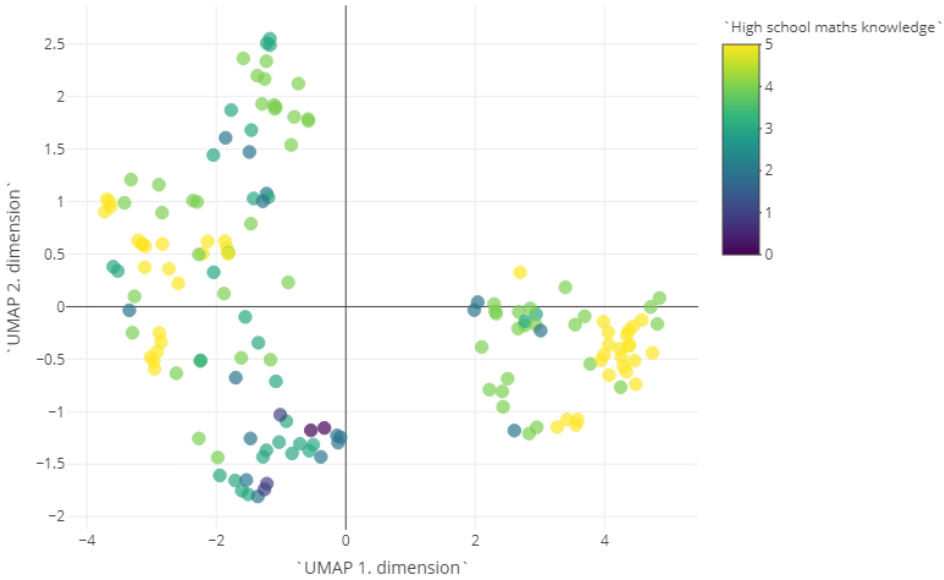

Fig. 1. UMAP results – the colour represents the high school math knowledge

The result of the clustering obtained by t-SNE is shown in Figure 2. Here again, each point represents one student, and the colours are defined according to the maths scores in the maths-language test. Red represents a score of 0, while purple represents the maximum score. The figure shows several small clusters, with those making the same type of error closer together. No larger, distinct clusters have emerged. It is also striking that students with a medium score are almost evenly distributed in the point cloud. This follows from the fact that they may have made the most type of mistakes.

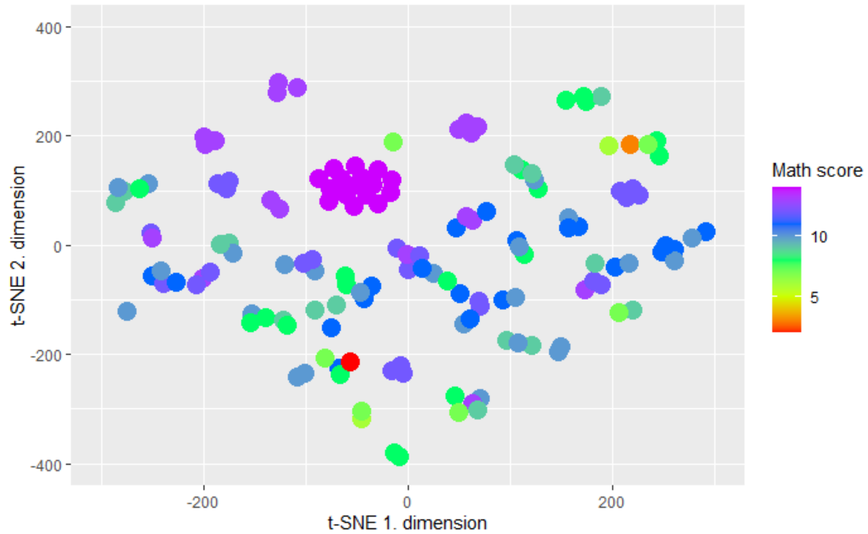

Fig. 2. Result of t-SNE based on the test – the color represents the total math score

In Figure 3, the dots are coloured according to the score on the mathematics test, representing one student. The figure illustrates the distance of each completer from a correct completion.

In the figure on the left, we have used the so-called L1 norm (Manhattan distance), while in the figure on the right, we have used L2 (Eucledian distance). The left graph shows that students with identical scores in mathematics are close to each other in this respect but can be very far apart in terms of their scores on the language test. Note, however, that those who scored poorly in maths were also far from perfect in the language test.

The figure on the right shows the distance according to the L2 norm. Here the reason for the clustering is due to the metric calculation, not to a real separation.

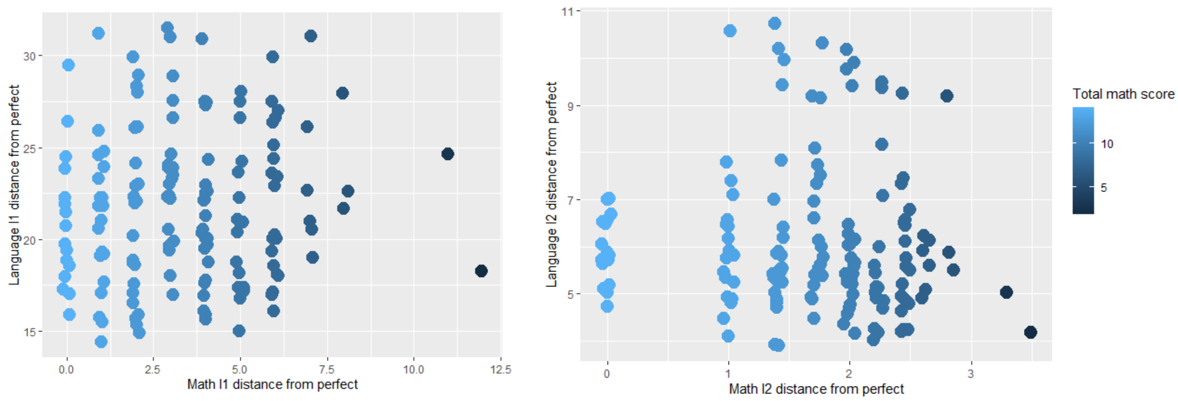

Fig. 3. L1 (left) and L2 (right) distance from a perfect test both in the math and language part

4.1 Investigating cooperations and cheating

The use of distance metrics and the overlapping of time periods allows cheating to be detected. If the match is high and the temporal relationship is given, cooperation may be at work in many cases. Proving this is difficult, but the closeness suggests that the students were working together. Cheaters are detected by examining the distance matrix and analysing it. There does not have to be a perfect match, just look for deviations much smaller than the average distances, for example, based on the histogram. The next step in the analysis is to examine the overlap in time. This procedure can play a key role in making online examinations more secure. A visualisation of our calculations is shown in Figure 4. The group circled in blue is the group of near-perfect candidates, where the reason for near-perfection is not cheating but few errors, while the group of a few candidates circled in green has the same number of errors and a similar temporal pattern. There is a suspicion that they wrote their test jointly.

4.2 Finding redundant questions

The 25 vertex graph in Figure 5 illustrates the results of the 25-question van Hiele test in the study population. The test reveals levels of geometric thinking. The van Hiele pair defined 5 levels of thinking, each level is measured by 5 questions. The first level is assessed by the first five questions, the second level by the second five questions, and so on. The test, questions and evaluations are described in detail in Usiskin's work [6]. The vertices of the graph are the tasks, which are connected by weighted edges. The weight of the edges is given by the probability of solving the problem of the two vertices of the edge. In the figure, the weight of the edges is represented by their thickness, length and colour. A thicker edge indicates a higher probability of solving. These are the short green edges in the graph. For example, many people solved problem 13 and 18 correctly. While the problems represented by the thin, long pink vertices (e.g., 2 and 9) were solved by few.

When assessing performance, we would like to assess the knowledge of those completing the tasks in depth. We would like to set a wide range of tasks, but the completion time should not be too long. The question arises as to which tasks can be discarded. The results of a test written in the framework of a pilot study can be visualised using the above procedure and it quickly becomes apparent that the middle tasks can be omitted from those that are linked with a heavy weighting edge. In this way we can optimise the completion time and reduce redundant items. This procedure can also help us in the teaching process: we can easily identify the types of tasks that need further practice and those that our students are already solving with good results.

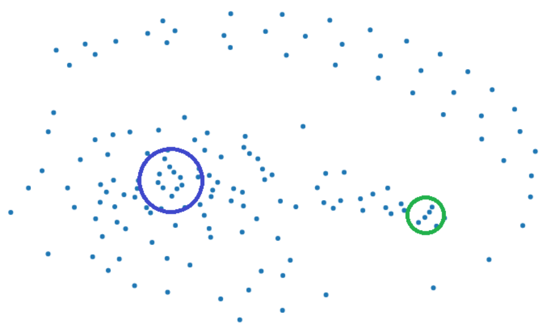

Fig. 4. Force-directed graph drawing of the knowledge similarity graph – blue circle shows the perfect tests, green circle for the suspicious students

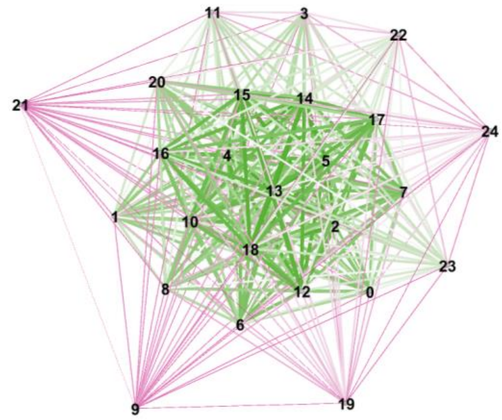

Fig. 5. Question similarity graph – green edge connects the similarly completed questions, purple for the large differences

5 CONCLUSION

Cheating became a huge problem in online exams during the pandemic and its detection requires manual reviews which is not feasible for large student groups. We encountered problems with knowledge homogeneity, some students lack a basic understanding of math due to inefficient online learning during their last year in high school. These large disparities make catch-up lessons essential.

Above, we have presented methods for evaluating test results, which not only visualize the results obtained in the exams but can also be useful for detecting cheating or for group creation based on similar knowledge, which can be crucial for efficient teaching.

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CHANGES IN LEARNING STRATEGY AND LEARNING TIME IN THE WAKE OF THE PANDEMIC

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ABSTRACT

University studies were also significantly affected by the pandemic. The first-year students had already spent the last months of high school, which are especially important for graduation, in distance learning. In Hungary, the graduation procedure was changed due to the epidemic. Education was completely digital in hybrid form: the lectures were held online, and the seminars were attended in-person and from September of 2021 again in-person. Our research team has been monitoring learning time and effectiveness for years using the EduBase online educational platform, which provides a framework for all teaching aids for the calculus subject. In our research, we analysed the learning processes and their effectiveness of mechatronic and energy engineering students who were admitted to BME in 2020. The results were compared with the learning habits of the class of 2018, with whom a detailed study was also performed. It can be stated that the pandemic greatly influenced the learning time: students took advantage of the available practice opportunities to a greater extent in digital education, which did not reduce the practice time during the end-of-semester spurt, thus, learning became more balanced. Considering the high school results, it can be observed that on average, those who took advantage level subjects spent more time practicing, even though they had

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already mastered some calculus in high school. In addition, test scores also influenced practice time, while students coped successfully even with the more difficult tasks.

INTRODUCTION

The transition from high school to university is challenging for students even without the difficulties of the epidemic. In 2020, it was especially difficult for graduates. Knowing that the first-year students had already spent the last months of high school in online education, and due to the epidemic, only hybrid education is implemented at the Budapest University of Technology and Economics, we paid special attention to our students' learning. In the summer of 2020, we created a carefully compiled workbook. During the online lectures, the students were able to fill in the missing parts of the workbook (e.g., proofs, examples) and take notes on it. During the semester, a video was created for each topic weekly, in which we presented a detailed solution to exercises. In the EduBase online education platform, students had parameterized practice exercises for each topic. Thus, each time they entered the platform, they got a different task. The students could do their weekly homework also in this EduBase system. Furthermore, they wrote the first and second midterms and the exam via this same platform. Lectures and weekly consultations took place at MS Teams. Therefore, the whole learning process became easy to monitor. For each student, we could see every day how much time they spend on the calculus subject (e.g. doing homework, practicing), when and how effectively they deal with the material.

We have carried out similar monitoring in previous years [1],[2],[3], while attendance education was still ongoing. The main result of these studies was the following: although students willingly learn using the online platform, towards the end of the semester, when their duties accumulate, they spend much less time practicing. We knew that we need to pay close attention to this in this pandemic and try to prevent this decline. At the beginning of the semester, we tried to assess the students' level of knowledge, skills, and level of thinking with several tests. Thus, we attempted to screen out students who may have difficulties during the semester to help them if needed. We assigned senior tutors to our students. A tutor dealt with 10-15 students, paid more attention to them, and held individual consultations for them. Both tutors and teachers were very enthusiastic and engaged with the students to help them successfully overcome the obstacles of the transition to higher education.

1 DATA AND METHODS

1.1 Investigated group

The students in our study population were admitted to two majors with the highest admission scores of the leading technical institution in Hungary. In 2020, the 433 points were for mechatronics, and 349 points for energy engineering were the inclusion point limit. A maximum of 500 points can be earned [4]. The average admission score of the mechatronics in our study population is 459 points, the standard deviation is 15, while the average score is 421.5, and the standard deviation is 33 points for energy engineering students. A large proportion of students came from a high school where they studied mathematics or science subjects in a higher number of hours. This ratio is 51.6% (32 students) for energy engineering students and 51.1% (47 students) for mechatronic students. 59 (64.1%) of the mechatronics students and 41 (66.1%) of the energy engineering students graduated in advanced level in mathematics. They studied math at an advanced level, which means they had at least 5 math classes a week as a high school student. Furthermore, their high school curriculum included differential and integral calculus, meaning that they had already learned a lot about what is described in the calculus subject.

1.2 High-school learning method during pandemic

It can be seen that 20% of energy engineering students had no part in any education, while this proportion was approximately half in the case of mechatronic students. This is a significant proportion, considering that students come from good ranked high schools for these majors.

2 TEACHING PROCESS

2.1 Course structure and requirements

For first-year energy engineering and mechatronics students, the calculus subject consists of 2x90 minutes of lectures and 1x90 minutes of seminars per week. The condition for participation in the oral and written final exam is successfully completing first and second midterm and tests at least 40%. The final grade is determined as follows: a student can get a maximum of 100 points during the semester, 20-20 points for the tests, 60 points for the written final exam, in addition to 10 extra points for additional optional tasks. Based on their score, students will receive a recommended grade. The final grade is obtained with a maximum deviation of ± 1 grade from the recommended grade based on the student's performance in the oral exam.

2.2 Education method during the semester

The first six weeks of the autumn semester went as so-called hybrid education at Budapest University of Technology and Economics: the lectures were held online, the seminars in the traditional, attendance way. Due to the worsening epidemic situation, the university switched entirely to online, distance education from the second half of the semester (November 16, 2020).

2.2.1 Lectures

The lectures of the calculus course were held online throughout the semester via the MS Teams system. At the scheduled time, the students were able to participate in the lecture together with the lecturer, at the same time. Thus, they could immediately ask their questions and react to the learning material. All lectures were recorded so students could watch them at any time after the scheduled time. A workbook was prepared for the lectures, which already contained the most important definitions and items, thus helping to take notes. However, there were omitted parts (e.g proofs and examples), thus encouraging the students to actively participate and pay attention to the lectures.

2.2.2 Seminars

The seminars were held in the traditional, attendance way with small groups during the hybrid system. Nevertheless, all seminars were uploaded to the EduBase digital classroom in a video format so anyone could watch them again, especially those who were unable to attend the seminars due to the pandemic. At the end of the attendance seminars, the students wrote a small test for one extra point from the material of the given lesson. In the second half of the semester, during the online education, the videos of the seminars had already been uploaded at the beginning of the week, and students had the opportunity to consult in the scheduled time of seminars via the MS Teams.

2.2.3 Homework

Throughout the semester, students had the opportunity to complete homework in the digital classroom for extra points and practice on quiz sets after the submission deadline of homework. In the first half of the semester, while the seminars were also held in attendance, students were able to begin completing their homework after the scheduled time of these seminars. In the second half of the semester, the homework always opened on Mondays after the seminar videos were uploaded into the digital classroom. The EduBase system allowed us to track students' learning processes. The first and second midterms, as well as all the written final exams were also conducted via this EduBase platform.

2.3 Education platform - EduBase

Online education was implemented with the unique testing and examination system of the cloud-based education platform EduBase (www.edubase.net) [1],[5].

3 RESULTS

3.1 Study-time patterns

The figure below (Fig. 1) shows how many seconds students worked in EduBase. Outlier data are not presented. Very short practicing (shorter than 600 s) was not considered. The horizontal axis shows the time of practice in hours and the vertical axis shows the number of entries. The approximately half-hour practice time is the most common. Students often practice for between half an hour and an hour, while practice times longer than 60 minutes are becoming less frequent.

Comparing data from the 2018 pandemic-free semester with 2020, it can be seen that more people practised for longer periods during the pandemic. The detailed analysis of the data also revealed that in 2020 there were 26 students (both populations were made up of nearly the same number of students of the same ability) who practiced more than 40 hours, compared to only 8 in 2018.

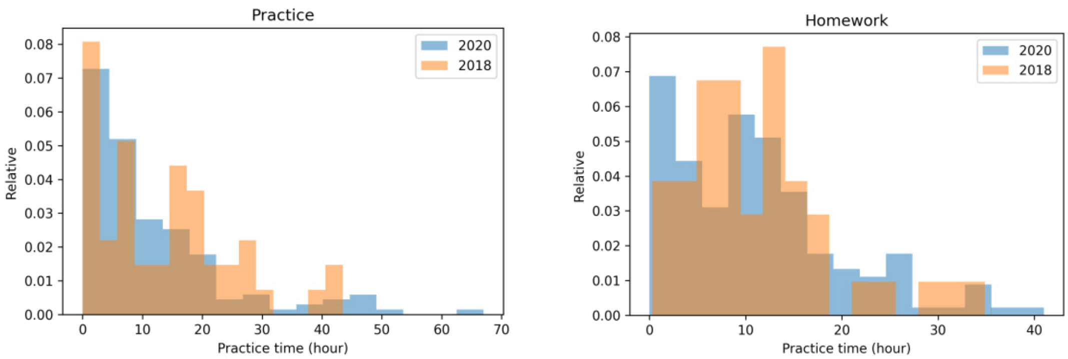

Fig. 1. Distribution of time worked during the semester

Fig. 2 shows how the opening of homework and practice quiz sets developed during the semester. The more intensive preparation for the first and second midterms in the middle of the semester and at the end of the semester is clearly visible with outstanding peaks. In these two cases they practiced more often and more. The peaks seen in late December and January are the preparation peaks for final exams. In these cases, if we compare the peaks to the number of participants in each final exam, we can say that the preparation takes approx. the same for all final exams.

The most remarkable difference between the autumn 2018 semester (left graph in Fig. 2) and 2020 (right graph) is that in 2020, students spent more time practising and solving homework in the second half of the semester. It can also be seen that learning was more even, which has a positive impact on learning efficiency [2], [3]. The data are in accordance with our experience: in pandemic-free periods, in the last weeks of the semester, students are usually so overloaded that many of them are already "struggling to survive", attempting to solve only the compulsory tasks in an acceptable way. Preparing for exams (highlighted in red) during the pandemic is also more characterised by distributed learning throughout the semester.

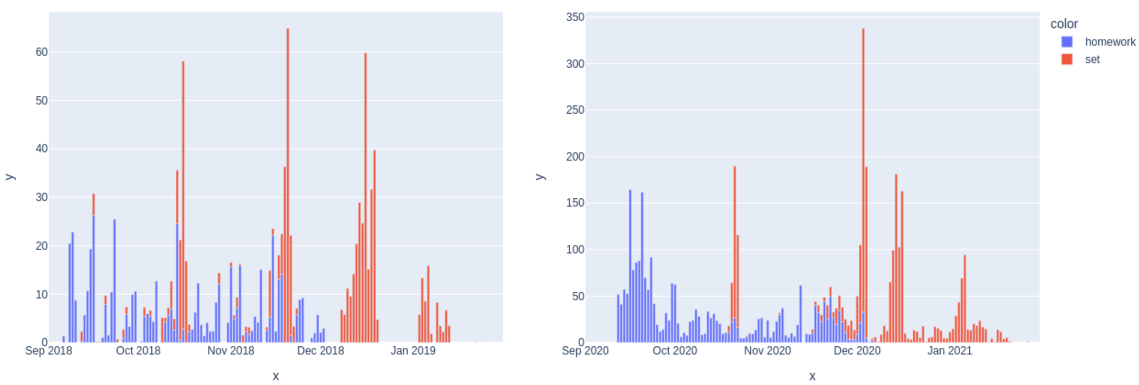

Fig. 2. Distribution of total homework and practice quiz set openings

The homework of the current week was open on Thursdays (after seminar) during hybrid education and on Monday evenings during entirely online education in the second half of the semester. Students had one week to solve their homework. Thus, for the online period, Monday midnight was the submission deadline of homework assignments. Examining the daily distribution of openings, we found that practice began most often on Wednesday, while homework was most often done on Thursday. Weekends were not preferred for practice or doing homework. We consider this fact important as it suggests that the students did not leave the preparation at the last minute, they tried to distribute the practice evenly.

Figure 3 shows the weekly distribution of learning time in 2018 and 2020. The peaks are the days of the week. In 2018, many students were most engaged with the curriculum the day before the deadline (Sunday high peak), while in 2020 the peaks show a much more even spread of learning.

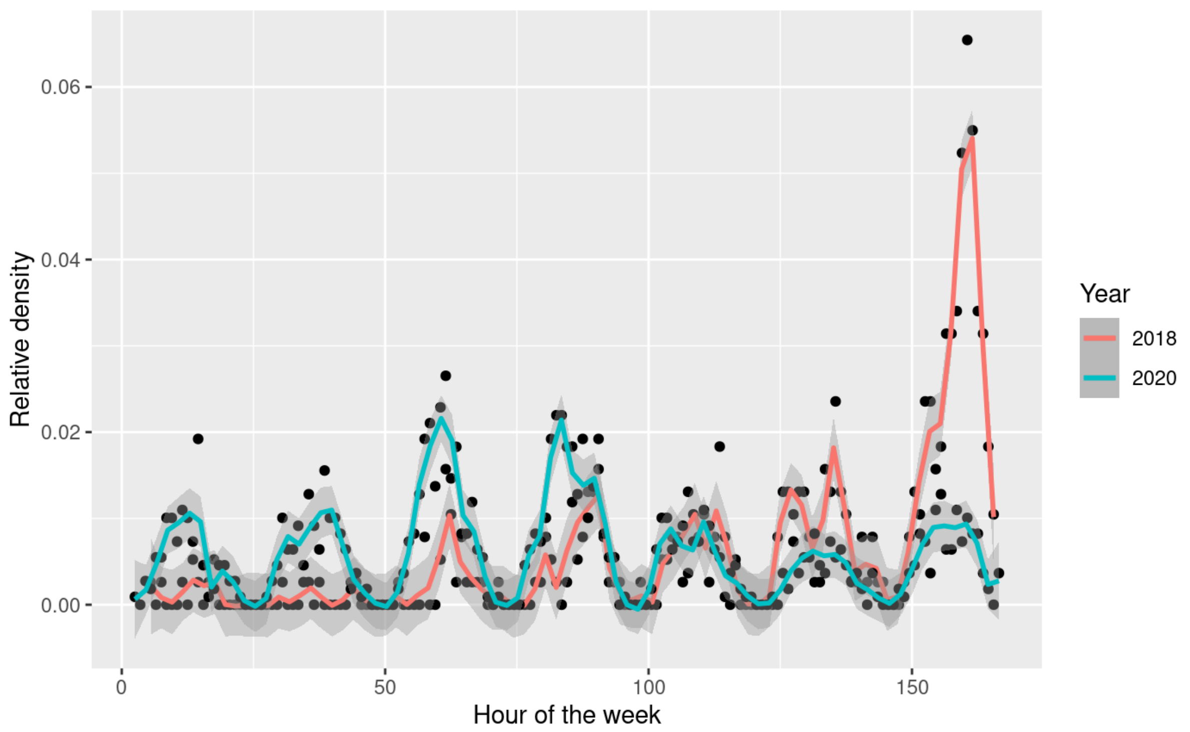

Fig. 3. Distribution of weekly homework and practice time

3.2 Test results

Let's see how students with different study periods performed in the tests in the autumn semester 2020. In the graph, the size of the dots is proportional to the time spent studying, the larger the dot, the more time the student is spending studying. Each dot represents one student.

Figs. 4 and 5 show the relationship between the results of the first and second midterms of the calculus subject and the results of the mathematical-language test written in the first week for each student. The math-language test was written to estimate the level of knowledge of the incoming students. The language part is unusual in technical higher education. The purpose of this section is to compensate for the distorting effect of excessive preparation for mathematics tasks [7]. Each dot in the figures represents one student. The radius of the circle is proportional to the online learning time (outlier data have been filtered out). The students marked with a blue dot attended a special mathematics or science class during high school, so mathematics had a greater emphasis in their high school education. Students marked with a red dot only attended basic maths lessons. Based on the figure for the first midterm, better math-language tests were generally coupled with better first midterm results. Furthermore, those who spent less time practicing and learning, rarely achieved good results. Although, you can see a few blue circles with a small radius and good results. This can be explained by the fact that the material of the first midterm was already discussed deeply in the special mathematics or science classes during high school.

Fig. 5 shows the results of the second midterm. The chart can be divided into 4 rectangles. As mentioned earlier, the second midterm mainly contained material that was not encountered or just mentioned in high school. The light blue rectangle in the lower left contains students with little incoming knowledge who also perform poorly at university. Luckily, it includes only one student who, as the size of the dot shows, didn’t spend much time practicing. In the lower right, light green rectangle, the students did poorly on the mathematics-language test, but apparently practiced a lot during the semester, and the second midterm was already written with good results. Students in the purple rectangle in the upper left, despite writing a good math-language test, practiced little and were not successful in the second midterm. The students in the upper right, yellow rectangle performed well on both measurements, and many of them also devoted a lot of time to practice. Only a few small radius circles can be seen in this range.

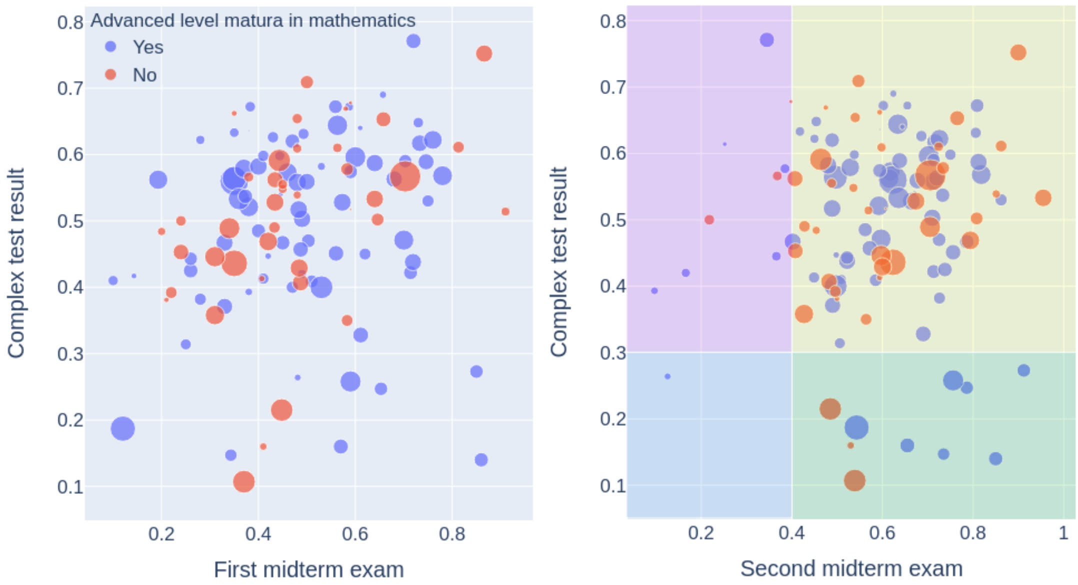

Fig. 4. (left) Relation of student performance on the 1st midterm exam and on the complex test result

Fig. 5. (right) Relation of student performance on the 2nd midterm exam and on the complex test result

4 CONCLUSION

As a conclusion, it can be stated from the detailed analyses of this partly hybrid and partly online semester that first-year students could solve the difficulties of the pandemic situation. Instead of the campaign-like learning that is so common in higher education, providing inadequate knowledge in the long term, students worked evenly, mostly devoting an adequate amount of time to learning. They did the calculus exam well. 20 (13%) students earned excellent grades, 34 (22%) good grades, 51 (33%) fair grades, 31 (20%) sufficient grades, while 16 students failed. The exams consisted of two parts, a 90-minute online written exam with numerical exercises, followed by an oral test on theory. The results were a little lower than usual, but when compared to the results during the pandemic, it was outstanding. In the case of exams with only an online written part, it was common to see better results than before during the pandemic, but much poorer results in the oral part. In calculus, the EduBase fraud detection system did not detect the same bias as in the written exams in other subjects. The slightly weaker results in the oral test could also be explained by the fact that there were no oral exams in Hungary in spring 2020, so that students had their first opportunity to orally test their knowledge of a large amount of material at university. Learning and then orally reproducing a large amount of theory was not easy for many.

For the academic year 2021/2022, education at our university was conducted in-person. For our students, this was more of a start than a return, as it was the first time during their university studies that all their classes were taught in-person format. Calculus 3 is the last regular mathematics course, followed by a comprehensive exam. In the autumn semester of the 2021/2022 academic year, we have tried to implement the distributed learning experienced during the online period. We also monitored the Calculus 3 course in EduBase. The analysis of these data and the comparison with the same subject in the previous academic years is still ongoing, and we intend to publish our results in further contributions.

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PERSONALITY DIMENTIONS, GLOBAL AND ETHICAL PERSPECTIVES AND ENGINEERING STUDENTS'S ETHICAL DECISIONS

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ABSTRACT

Motivation is an important predictor of ethical awareness; however, it is not easy to assess. The goal of our study is to examine the relationship between motivation and ethical awareness in engineering students. We focus on two personality measures: person-thing orientation and spheres of control and test their association with ethical awareness using engineering scenarios that present ethical dilemmas. We predict that engineering students who score higher on the personality dimension of person-thing orientation will display more ethical awareness than those who score lower. We also predict that students with a higher level of personal control will also display more ethical awareness. Two groups of students were involved in the study. Group 1 was formed by fifty-three first-year engineering students from University in the United States and Group 2 was represented by sixty-four sophomore engineering students in Engineering School in Spain. Students worked individually on case studies that presenting ethical dilemmas; they were asked to write short essays describing how they would respond to each situation. Then the essays were analyzed using an ethical

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reasoning and a global awareness rubric. Results revealed that 1) the context/nature of the students' responses to the case study varied greatly, 2) personality traits and global and ethical perspective, all correlate to students' ethical decisions as measured by their responses to the case studies scores, 3) there is an alignment between the SOC and the Global Perspective Inventory (GPI) dimensions that merits further exploration.

1 INTRODUCTION

1.1 Engineering students and ethical reasoning

Since its formalization nearly four decades ago, engineering ethics has made considerable progress, from creating communities of practicing scholars and journals partially devoted to the field, to obtaining recognition, increased emphasis, and formalized courses within the larger engineering community. One of the major goals of engineering education to date has been increasing the ethical sensitivity of students in engineering programs. However, Michael Davis emphasizes three components of the engineering ethics curriculum that are vital for the next generation of engineers that go beyond ethical sensitivity: the history and sociology of engineering, the ability to communicate the complexities and ethical issues of their work to other engineers, and the philosophical knowledge to ground the decisions they make in their work [1].

Codes of ethics, as outlined by many professional organizations of engineers such as ASME and ASCE, have become the commonplace method for introducing collegiate engineering students to ethics education. While the details of these codes of ethics differ across disciplines, some common themes across disciplines include 'acting in the best interests of your employer or client,' avoiding conflicts of interests, and ensuring public safety. In addition to examining codes of conduct, case studies have been the primary pedagogy utilized in ethics education. Case studies can take a complex situation allow students to explore and condense it down to the core issues within the case, which can range from issues of human error to examining competing interests between involved parties [2].

Utilizing codes of ethics, case studies, and various other pedagogical techniques, ethics education has been shown to have an impact of the moral outcomes of students. In a quasi-experimental study conducted on business students at a US university, May and Luth found that students, when exposed to ethics training, whether it was imbedded in other courses or in a stand-alone course, displayed higher levels of moral efficacy (the ability to make ethical decisions), moral courage (the motivation to act on the morally responsible decision), and perspective-taking than students did not have exposure to ethics education [3].

1.2 Personality dimensions and motivation of ethical awareness

Motivation is an important predictor of ethical awareness; however, it is not easy to assess. Multiple scales and theoretical frameworks have been created to examine how to predict ethical awareness and behaviour, with varying success. One framework for understanding how students think about ethical scenarios, presented by Magun-

Jackson, adapts Kohlber's Theory of Moral Development to implement ethics in engineering education. The framework highlights how students, as they develop morally, move from thinking of their own needs to thinking about those related to them (i.e. family) and eventually to how actions will affect society [4]. Another theoretical framework, presented by Bairaktarova and Woodcock, outlines a theoretical framework for predicting ethical awareness and behaviour based off Ajzen's theory of planned behaviour and Harding et al. inclusion of moral obligation [5], [6]. The revised framework included three personality scales to better predict student behaviour, Person Orientation, Thing Orientation, and the Spheres of Control.

Person and Thing Orientation have been used in recent literature to discuss potential reasons for the underrepresentation of women in various STEM fields, including engineering. Su and Rounds , in their meta-analysis of various studies examining gender differences across STEM professions found that women's interests lead to them choosing more people-oriented and less thing-oriented work environments when choosing their career in STEM [7]. Similar work discussing the usage of person and thing orientation in STEM, completed by Graziano, Habashi, and Woodcock (2011), who worked to remodel the PTO model, found that Thing Orientation differed across men and women, but that PO did not [8].

Highlighted in Bairaktarova and Woodcock's proposed framework for predicting ethical awareness and ethical behaviour is the Spheres of Control. Divided into three domains of control, Personal Control (PC), Interpersonal Control (IPC), and Socio-political Control (SPC), which each examine an individual's perceived control, or personal efficacy, within an environment [9]. Each of these Spheres represents an environment in which a student may feel they are in control of the decision-making process. This directly ties to the research of May and Luth which found that ethical teaching directly increased moral efficacy [3].

The goal of our study is to examine the relationship between motivation and ethical awareness in engineering students. We focus on two personality measures: person-thing orientation (Graziano et al.) and spheres of control (Paulhus) and test their association with ethical awareness using five engineering, scenarios that present ethical dilemmas. We predicted that engineering students who score higher on the personality dimension of person-thing orientation will display more ethical awareness than those who score lower. We also predicted that students with a higher level of personal control will also display more ethical awareness.

2 METHODOLOGY

2.1 Study settings & participants

Two groups of students were involved in the study. Group 1 was formed by fifty-three first-year engineering students from Virginia Tech in the United States and Group 2 was represented by sixty-four sophomore engineering students in the Engineering School the Universitat Politècnica de València. Students worked individually on case studies that presenting ethical dilemmas; they were asked to write short essays describing how they would respond to each situation. Then the essays were analyzed using an ethical reasoning and a global awareness rubric.

2.2 Study measurements:

Person and Thing Orientations

We administered Graziano et al.'s Person-Thing Orientation Scale, which taps into the alignment of participants' interests with people and things. The scales consisted of 9 and 5 Likert-like questions for Person-Orientation and Thing Orientation, respectively, with reverse-coded questions. Participants took both the Person subscale (PO) and Thing subscale (TO), which had reliabilities of α = 0.76 and 0.85, respectively.

Spheres of Control

The Spheres of Control (SOC) Scale was developed by Paulhus to measure perceived control in three domains - personal control (PC), interpersonal control (IPC), and socio-political control (SPC) [9]. Each subscale consists of 10 Likert-like questions (30 total), that contained 5 reverse-coded questions. The subscales have reliabilities of α =0.80, α =0.83, and α =0.75, respectively.

Ethical Case Studies

Students were provided with 4 ethical scenarios, each one paragraph long, that asked students to identify if there was an ethical issue within the scenario and to come to a decision based on the information provided. The scenarios described:

- *Scenario 1*: A Material Engineer faces a dilemma of using a cheaper polymer in a biomedical device that carries some risk of damaging human skin or choosing a more expensive polymer that has no known risks that will also take a much longer time to deliver.
- *Scenario 2*: A Mechanical Engineer is asked to by the CEO to change the data of a competitor's product listed on their company website to make their company's products look better.
- *Scenario 3*: After a time-intensive and expensive design process for a new microchip, a microchip testing engineer is asked to lie about a the new products output specifications to the client.
- *Scenario 4*: A Team Lead is left in charge of an underperforming new hire and tight deadlines and are left to decide if they need to be replaced with a hopefully better hire or given enough time will improve.

Each of the 4 scenarios was followed up by questions prompting students to describe the ethical dilemma within the scenarios and the course of action they would take if they were the engineer in the scenario. The student responses to the scenarios were then rated as either 'below competent (0),' 'competent (5),' or 'above competent (10)' across three criteria:

Criteria 1: Explain and contrast relevant ethical theories
Criteria 2: Identify ethical issues in a complex context
Criteria 3: Articulate and defend positions on ethical issues in a way that is both reasoned and informed by the complexities of those situations

Two members of the research team rated each of the student responses for the three criteria listed above. Across all three criteria and all four ethical scenarios, an interrater reliability of 0.8, which is suggests substantial agreement across raters [10].

3 RESULTS

3.1 Scale Reliability

While the results analyzed below only represent those of the students from Group A, the data has been collected for the students in Group B, and is currently being analyzed and will appear in the final version of this conference paper. Additionally, initial analysis of Group B's data corroborate the findings of Group A across many of the subscales scales, from both the PO-TO and SOC respectively. The two groups (VT international students and UPV, Spain) were not significantly different from each other on any of the variables except thing orientation (TO). The first group had higher TO (M = 3.44) than the second group (M = 3.13) and the difference was statistically significant ($p < .05$). This difference will be reflected and explored more in the final draft of the paper.

The first step of the analysis was to ensure the reliability of the various subscales for the Person-Thing Orientation and the Spheres of Control. From these two scales, the PO, TO, PC, and IPC subscales all had acceptable fits, ranging from $0.7<\alpha<0.8$. However, the SPC scale had an unacceptable fit (α=0.342), which may be due to small sample size.

As seen below in Table 1, independent sample t-tests found no significant difference between the Total Ratings (all ratings combined) of the four case studies between males and females. Similarly, for many of the personality scales, there was no significant difference between males and females in all the variables except in the Thing-Orientation (TO) variable. Females had a significantly lower score (M = 2.95, SD = 3.20) compared to males (M = 3.57, SD = 3.60) on Thing Orientation. This was not expected as previous work by Graziano et al. (2012) found that females in STEM reported similar TO scores to their male counterparts while also reporting higher PO scores [8]. This difference may be due to the smaller sample size, which when the data from Group 2 is analyzed may align with previous works.

Table 1. Independent Sample t-tests for all variables by gender

	Statistic	df	p	Mean difference	SE difference	Effect Size
PC_Mean	-0.3576	50.0	0.722	-0.0949	0.265	-0.1214
IPC_Mean	-0.5900	50.0	0.558	-0.1594	0.270	-0.2003
SPC_Mean	0.2982 ᵃ	50.0	0.767	0.0563	0.189	0.1012
TO_Mean	2.4978	53.0	0.016	0.6273	0.251	0.8420
PO_Mean	-0.6424	52.0	0.523	-0.1897	0.295	-0.2171
Case1_Total	0.9645	52.0	0.339	1.5433	1.600	0.3259
Case2_Total	-0.6695	52.0	0.506	-1.4271	2.132	-0.2262
Case3_Total	0.5770	49.0	0.567	1.1341	1.966	0.2035
Case4_Total	0.0762	49.0	0.940	0.1585	2.080	0.0269

ᵃ Levene's test is significant ($p < .05$), suggesting a violation of the assumption of equal variances

A Pearson Correlation Matrix found that with cases 1, 3, and 4 the Total Ratings (all ratings combined) was not significantly related to PC, IPC, SPC, TO, or PO, which is depicted below in Table 2. However, Case Study 2 total score (the sum of a student's scores for the three ethics criteria for a given case study) was significantly related to Interpersonal Control (positive relationship; $r = .315$) and Thing Orientation (negative relationship; $r = -.269$). A positive relationship with IPC indicates that feeling in control of a situation with other people leads to better ethical decision making, which is consistent with the idea of moral courage described by May and Luth [3]. The negative relationship between the case study ratings and TO indicates that students may not have been thinking about how the results of fudging company data would affect other people, and simply saw the issue as a technical one of fixing an error.

Table 2. Pearson Correlation Matrix for all variables

	PC_Mean	IPC_Mean	SPC_Mean	TO_Mean	PO_Mean	Case1_Total	Case2_Total	Case3_Total	Case4_Total
PC_Mean	—								
IPC_Mean	0.272 *	—							
SPC_Mean	0.288 *	-0.050	—						
TO_Mean	0.166	-0.076	-0.034	—					
PO_Mean	0.089	0.076	0.065	0.358 **	—				
Case1_Total	0.224	0.259	0.034	-0.015	0.123	—			
Case2_Total	0.064	0.315 *	0.024	-0.269 *	0.157	0.483 ***	—		
Case3_Total	0.038	0.181	0.031	-0.089	0.054	0.570 ***	0.212	—	
Case4_Total	0.121	0.249	0.001	-0.205	0.155	0.502 ***	0.435 ***	0.479 ***	—

Note. * p < .05, ** p < .01, *** p < .001

Linear regression examinations of Case Study 2 found that both TO and PO were significant in predicting Case 2 total score. Thing Orientation was found to be negatively related to case study rating total score (β=-2.953, p=0.016). Students with higher scores on TO would be expected to have a lower score on the Total Rating on Case Study 2. Dissimilarly, Person Orientation was found to be positively related to case study rating total score (β=2.144, p=0.054). Students who have higher scores on PO would be expected to have a higher score on the have a higher Total Rating on Case Study 2. It is important to note that these trends did not exist for the other case studies. While it may be due to low sample size, which will be remedied with the addition of data from Group 2, it may be that Case Study 2 is unique in and of itself. This may have to do with the fact that Case 2 is the least lengthy of the four, and therefore may not have as much context surrounding it that students needed to identify ethical issues. Regarding the regression scores for TO and PO, Case Study 2 described interactions with people the least, instead focusing on the actor making up false schematics, which might be why people who had higher Thing Orientation scores had lower scores on this Case Study.

Table 3. Linear Regression for Case Study 2 Total Ratings

Predictor	Estimate	SE	t	p
Intercept	-3.494	9.31	-0.375	0.709
PC_Mean	0.152	1.16	0.131	0.896
IPC_Mean	2.099	1.10	1.907	0.063
SPC_Mean	-0.417	1.60	-0.260	0.796
TO_Mean	-2.935	1.17	-2.507	0.016
PO_Mean	2.144	1.08	1.979	0.054

4 SUMMARY AND ACKNOWLEDGMENTS

This research has found that for Case Study 2, Interpersonal Control is a positive predictor and Thing Orientation was a negative predictor of the student scores on Case Study 2. This aligns with previous research and the framework presented by Bairaktarova and Woodcock [6]. However, the research team is continuing to examine why IPC and TO correlations existed for Case Study 2 that did not exist for the other Case Studies and in future iterations may revise the Case Studies to be of similar length, description, and ask similar probing questions to the students. Future research will more closely examine the differences in scores between the first-year students from Group 1 and the sophomore students from Group 2, both in experience within the program as well as cultural differences that may exist.

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AN ANALYSIS OF ENGINEERING EDUCATORS' UNDERSTANDING OF COMPLEMENTARY STUDIES COURSES USING THE REPERTORY GRID TECHNIQUE

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ABSTRACT

Accreditation bodies such as the Engineering Council of South Africa and the Canadian Engineering Accreditation Board have a group of courses that fall under the umbrella of Complementary Studies. This term is used to describe a set of engineering courses that include knowledge areas other than the more common mathematical sciences, natural sciences, engineering sciences, design and synthesis, and work-integrated learning. Studies have shown that engineering educators sometimes view these courses negatively. They are seen as distracting the focus of the students on the so-called technical courses, which the educators feel are more important. This paper reports on a research study that explored the way that engineering educators make sense of complementary studies courses within an industrial engineering curriculum. The repertory grid technique was used to explore complementary studies courses when compared to other engineering courses within the same curriculum. The relationships between elements and constructs in the grids were analysed using the repertory grid techniques of principal component analysis and cluster analysis. What became clear was that while most of the educators interviewed did recognise complementary studies courses as different to courses considered as core or technical, what made them different was very unclear. Each educator had a very different conception of what defines, differentiates or constitutes a complementary studies course. This range of variation may go some way to explaining why complementary courses seem out of place in engineering programs by educators and students alike.

1 INTRODUCTION

The undergraduate engineering curriculum includes courses which span a range of knowledge areas including mathematical sciences, natural sciences, engineering sciences, design and synthesis, and work-integrated learning. There are also courses which accreditation bodies such as the Engineering Council of South Africa (ECSA) refer to as complementary studies. This is a term used to describe courses that include knowledge areas other than the aforementioned, that complement the practice of engineering (ECSA, 2016). Complementary courses are intended to create, amongst other benefits, well-rounded, socially conscious engineers who are able to work in multi-disciplinary environments (Donald et al., 2017). As with many other universities around the world, universities in South Africa are required to incorporate these courses into their engineering curriculum.

As suggested in the literature (see for example (Donald et al., 2015) and (Dubreta, 2014)), many engineering students appear to face difficulties when engaging with complementary studies courses in the engineering curriculum. They are often perceived as unimportant and an unnecessary hurdle to overcome by both educators and students. Educators often view these courses as distracting from the focus of the students on the technical courses which they feel are more important (Arms, 1993). Navarro et al. (2016) do however argue that if educators are given enough guidance, it should be possible to successfully deliver engineering curricula which include complementary studies courses. This suggests a certain amount of uncertainty around complementary subjects.

The purpose of this study is therefore to explore the way that engineering educators perceive (construe) complementary subjects and their role in the curriculum. Engineering educators in an industrial engineering curriculum that includes complementary studies courses were interviewed to determine their perceptions of these courses. The interviews were conducted using the repertory grid technique, a structured interview protocol associated with Personal Construct Theory (PCT).

2 METHODOLOGY

2.1 The Repertory Grid Technique

The repertory grid technique is a widely applied tool which is associated with Personal Construct Theory (Fransella, 2003). According to this theory, people make sense of the social world around them by creating and recreating implicit theoretical frameworks which become their personal construct system (Fransella, Bell and Bannister, 2004). Any concept encountered is contrasted with concepts within their existing construct system. Each construct has two poles that represent the range that the person uses for ‘sensemaking’ of a particular concept. For example, one of the constructs evident from a participant in the current study was a range from ‘real-world’ oriented courses on one pole, to ‘classroom oriented’ courses on the other. Any course would then be located on the continuum between these poles.

The purpose of the repertory grid technique is to elicit constructs from participants through a structured interview process. The first stage of the interview is to derive a set of elements with which to elicit a participant's constructs. In this present study, the elements were different courses in the curriculum which the participant was familiar with. For example, a course such as Engineering Mathematics could be one element, while Operations Research and Labour Law would be other elements. From a set of elements, a participant would be asked to compare and contrast three elements (a triad) in order to elicit constructs. Participants are asked to group the triad into a set of two that are different in some way to the third. The interviewer then probes the reasons for the distinction the participant is making. A participant's bipolar constructs are elicited from this process.

2.2 The Interview Process

Six engineering educators (referred to as Participant 1, Participant 2 etc.), were identified from the same industrial engineering program as a pilot study for a larger PhD study. Considering that this was a qualitative study, this number of participants proved sufficient in generating rich data for analysis. The repertory grid technique was new to all the participants who expressed both fascination with the unique way of collecting data, and a general appreciation for the benefit of such a study of complementary studies. All six of the educators had knowledge of both complementary and non-complementary studies courses with three of them having recent experience of teaching complementary studies courses in the curriculum.

The interview began with agreeing on the set of seven elements, in this case seven industrial engineering courses, to be used in the discussion. The courses had to cover both complementary and non-complementary studies in order to ensure that a comparison is made between the two types of courses. The interviewer provided a list based on the courses currently offered by the institution in the Diploma in Industrial Engineering programme. From this list, each participant had to pick seven elements based on seven different eliciting questions asked by the interviewer. These questions were asked so that there were at least two complementary and two non-complementary courses in the chosen list which would allow for a comparison to be made.

Once the participants and the interviewer had agreed on the seven elements to be used, different constructs were elicited by using a triad of three elements at a time. For each of these triads, the participants had to state which two were the same in some way and different from the third. Through a laddering process, they then had to state what exactly the two had in common, as opposed to the third. The thing that the two elements had in common was written on the left side of a grid sheet and the reason the third element is different, on the right of the grid sheet. This created a bipolar expression in the form of words or phrases which express a contrast and thereby the person's construct. These three elements then had to be rated by the respondent based on a 5-point scale with each rating being recorded on the same grid. The remaining elements were then also rated based on the same construct. This process was repeated several times with different triads until a set of constructs and ratings were elicited and recorded on the repertory grid. The result was six repertory grids, consisting of elements and constructs with ratings from six interviews.

3 RESULTS

Three kinds of analyses were conducted and are discussed below. Firstly, by thinking back to the interview itself and the participants' responses to particular questions, a process analysis was done. This was then followed by conducting a cluster analysis, which involves highlighting the relationships amongst constructs and elements in a grid so that they become visible at a glance. Finally, a principal components analysis was conducted with the same purpose of highlighting relationships amongst elements and constructs. In the pilot study, the analyses were conducted on six participants. In this paper, the results of two of them, i.e. Participant 1 and Participant 6, are illustrated as examples that show the greatest variety of the responses received.

3.1 Process Analysis

The process of agreeing on the set of seven elements to work with provided some early indications of the perceptions that the participants had towards certain courses. Questions such as, *"Name one course which, if given the opportunity, you would like to teach."* were posed with the aim of eliciting the elements which the participant viewed in a positive light. In all six instances, no complementary studies courses were chosen by the participants as a course that they would like to teach. A question was also posed to each participant with the aim of including a course which the participants felt was the least relevant to the curriculum. The question in this regard was, *"Name one course that surprised you with its presence in the curriculum."* There was only one out of the six instances, where the course that was chosen was from the complementary studies group. The rest of the courses were from the non-complementary group with the second year Engineering Mathematics course surprisingly being chosen more than once.

The process of eliciting constructs from the participants revealed just how varied their initial perceptions were of complementary studies courses when comparing them to the other engineering courses. In most instances, it was necessary for the interviewer to employ the technique of laddering down in order to get to the actual construct and not the initial answer that was provided by the participant. Despite the diversity of constructs, there seemed to be an understanding by the educators that complementary studies courses are necessary in the curriculum even if they might look different and not be the ideal course they would like to teach.

3.2 Cluster Analysis

Cluster analysis is a technique for highlighting the relationships in a grid so that they become visible at a glance. The elements and constructs within the grid are organised so that those with the most similar ratings lie side by side. The extent to which the ratings are similar is indicated by percentage similarity scores with the higher percentages indicating more similarities between the elements or constructs. This is useful for the present study as it can help us to determine the extent to which complementary studies courses are similar to the other courses based on the construals of the participants. Figure 1 and Figure 2 show the cluster analysis output for Participant 1 and Participant 6 respectively with the percentage similarity scores for adjacent elements and adjacent constructs provided. The RepPlus grid analysis software (Gaines and Shaw, 2021) was used to generate this output.

Participant 1 construes the Leadership (complementary) and Industrial Production Engineering (non-complementary) courses as the same with a similarity score of approximately 85% (arrow 1 in Figure 1). Engineering Mathematics and Operations Research, which are both not complementary, have a weaker relationship of approximately 70% (arrow 2). There is one distinct branch which stands out with regards to Participant 1's constructs. This branch comprises the constructs of 'Macro (funnel) vs Micro' and 'Mixed vs Purist' which have a similarity score of over 92% (arrow 3) according to the educator's construal.

On the other hand, Participant 6's highest similarity score is on two non-complementary courses, with Systems Engineering and Industrial Engineering Design being construed to be the same with a similarity score of approximately 87% (red arrow 1 in Figure 2). The complementary courses of Accounting and Leadership are also construed the same with a score of approximately 83% (red arrow 2). With regards to Participant 6's constructs, there is one distinct branch which stands out (red arrow 3 in the diagram). This branch comprises the constructs of 'Industry agnostic vs Closer to industry' and 'Generally applicable vs Specific to IE (Industrial Engineering)' which have a similarity score of over 92% according to the educator.

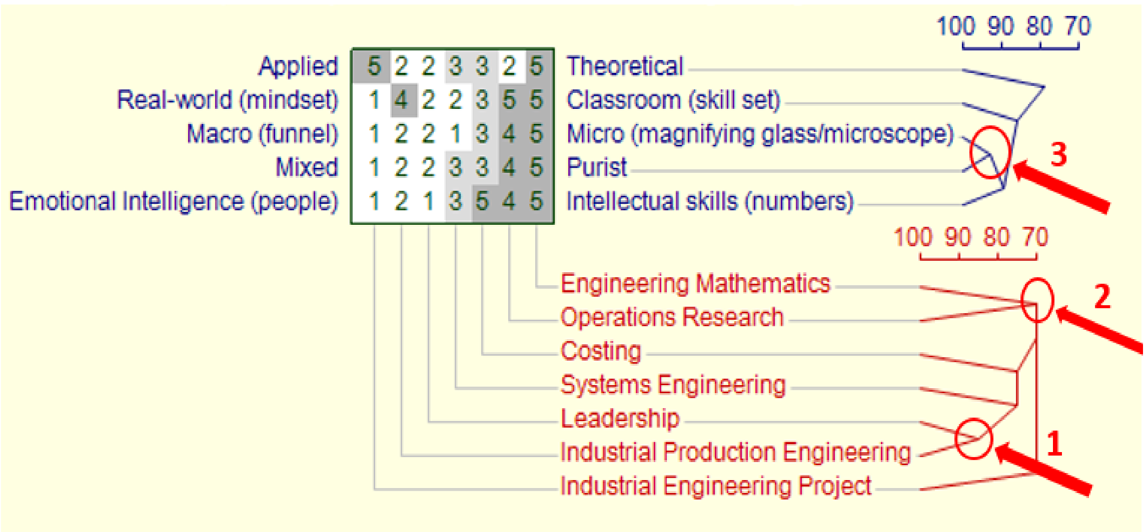

Figure 1: Cluster Analysis Output for Participant 1

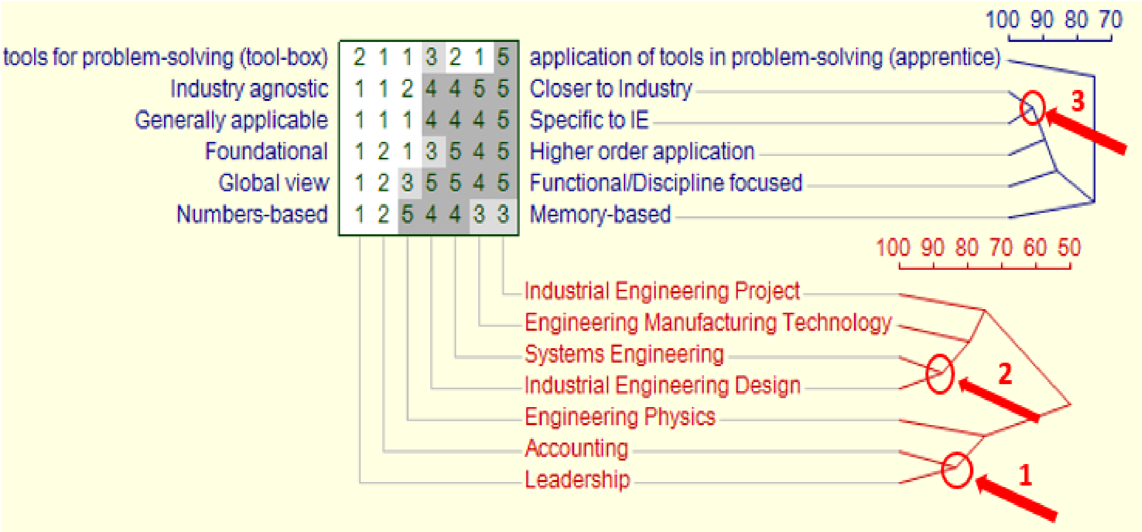

Figure 2: Cluster Analysis Output for Participant 6

3.3 Principal Components Analysis

Principal components analysis identifies distinct patterns of variability from the ratings supplied by the participant. Through an iterative process which is best performed using grid analysis software, the patterns of variability are grouped into components. The two components with the largest amount of variability, that is the principal components, are selected and plotted on the horizontal and vertical axis of a graph with the percentage amount of variability shown (see Figures 3 and 4 where the percentage variability is shown in green). The constructs are plotted as straight lines and the elements are positioned along each principal component. The angle between any two construct lines reflects the extent to which the ratings of elements on those constructs are viewed as the same by the participant, with a smaller angle showing greater similarity compared to a larger angle (Jankowicz, 2005). Similarly, the elements are positioned along each principal component and the distance between any two elements reflects the ratings each element received on all the constructs.

Figure 3 shows the results for Participant 1. Four of the five constructs lie close to the horizontal principal component axis. This means that, according to the educator, these constructs have strong similarities which are distinctly different from the single construct which lies closer to the vertical principal component axis. For example, the 'Mixed vs Purist' construct is seen in the same light as the 'Emotional Intelligence (people) vs Intellectual skills (numbers)' construct. With regards to the elements on the graph, courses such as Leadership (complementary) and Industrial Production Engineering (non-complementary) are construed the same and are distinctly different from a course such as Engineering Mathematics which is not complementary.

The constructs in Participant 6's principal components analysis graph are not as clearly differentiated as they spread evenly all round the plot as shown in Figure 4. There are, however, two groupings of constructs that seem to emerge. The first grouping, which lies closer to the vertical principal component axis, consists of the 'Memory-based vs Numbers-based' and 'tools for problem- solving vs application of tools in problem-solving' constructs. The rest of the constructs fall into the second grouping which is closer to the horizontal principal component axis. With regards to the elements on the graph, the complementary courses of Leadership and Accounting are construed the same and are distinctly different from a non-complementary course such as Systems Engineering.

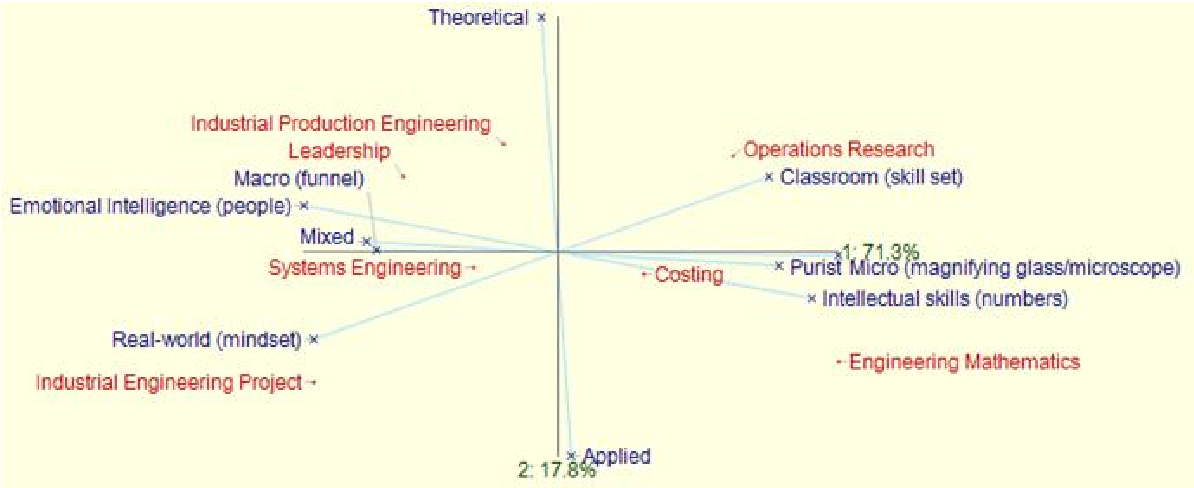

Figure 3: Principal Components Analysis Output for Participant 1

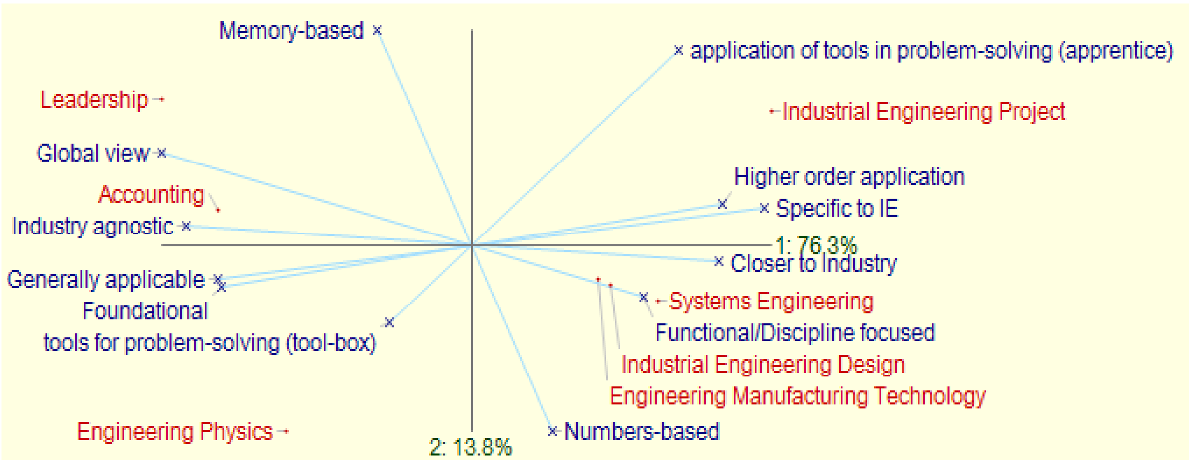

Figure 4: Principal Components Analysis Output for Participant 1

4 DISCUSSION

If, as assumed, complementary courses are different to ‘core’ engineering subjects, one would expect to see them clearly separated from other types of courses when analysed using the repertory grid technique. This is not the case in our present study. For example, Participant 1’s construal of the Leadership (complementary) and Industrial Production Engineering (non-complementary) courses as being similar is very interesting. This is firstly shown by the Cluster Analysis in Figure 1 where the two courses form a distinct branch based on the educator’s ratings. The principal components analysis in Figure 3 then confirms this by showing that the educator was inclined to see both courses as leaning towards the people-focused/real-world constructs. A course such as Costing (complementary) is seen as being less similar to Leadership even though they are both considered to be complementary. This could be due to the fact that Costing involves a lot more numbers and calculations when compared to a course like Production Engineering. This indicates how unclear the distinction between complementary and non-complementary courses can be.

On the other hand, Participant 6's construal of the Accounting and Leadership courses as similar is not as surprising. This is in agreement with the generally accepted classification of these courses as complementary in the curriculum. The educator was inclined to see these courses as being further removed from industry when compared to a course like Engineering Manufacturing Technology, as shown by the principal components analysis in Figure 4. The meaning of 'industry' for the educator was within the context of a manufacturing or factory set-up where most industrial engineering graduates end up working. This closeness to industry is generally seen as an attractive feature of any course as this implies that the graduate can directly use what they learn in the workplace. Another interesting construct that was elicited from the educator was the 'Generally applicable vs Specific to IE ' construct. As can be seen in Figure 4, the educator does not see the complementary studies courses as being specific to industrial engineering (IE) which could make them less attractive as well.

5 CONCLUSION

The aim of this study was to understand how engineering educators understand, or construe, complementary studies courses which have been found to be problematic in the curriculum. This was done by analysing repertory grids that were obtained through interviewing engineering educators from an industrial engineering programme. The most significant finding is just how varied the understanding of complementary subjects is, with the participants having different constructs and ratings that are associated with them. There was general consensus that complementary studies are different from the other engineering courses although there were some unique cases where educators construed them to be the same. It was also interesting to see how when asked to pick a course they would like to teach, none of the educators picked a complementary studies course.

This study does not yet get to the root-cause of why complementary studies courses are found to be problematic by some educators, and students alike. It does however provide a good starting point by first exploring how educators understand, or construe, these courses. In order to get to the root-cause, it might be necessary to go back to the participants with the results of the analysis and confirm if the conclusions are indeed a true reflection of their perceptions. It would also be valuable to carry out a similar study with a group of educators in other engineering disciplines where complementary studies are not as integrated into the curriculum as is the case with industrial engineering.

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LEARNING TO LEARN, BOLT-ON, OR INTEGRATED?

ANALYSIS OF STUDENT FEEDBACK FROM A PILOT WITH LEARNING TO LEARN INTEGRATED INTO FIRST-YEAR ENGINEERING MATHEMATICS.

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Keywords: *Learning to learn, higher education, mathematics education.*

ABSTRACT

Learning to learn is one of the generic skills that are important to becoming an engineer. One outcome of the education is to be prepared for a role as an engineer with lifelong learning. In this paper, I convey experiences gained from two different approaches when implementing “learning to learn” into engineering math courses. The first approach, learning to learn was added to a mathematical course as a “bolt-on” approach in two initial pilots. A second approach was to include learning to learn in the course. In this approach, I wanted to utilize feedback cycles and provide information on learning to learn “as needed”.

Interviews of students and experiences from the pilots have been analyzed using thematic analysis. Two different experiences were described by the students in the two classes that were included in the pilot. In one group, the smallest of the two pilot classes, not a single student dropped out in the remaining three-year of the study program. The program had a major impact. The other group, the biggest class, was more resistive.

In the second approach, I wanted to utilize the role of a mathematics teacher. Here I could use the authority and the relation as a math teacher. However, introducing learning to learn as a teacher conflicted with the role as a teacher. Here I discuss key findings from four focus group interviews, in addition to my experience as a teacher, that can help to plan future course design when learning to learn is included.

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1 INTRODUCTION

1.1 Introduction

Higher education requires efficient learning. But learning in higher education is complex, it is a personal development process, and involves a change of perceptions, learning habits, and epistemological beliefs [1]. It is well known that the transition from school to higher education is challenging since students often lack an understanding of the kind of learning that is required [2, 3]. Wingate [1] claims that two things have to be present for efficient learning in higher education. Firstly, students must understand learning and become independent learners that take responsibility for their learning. Secondly, to understand the knowledge and become competent in constructing knowledge within the discipline.

A theory that focuses on what the students can do, and hence is relevant as a toolbox is self-regulated learning [4] and related constructs. Self-regulated learning strives to understand self-regulation, as an active learning process and how it is used to actively pursue individual goals. Self-regulated learning refers to the modulation of affective, cognitive, emotional, and behavioral processes throughout a learning experience, to reach the desired level of achievement [5-7]. Research has shown that self-regulated learners are autonomous, reflective, and efficient learners who have the cognitive and metacognitive abilities as well as the motivational beliefs and attitudes needed to understand, monitor, and direct their learning [8].

Learning to learn (LTL) or developing lifelong learning skills is one of the many generic skills that is envisioned integrated into the study programs at NTNU The question is, how could this be done? A common approach is to hire an expert in learning from outside the faculty, that can teach how to learn. However, these generic, often in separate 'bolt-on' courses [9] are often found to be inefficient. Another approach is to include elements of LTL in the course, challenge the learning process, and provide information according to needs throughout the course.

The results presented here are from two pilot periods. The first period with a bolt-on design, and the second period, with an integrated design where the author integrated LTL in a qualification course in mathematics. Here I discuss results considering my experience gained from the two different approaches to embedding LTL.

1.2 The context

In the first test period, in the autumn of 2014, LTL subjects were integrated into two mathematics courses in a first-year bachelor of engineering mathematics course. Subjects from SRL that were considered relevant to learning, were introduced in a weekly 20 to 40 minutes lecture as a part of the mathematics lectures. The LTL lecture was an additional hour added to the timetable of two math courses, but the subjects were presented by the author and not the math teacher. The concepts introduced to the students were; goals how and why, self-regulated learning in general, work habits, ways of thinking, memory, bulked vs spread practice, self-testing and retrieval practice, implicit theories of intelligence [10], motivation, reflection, self-efficacy, teamwork, and exam preparation.

In the second test period, the author entered the role of a mathematics teacher. Here LTL subjects were initiated by problems that students encountered during their process of learning mathematics. Frequent assessments with integrated reflection forms were used as a source to gather information about the challenges that students faced. No interviews were made and hence the data from this period are only from my own experience as a teacher attempting to integrate LTL in a math lecture. The difference between the two designs was that I changed my role from a bolt-on-teacher to a mathematics teacher. The level in the second design was a qualification course with 12 hours a week of contact. Entering the role as a teacher in the second period was a wish of the author, to establish a closer relationship with the students.

In both periods, learning-to-**learn** was linked to a feedback cycle in what we called classroom assessments, a design inspired by Nicole and MacFarlane-Dick's [11] recommendations on feedback. A classroom assessment consisted of a 1-hour test, where students worked individually to solve problems without any tools. In the last 10 minutes of the test period, students were given alternatives and the results were submitted electronically. After the test, scores were given, followed by an immediate review of the problems, prioritized by the average score on each task. Here the students could correct and pick up immediate feedback. At the end of the assessment, students were given a reflection form, where they were asked to observe reactions to the problem solving, and reflect upon goals and progress. Parts of these reflections were collected and included in the LTL sessions the following week. The second test pilot had a significantly higher frequency of tests than the first and the period lasted for a full year.

2 METHODOLOGY

In the last week of the first test period, four semi-structured focus group interviews were performed by a fellow faculty member. 5 female students and 6 male students participated resulting in 4 hours of interviews that were transcribed. The data corpus, in addition to the interviews, consists of written assessment reflections, student responses in lecture interactions, and evaluations that were available for analysis but were not included in the dataset analyzed. The data set was mainly transcribed interviews.

Interviews were analyzed using a thematic analysis approach[12]. The content was organized in thematic groupings, reviewed, and reorganized according to extracts that essentially describe the student experience. Some relevant codes were structured by the interview guide and some by themes that appear.

In both pilots, every subject was introduced with questions, where students responded through a student response tool iLike [13]. This tool allows for text-based responses in addition to standard multiple-choice questions. As an example, initializing a lecture about motivation text response question "what do you experience as demotivating?" The next question was "What motivated you?" followed by the question "How do you regulate your motivation?" Throughout the lecture series the "what can you do?" was a core concept. The purpose of this initiation was to connect to preexisting knowledge and ideas, for me as a teacher to see how they were thinking, and at the same time, allow students to interact with the content both before and during the lecture

3 RESULTS

3.1 Getting close

Entering a mathematics lecture and starting talking about emotions, does not feel natural for a physicist. There are shifting emotions related to learning mathematics. Emotions change dynamically between confusion, frustration, boredom, engagement, flow, curiosity, anxiety, delight, and surprise. One of the first questions that were asked in the lectures was, how do you agree with this statement "Emotions have nothing to do with learning and should therefore not be mixed with learning" only a few partly agreed 27% and around 60% disagreed. A surprising 17% answered I don't know. In the interviews, this focus on emotions and regulation of emotions became one of the biggest themes and seem to have been easiest to transfer to their own experience. Discussing experiences, emotions, and ways we think opens the door to a personal and private sphere. Allowing students to come closer, and at the same time, coming close to the students.

The superordinate theme of getting closer appears in all interviews in one way or the other. This kind of work with personal development, where thoughts and emotions are discussed, requires a safe space where it appears safe to discuss traits, reflect on learning, and discuss private thoughts. The experience of the students when you succeed is a sense of getting personal.

> *Everything gets more personal. We got a stronger relationship with the school. Instead of a situation where there is a lecturer that we don't even know the name of, is standing there, talking, and babbling about something.*
> - Male student 3 -

Asking questions about well-being and displaying results for the entire class, seem to have influenced individually. But revealing how others are doing also influenced the class environment:

> *It feels like the class environment got better from this.*
> - Male student 3 -

Throughout the semester I allowed students to come close to what I as a teacher was thinking, what I experienced, and the choices I had to make when facing challenges that appeared. Being open about reactions, and insecurity, and allowing for my thoughts and reactions to be bot considered and criticized was interpreted as "down to earth" or honest.

> *The thing is that he is really present and very personal with us. Then you automatically get people interested. He uses examples that we recognize from his life when he was a student, and that is relevant today also.*
> - Female student 1 -

This openness and honest communication lead to a sense of belonging

> *Everything becomes more personal. We got a better relationship with the school. Instead of a lecturer standing there talking and we don't even know his name… I feel that the class environment improved from it too.*
> - Male student 2 -

When the class accepted and created their rationale for why the interventions were there, the perceived effect was a sense of being cared for.

> *It felt like the faculty cared, in a way… because at other schools it's been like, if you fail you fail, bad for you!*
> *- Female student 3 -*

These are all factors that are important in the sense of belonging, an important factor for motivation according to self-determination theory [14]. The establishment of this relation to the class was a key ingredient to opening up for reflections on a private subject like learning.

3.2 Integration in a course vs. bolt-on solution

How do students perceive LTL as a part of the mathematics lecture? When asked about which subject is best suited to include LTL, the students are clear. It had to be entangled in an **important** course.

> *…mathematics is kind of hard for a lot of students, a lot of students have forgotten, and it is — yes it's a lot to remember in that subject, and it is a lot—*
> - Female student 1 -
>
> *And then it's kind of relevant since...*
>
> - Female student 2 -
>
> *But it is, after all, okay that it is given in the connection of a course*
> - Female student 1 -

Another aspect here is that since most students take the subject of mathematics seriously, integrating LTL into the math curriculum will make most students participate. They both appear to share the same experience that since mathematics is demeaning, a course that most students experience as demanding. According to the students, to get a sense of a shared development process, most students must participate. When asked, could it be a part of generic subjects like an introduction to engineering, the students immediately responded "no!"

3.3 Criticism / Resistance

Not all students participated in the lectures and the attendance in the additional lecture dropped throughout the semester. Most students reported that the time of the week, Fridays, was one major reason why they dropped out.

Some resistance lies in the individual beliefs that students hold about learning and how to develop these skills.

> *… I am kind of skeptical to these kinds of self-development-things —my meaning is that these kinds of things must appear from our own experience —*

> *in a way be learned on our own...*
> *My experience is that these kinds of things will appear in a way— and it will appear from the inside.*
> Male student 6

This statement was immediately contradicted by the female friend during the interview. But, there are elements of truth in this statement, you cannot force learning and development on students. Internal motivation is a better starting point than external pressure.

One type of criticism found was on the format. But this is also one part of the resistance you will notice when you introduce LTL without proper integration.

> *Even though I find the subjects interesting, I am very bad at trying them out without having the motivation to do so. I would like to have a challenge or something, just to try it out.*
> - Male student 6 -

Learning activities where students must participate and in learning activities that should be closely linked to active learning situations where the learner is engaged in thinking, learning, and performing.

> *It depends on how willing you are to accept it, I think. I feel that the entire purpose of the project is to get this self-awareness. You cannot sit and listen to someone telling you how your self-awareness should be. … but he has been good at giving us the tools, he has just not given us the chance to use them.*
> - Female student 4 -

This student reported in the interviews, that she had been reading about study strategies and had an interest in developing her skills, which in it selves an autonomous activity. She says she has been given the tools, but given the chance to use them. It is expected that if she was to use the knowledge we had to require and provide a learning activity where she could use them.

4 SUMMARY

There are several known barriers to implementing LTL in higher education [15]. Instead of accepting the responsibility for educating everyone, the easy way out of the challenge is to explain the lack of student success to the student readiness. When the challenge is taken, the easy way to fix the problem is a bolt-on solution that is cheap seen from an economical point of view. One external expert can be hired, to give excellent lectures on learning in general. An expert might have deep knowledge about learning and provide up-to-date information about learning. The other advantage, lectures are released from the responsibility to help students to develop their learning and may spend more time on research. There is a lot to learn when a lecturer starts shifting from a transfer of knowledge model to start feeding and informing students in their process of learning. However, relying on external experts does not shift the institutions' way to teach into a focus on how to facilitate learning.

Picking up the glove and accepting the responsibility for the students learning process, is the first barrier [15]. However, it is worth noticing that facilitating the development of the students learning process is not something that is done without resistance. Priorities at the universities are often directed toward research. The easy way is to initiate a bolt-on solution, where external experts in learning are hired to remedy a need. University teachers as representatives of the domain that we invite our students into are also authorities that make information about how to enter the domain more relevant. The main challenge here is that we repeat what worked for us, lecturing.

> *It's like—what he asks for us to do, is to invest in his ways of thinking...*
> Male student 5

Students prefer to continue to work and do things in the way that they perceive as their model for successful learning, rather than taking the risk to spend time on something that may not work, which requires extra effort. Investing in new ways of working, and experimenting with ways of thinking that might not give immediate results is experienced as a risk. The same is true for teachers that give lectures or facilitate learning.

Who else other than representatives of the domain, the faculty, are more trustworthy of what ways of thinking are needed to enter the domain? However, the faculty must value learner development in addition to the learner's curriculum. In a healthy learning culture, the entire institution should engage in a culture where the students learning process, and experience with learning is in focus. If the faculty use a dialog with students as input for development and learning, students will find an improvement culture more relevant and natural. Keeping the development culture inside the institute is important for continuity in these developments.

Criticism was given on only teaching LTL and not allowing students to "try" techniques. First, it is known that knowledge about the health effects of physical exercise does not automatically create more physically active behavior [16]. The problem of translating knowledge about the benefits of an action does not create a change in what people do. This is known as the knowledge-behavior gap. The same effect might also be present when it comes to the way students learn. Knowing how to study, does not necessarily make students change the way they study. LTL activities have to be integrated into learning activities. In the second period, a stronger link between assessment and reflection schemas was considered more natural. Secondly, learning is more than a technique! Learning to learn is to know and understand oneself and be willing to challenge reactions, patterns in ways to think, and ways to work. It is an agentic search for better ways to interact with the learning process.

The overall purpose was to make students more aware of their learning process. It appeared as an opening ut a safe space where it is safe to talk about how we think, experiences, feelings, and thoughts seemed to be essential to initiating the LTL process. The use of response technology was a key ingredient to picking up information and simultaneously creating a sense of interaction with large groups of students on rather private subjects that LTL is. Technology allowed students to see how other students were thinking about central topics, thoughts, and reactions of others were perceived as an effective element to both inform and create a sense of belonging.

> *We got to know each other through these survey questions, even though we answered anonymously.* - Male student 2 -

Finally, LTL, applying the knowledge, and gaining experience as a learner takes time. For some students, the first exam is real feedback. Then they know for real how their learning worked. This requires constant focus throughout several courses and not just a one-time intervention.

In the second period, LTL lectures were given as a part of a feedback cycle from the author as a mathematics teacher. The feedback cycle was initiated from improved and varied reflection schemas. LTL subjects were chosen according to what students discussed in their reflections about learning. But, here there was a conflict on how to spend the time as a mathematics teacher.

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LEARNING IN A BLENDED LEARNING ENVIRONMENT: NEEDS AND INFLUENCING FACTORS

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ABSTRACT

In blended learning, students have the opportunity to choose either online or classroom lectures. For higher education institutions, blended learning has many advantages, such as accessibility to students and teachers, cost efficiency, alleviation of the teacher shortage, etc. But what does this mean for the students?

The aim of the study is to find out students' further need for blended learning, its reasons and factors influencing it. An online survey was conducted to answer the research questions. The collected data was analyzed by using statistical analysis methods.

The results of the survey revealed that the technical prerequisites for students to participate in blended learning were met. The biggest problems are related to the self-regulation skills of students. Problems with blended learning are stronger among first-year students. However, the respondents were rather positive about blended learning. Blended learning is most strongly supported by distance learning students who live far from university and are over 25 years old. The least supportive of blended learning are full-time students living near of the university and who are under the age of 25. This is due to the fact that full-time students experience blended learning problems on average more often than distance students because of the weaker learning skills.

The results of the survey help to understand students' views on blended learning, to plan and conduct studies in a student-friendly way, and to plan trainings for teachers to improve the blended learning process.

1 INTRODUCTION

1.1 Aim and research questions

The learning experience of students is influenced by the professionalism of the teacher. It makes it easier to understand what is being learned and diversifies learning [1]. The COVID-19 crisis tested the professionalism of teachers. The contribution to the development of teachers' digital and pedagogical competencies, as well as the continuous development of teaching infrastructure, have made it possible to organize blended learning at TTK University of Applied Sciences (TTK UAS) during the COVID period. In order to find out students' satisfaction and further expectations, the university conducted a survey “How to support learning in blended learning?” The aim of the survey was to find out students' further need for blended learning, its reasons and factors influencing it. In order to achieve this goal, the following research questions were set:

- What are the conditions for participating in blended learning?
- What are the main problems experienced in blended learning?
- How do students evaluate the first blended learning experience in their studies?
- What is the profile of the proponents and opponents of blended learning?

1.2 Background

Blended learning is defined in TTK UAS [2] as a form of study in which it is possible to successfully participate in studies either in the classroom or via the web. Conducting blended learning is a challenge, as it requires the teachers to reshape their approach to teaching and the students to get used to the renewed learning environment and conditions [3]. Issues in blended learning have been studied extensively. One of the aspects that emerges is lack of students' self-regulation skills. Self-awareness and self-motivation have a direct, positive, and significant impact on study habits, but it is concluded that students face higher-than-usual challenges in building study habits in blended learning [4]. According to Susanna et. al [5] there is a positive influence between self-regulation and motivation on student learning outcomes in a blended learning approach aswell. Rasheed et.al states, that the implementation of blended learning in higher educational institutions is increasing due to its perceived effectiveness in affording the benefits of both face-to-face traditional mode and the fully online mode of instructions. However, the leading challenge associated with the online component of blended learning is students' inability to properly self-regulate their learning activities [6]. But, students are obliged to regulate, manage and carry out their study activities and learning tasks independent of their instructor, at their own pace, and also using online technology for in the online component of blended learning, but they encounter here with problems [7]. Kotturi et.al argues that one of the main challenges that students face in an online environment and a more importantly online component of blended learning is self-regulated learning due to the learning flexibility and autonomy granted to students [8]. According to Adnan and Anwar [9] students who have high motivation in conventional learning, do not necessarily have the same motivation for blended learning. According to Lim and Morris [10] and Kassner et al. [11], students' age and preference for the form of study are the factors that differentiate learning outcomes between students either. Based on the foregoing, it can be pointed out that in studies related to the implementation of blended learning, it is necessary to pay attention to these factors.

2 METHODOLOGY

To respond the research questions, the online survey was conducted. The survey form consisted of four parts: conditions for participation in blended learning (6 questions), blended learning experience (8 questions), organisation of blended learning (4 questions) and demographics (6 questions). With the multiple-choice or scale questions the students were asked to evaluate the effectiveness of blended learning, their satisfaction and how willing they would be to learn in blended learning in the future. The open-ended questions identified the factors supporting blended learning, which is not in the scope of this paper. The survey form was made by using Google Forms and it was sent to all TTK UAS students in spring 2021.

In order to analyze the data the following statistical analysis methods were used. The Likert scale was used to weigh the questions, and an overview of the results of the survey was presented in the form of text, figures and tables. The differences between groups were checked by using descriptive statistics on the means and standard deviations. Correlations between variables were examined using the Spearman rho correlation coefficient, and internal reliability was measured using the Cronbach's alpha coefficient [12]. Based on the survey, various statistical hypotheses were formulated and their validity were checked by an appropriate statistical method. The quantitative statistical analysis was performed with MS Excel and statistical softwere R. If there no statistically significant differences were found in some of the groups (eg full-time/distance students), then this group was not considered separately in the analysis.

3 RESULTS

3.1 The structure of study participants

In the 2020/21 academic year, the total number of TTK UAS students was 2931, of which 570 students responded to the survey. Thus, the response rate in the population was approximately 20%. The first-year students responded the most actively (38%), followed by the second-year (32%), third-year (20%), fourth-year (9%) and time limit extension (1%) students. Among the respondents there were more distance students (64%) than full time (35%) and external (1%) students. The respondents came from all institutes (Fig.1), with the largest number of responses coming from students in the fields of transport and logistics (11%), building construction (11%), accounting (10%), social work (9%) and production management (9%).

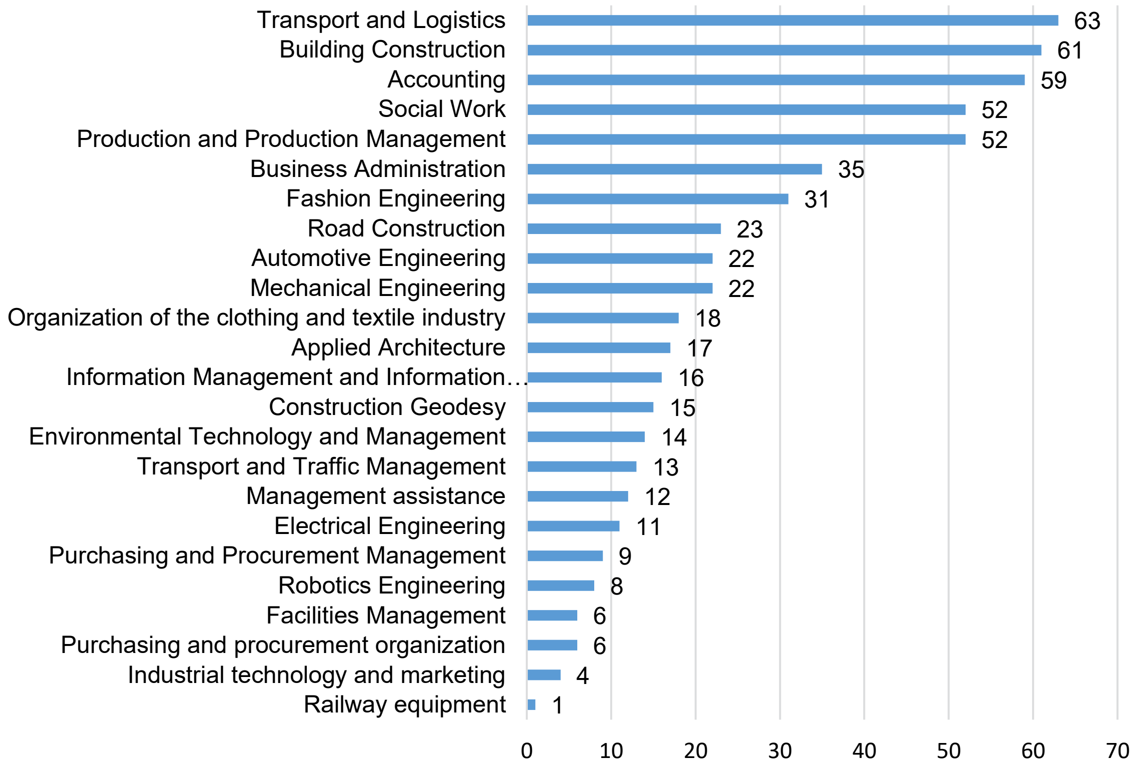

Fig. 1. The structure of study participants

The highest number of respondents coming from the younger age group under 25 years old (47%), with fewer and fewer respondents from each subsequent age group: 26 to 35 years old (27%) , 36 to 45 years old (20%), 46 to 55 years old (5%) and over 56 years old (1%). The highest response rate was among students from Tallinn (39%), followed by learners from rural areas (24%), from other cities (21%), from bigger cities (15%) and from outside of Estonia (1%).

3.2 Technical conditions for remote participation

Based on the results presented in Table 1, it can be concluded that there are no major problems for students to participate remotely in blended learning process due to technical conditions.

Table 1. Technical conditions for remote participation

Technical condition	Yes	No
Private room	82,8%	17,2%
Computer	99,5%	0,5%
Stabile internet connection	92,8%	7,2%
Webcam	94,4%	5,6%
Microphone	98,6%	1,4%

It is a common belief that students use a mobile phone a lot, but only 13% of the respondents used a mobile phone when participated remotely. This is a small proportion, but a potential danger, as it is not possible to carry out all tasks in a high-quality way using a mobile phone alone. For example, if it is necessary to solve tasks with a teacher or view a teacher's drawings for which the screen of a mobile phone is too small, etc.

3.3 Problems in blended learning

The survey revealed that students most often experienced problems in the following aspects: 29% of respondents often experienced difficulties with concentrating, 28% stated that they often felt a decrease in self-discipline and learning motivation, and 26% felt that remote learning often remained superficial. The above results are explained and supplemented by the students' answers, in which problems related to the organisation of studies were seen as barriers for the effective learning (approximately 19% answered “often”), about the same number (18%) experienced a communication barrier with the teacher and other students, and 16% assessed their own learning skills as insufficient for remote participation. The increase in the volume of learning during the blended learning period was felt by 26% of the respondents, and 25% of the respondents also pointed out some technological problems. The remaining problems were mentioned less frequently: the environment is not supportive enough when participating remotly (15%), teacher’s attitude (14%), cannot find the necessary information (11%) and the volume of learning decreases in blended learning (6%).

The analysis showed that first-year students experienced 40% more different learning difficulties than older students.

3.4 Blended learning experience

Students' evaluation of the efficiency of blended learning was rather good (on a 6-point scale the mean is M=4,19 with standard deviation SD=1,08). The students believed that the learning outcomes in the conditions of blended learning were partially achievable (on a 5-point scale M=4,02, SD=0,95). The general attitude of students towards blended learning was rather positive (on a 5-point scale M=4,05, SD=0,96). In the future, students wanted to attend an average of 50% to 60% of the lectures at a distance (on a 7-point scale M=4,24, SD=1,67, mean confidence interval is 4,24 +\- 0,14 with 95% confidence level).

It was also analyzed how the answers to the previous questions are related to the students' form of study, age and distance between the university and place of residence.

Table 2. Mean scores and standard deviations of variables (except for external students and students living abroad)

Variable\Form of study	Full-time students		Distance students	
	mean	SD	mean	SD
Efficiency of blended learning (1…6)	3,77	1,08	4,40	1,01

Achievability of learning outcomes (1…5)	3,68	1,02	4,20	0,87
Attitudes towards blended learning (1…5)	3,67	1,01	4,24	0,87
Problems related to blended learning (14-40)*	27,65	5,71	24,94	5,72
Willingness to participate in studies remotely (1…7)	3,62	1,57	4,59	1,60

* Students were asked to rate the incidence of 14 problems related to blending learning according to the 3-point scale: not at all - 1, rarely - 2, often - 3. The values of the variable are obtained by summing the individual points, where the minimum possible sum is 14 and the maximum possible sum is 42.

In the Table 2 there is a difference between the means of two groups of students. It shows that distance students rate the efficiency of blended learning higher than full-time students. Distance students believe that learning outcomes are achievable in blended learning, they are more positive about blended learning and they are more likely to participate in distance than full-time students. On average, full-time students experience blended learning problems more often than distance students.

There also appear the difference in mean scores depending on age. In the age group up to 25 years the mean scores are lower than in other age groups. This statement is in line with the previous results, becouse the most full-time students are under 25 years old.

There appear statistically significant moderate correlations between pairs of variables from Table 2. Positive correlations show that the higher the students' appreciation of the benefits of blended learning, the more positively they wanted to participate remotely (Spearman’s rho 0,77), and the more they believed that the learning outcomes of the subjects in blended learning were achievable (Spearman’s rho 0,75). The opposite relationship also applies.

The positive correlation coefficients are in range from 0,59 to 0,77, confirming an uniform strong positive relationship between variables. In order to obtain an assessment of the students' first experience in blended learning, a characteristic group of blended learning variables was formed, in which only positively correlated variables were included. The reliability within the group of variables of the flexibility assessment is high (Cronbach's alpha coefficient 0,87), which means that the average correlation between the variables is uniformly strong and there is an internal consistency of the variables.

The negative correlations between variables show that the more often students experienced different problems with the remote participation, the lower they rated the benefits of blended learning (Spearman’s rho -0,64), the less often they wanted to participate remotely (Spearman’s rho -0,49) and the less they believed that the learning outcomes in blended learning are achievable (Spearman's rho -0,54). The opposite relationship also applies.

The further away the distance students live, the more positive they were about blended learning, the higher they valued the benefits of blended learning and the more often they wanted to participate remotely. In the case of full-time students, a statistically significant weak positive correlation has been found between the distance from the educational institution to the place of residence and their willingness to participate in studies remotely.

3.5 The profile of a supporter and an opponent of blended learning

In order to get the answer to the one of the research questions of this study, the profile of the supporter and of the opponent of a blended learning was determined according to the demographic data. The supporter of blended learning is a distance student, who does not live close to the educational institution and is over 25 years old. The opponent of blended learning is a full-time student, who lives close to the educational institution and is under 25 years old.

4 SUMMARY AND ACKNOWLEDGMENTS

The survey showed that the technical prerequisites for students to participate in blended learning are met, as the vast majority have access to a private room, computer, Internet connection, microphone and speakers. Instead, the biggest problems are related to students' self-regulation skills, ie difficulties related to concentrating, self-motivation and superficial learning. Participating in blended learning at a distance requires even more self-discipline and an awareness of how to manage one's own learning so that learning does not remain superficial. Problems with blended learning are stronger among first-year students. However, the respondents were rather positive about blended learning. This shows that students perceived the need for blended learning and also the fact that blended learning has become a so-called new reality that will continue in the future. Blended learning is most strongly supported by distance learning students who live far from university and are over 25 years old. Blended learning helped increase access to the learning process. The least supportive of blended learning are full-time students living near of the university and who are under the age of 25. This is due to the fact that full-time students experience blended learning problems on average more often than distance students because of the weaker learning skills. Thus, the modern learning process requires the university to teach self-regulatory techniques in parallel with the mediation of learning content.

The results of the survey help to understand students' views on blended learning, to plan and conduct studies in a student-friendly way, and to plan trainings for teachers to improve the blended learning process.

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ORGANISING EVIDENCE-INFORMED INNOVATION: THE DEVELOPMENT OF A RESEARCH AGENDA

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ABSTRACT

Educational innovation often builds on existing practices, and focuses on improvement, rather than a radical change. One current example of educational innovation is Challenge-Based Learning (CBL). At university [blinded] the approach is a curriculum wide implementation of CBL based on a integrated programme that combines implementation of bottom-up innovation projects with research. The result of this research contributes to the translation of CBL to practice, thus helping curriculum designers and teachers in designing and executing their courses. In the process evidence is collected about principles of CBL, learning behaviour, learning outcomes, and didactical aspects of CBL, such as coaching and self-directed

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learning, assessment, pedagogies, and design of challenges, and facilitating structures.

The goal of this paper is to explore the development of a research agenda, which aligns research and practice, and to contribute to evidence for successful CBL implementation as result. The CBL research agenda shows which topics and aspects of CBL are addressed by research and practice, and which are overlooked. It is a systematic way of collecting strategic and practical problems related to CBL implementation, and how these are translated into research questions, methods, and results. The CBL research agenda leads to dialogue, which in turn guides our CBL programme. This integrated programme, including the research agenda is governed by a Taskforce CBL and supported by programme management, and a university wide research community. This approach enables the curriculum wide implementation and research of CBL as a concept for educating engineers of the future and strengthening on-campus education.

1 INNOVATION IN HIGHER EDUCATION

1.1 Challenge-Based Learning as a case of innovation

Educational innovation often builds on existing practices, and focuses on improvement and renewal, rather than a radical change. One current example of educational innovation is Challenge-Based Learning (CBL) [1]. In CBL challenges are seen as self-directed work scenarios in which students engage [2]. For CBL the objective is to learn how to define and address the problem and to learn what it takes to work towards a solution, rather than to solve the problem itself. The final deliverable can be tangible or a proposal for a solution to the challenge [3]. Central to CBL is that students develop knowledge, skills, and attitude by engaging in real-life challenges, often in interdisciplinary teams.

CBL as a concept allows for flexibility in and experimenting with effective teaching and learning activities, rather than predefining them. The aim of these experiments is to translate CBL as an educational concept to practice, thus helping curriculum designers or teachers in developing their courses and teaching, and in formulating support requirements.

1.2 Curriculum wide implementation of CBL

If universities intend to use CBL as a concept for innovating the curriculum, a developmental perspective is needed, which implies a variety in CBL characteristics across study components, i.e. courses and projects. This developmental perspective helps to align initiatives and bring a sense of coherence to the discussion, rather than anchor and confine research and practice. The result is a flexible approach in what are considered challenges suitable for CBL.

At a university of technology in the Netherlands, the approach is a curriculum wide implementation of CBL based on an integrated programme that combines bottom-up innovation projects with research. This combination leads to evidence about what works in the context of this university, which in turn informs educational design and practice. This approach fits the university's ambition to move towards CBL as a concept for educating engineers of the future and strengthening on-campus education. Implementation of CBL in the university's educational program, allows for a further integration of supporting students to develop knowledge, skills, and attitude, which already was part of the Bachelor's curriculum.

The integrated CBL programme allows for experiments in which teachers explore ways to make their study components more CBL. With an evidence-informed set-up the effects on student learning behaviour of these bottom-up experiments are carefully studied, answering questions about didactical aspects, such as coaching and self-directed learning, assessment, pedagogies, and design of challenges. In addition, staff engages in a range of research projects bridging the concept of CBL and everyday educational practice. The findings of this programme thus guide the design of CBL.The large-scale curriculum approach, in combination with research contributes to the current limited body of evidence for mechanisms that cause CBL interventions to be effective.

Facilitating bottom-up innovation projects implies allowing that teachers can have their own interpretation, which translates the educational concept CBL to educational practice. Furthermore, because educational practice aims to stimulate and facilitate student development, the need arises to allow for different forms of challenges. Hence, a working definition and conceptualisation was applied that supported the developmental perspective and the bottom-up innovation projects [4]. However, to stay in touch with and build on current research in the field, the aim was a definition and conceptualisation that both included commonalities emerging from CBL literature, and that allowed for variety in CBL characteristics between study components or curricula. The resulting framework thus serves as a methodological approach to make engineering education (more) CBL [4].

The framework consists of the higher order concepts vision, teaching and learning, and support, each with subsequent dimensions and indicators that describe CBL in a fine granulated way (please see [4] for a detailed description). These dimensions and indicators together form the basis for an educational view on CBL.

1.3 Organising the curriculum wide implementation

The main body governing the CBL programme, is the taskforce CBL. This taskforce consists of scientific staff, educational programme directors, support staff, and students. The Taskforce CBL will in 2024 advice the University Executive Board on CBL in the university's education. All local research on CBL supplies input for this advice; the university allows itself the coming years to experiment with new initiatives before implementing the initiative at full scale. The aim is to learn how CBL should be shaped to optimize student learning in terms of for instance required fundamental knowledge/skills or combining a deep understanding and a broader view, and what changes are needed to vision, teaching and learning, and support [5]. Furthermore, all researchers involved in CBL at our university grouped themselves in a community of practice [6], with regular meetings to develop and share knowledge.

The variety of research questions on CBL called for a research agenda on student learning behaviour and outcomes, and didactical/pedagogical aspects of CBL with the purpose to:

- make the CBL implementation evidence-informed,
- make the implementation and research projects provide new evidence, which feeds iteratively in the implementation,
- bring together/align all CBL research and projects,
- give direction and guidance to this research and projects,
- support scale and scalability of CLB as a unique selling point.

The aim is a research-based grounding for developing CBL in engineering education. This grounding answers for the university context the basic "what works and why"-question, which in turn would allow teachers and educational leadership to take the next step towards a more systematic less diffuse approach to CBL [7].

The CBL research agenda as part of the CBL programme is the guiding document for research on principles of CBL (vision), student learning behaviour and learning outcomes, didactical/pedagogical aspects of CBL (teaching and learning), and facilitating structures (support). The findings of CBL research form a foundation for evidence informed development of the CBL experiments.

The remainder of this paper explores the development of a research agenda. This agenda aligns research and practice, and contributes to evidence for successful CBL implementation as result. Although the context is a curriculum wide CBL implementation, we believe that the research agenda can be used for a range of evidence informed innovations in higher education.

2 BUILDING A RESEARCH AGENDA

2.1 What is a research agenda?

In general terms a research agenda shows which themes and aspects of a specific topic are addressed by research and practice, and which are overlooked. It is a systematic way of collecting strategic and practical problems related to educational innovation, and how these are translated into research questions, methods, and results. It allows individual experiments and research projects to focus on issues and ideas in a subset of the topic. Yet, it offers an overview of all issues addressed by research. A research agenda is not set in concrete; it naturally changes over time as knowledge grows, practice evolves, and as new research questions emerge.

The research agenda on a larger scale thus guides the governing body - in our case the CBL taskforce - throughout all parallel research processes. Because of the overview, it can also serve as a concept note to advisors and stakeholders including university deans, department deans, teacher education, policy advisors, and teachers, while guiding possible new research proposals.

2.2 How to design a research agenda?

Existing literature gives little starting points for designing a research agenda on a curriculum scale. Especially in nascent fields such as CBL, conceptualisations have not yet been set, and by result relevant themes go in many directions and are only emerging [8]. Our first approach was to follow the lines of a common research plan and report:

- What is the practical/strategical problem to be addressed?
- What is the research area: short problem definition, and possibly description of context (e.g., courses, department)?
- Need to know: research question to be answered, what lack of knowlege can be identified?
- Need to do: research method/approach
- Need to do: what knowledge needs to be implemented? Is additional research needed?
- Need to do: sustainability, dissemination. How to make research less person-dependent. How to add to the researcher community.

Of course, these questions can be extended with organisational aspects:

- Which project addresses this problem?
- Who is involved?
- What is the project's timeframe?

The next step was to answer all these questions for each bottom-up experiment and research project. The result is a matrix with in the columns these questions, and each project filling a row (see also Table 1 for an example). Although this matrix gives a clear overview of projects and how these address practical or strategical problems, it is not yet related to aspects of the innovation topic, in our case CBL.

Table 1. Margins of the page size A4 [mm]

Practical/ strategical problem	**Research area/ problem definition**	**Need to know: research question**	**Need to do: research method**	**Need to do: knowledge to be implemented**	**Need to do: dissemination**	**Project**
Effective teaching	Coaching/assessment	What are effective combinations of coaching/supervision and assessment?	Survey, interview	Starting points for redesign/ design principles	SEFI paper, 4TU innovation map, presentations	Preparing engineering students for the future
How to design effective pedagogies for learning from challenges?	How to structure the process of learning from challenges?	What are effective pedagogical approaches to help students learn from challenges?	Interview, portfolios			CBL pedagogy; Interuniversity
How to integrate disciplinary knowledge and skills acquisition in CBL	1a. - In prior learning and just-time-learning; 1b. - In formative and summative assessment		Interview, observations, course materials		Conference paper, presentations, article, teacher sessions	Modularisation

2.3 The CBL research agenda

To increase our understanding of which project addresses what CBL aspect, the fine granulated CBL conceptualisation presented by [4] was added to the matrix: each dimension and indicator of that framework was placed on a row in the matrix. Next, all experiments and research projects were re-ordered and grouped with the dimensions and indicators. The result is a theory driven overview of all experiments and projects.

Because the input for the matrix came from both researchers and teachers, and from the taskforce CBL, the overview also made clear which practical and strategical problems were considered relevant, but were not yet addressed by any experiment or research project. The research agenda thus serves as a steering instrument for new experiments and research proposals.

3 CONCLUSION

Initial goals for a research agenda can be defined as:

- Themes: Identify guiding themes and setting research questions, crucial for identifying current and future experiments and research,
- Informed decision making: Prioritizing themes with stakeholders (i.e. taskforce, university deans, department deans, teacher education, policy advisors, and teachers),
- Evaluate experiments: Develop a QA system to secure delivering evidence,
- Research community: Build a research community and ensure dissemination,
- Level up experiments: The experiments in the first stage are mainly done on course-level. The timeline for the research agenda also suggest the next phase, once we have had ample time to learn from these experiment.

Each goal consists of multiple actions to reach that goal. Urgency of goals and actions need to be aligned with the CBL programme plan. Furthermore, it is important to tap into existing knowledge and experience from research and experience at our university.

The main outcome of the research agenda is to support the taskforce CBL and the CBL programme in their planning and decision making. The agenda defines the playing field for research resulting in evidence for grounding educational developments. This requires a typology of challenges, including context, which in turn supports developing a shared language among stakeholders, and allows for a local flavour of CBL.

Currently the research agenda shows preliminary results of ongoing projects. Next step is a more elaborate overview of final results. However, even with only preliminary results, the agenda makes clear where the gaps are, which gives starting points to guide research towards those topics.

The strength of a research agenda, as may be clear from this exploration, is an overview of all university wide initiatives on CBL. This informs policy makers, education designers, and researchers alike. The weakness of a research agenda is the effort required to build and maintain it. Furthermore, it requires a culture of sharing and trust: teachers need to be open about the progress and outcomes of their bottom-up innovations, researchers need to be willing to share already at early stages of their project. In our case, the research community helped to overcome this possible weakness.

The main opportunity for a research agenda based on a research plan combined with a theory driven educational view, is that the similar approach can be used on different topics to make innovation truly evidence-informed.

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LIFELONG LEARNING AS AN EXPLICIT PART OF ENGINEERING PROGRAMMES: WHAT CAN WE DO AS EDUCATORS? – A SCOPING REVIEW

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ABSTRACT

Whilst engineering education has primarily focused on providing students with the required technical competencies, new visions emphasise the importance of lifelong learning (LLL). They point towards the need to acquire the necessary competencies for LLL during the study

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programme. This requires a shift in mindset for both lecturers and students. Other studies have provided some key recommendations on how HEIs should integrate the development of LLL competencies in study programmes such as using authentic discipline-specific learning contexts and explicit teaching of the LLL competencies. This scoping review will provide an overview of which LLL interventions have already been implemented in higher education and aims to answer the question: How can HEIs support the development of students' LLL competencies? The included LLL interventions are categorised based on the type and content of the intervention, the duration, the target audience, the effectiveness, and the efficiency. The outcomes of this review serve a dual purpose: (1) to define research gaps and (2) to provide educators with some general advice regarding the integration of LLL in engineering study programmes.

1 INTRODUCTION

Whilst engineering education has primarily focused on providing students with the required technical competencies, new visions emphasise the importance of lifelong learning (LLL) and point towards the need to acquire the necessary competencies for LLL during the study programme [1]. This requires a shift in mindset as confirmed by [2]: "The educational system will not only have to re-think the content of the curriculum and its function as educator of new professionals but, indeed, to combine engineering education with continuing education in formal and informal learning communities. Individual engineers will become much more responsible for their own personal learning paths, and they will need to learn how to organise and construct their individual learning growth within combined collaborative learning communities."

Resilient students that are ready for the profession and able to pursue a sustainable career, require a HE setting that makes them aware of their professional identity and trains them in continuously re-inventing themselves [3]. The latter is also confirmed by [4] : "Universities play a critical role in promoting lifelong learning through research on the topic, training of teachers to believe in the importance of lifelong learning and serve as role models and providing learning experiences which encourage students to continue learning throughout their lives." Recommendations on how HEIs can integrate the development of LLL competencies in the study programmes are: (1) the use of authentic discipline-specific learning contexts [5], [6] and (2) explicit teaching of the LLL competencies [5], [7].

LLL is, however, a container concept and there is no agreement yet about what lifelong learning entails precisely [7], [8]. The complex nature of this broad concept is also confirmed by knowledge technologists [9] who conclude that lifelong learning is an interesting but challenging concept to capture. Fortunately, there is no doubt about the importance of LLL and the responsibility of HEIs to guide and support students in the development of LLL competencies so that each graduate is prepared for a life full of learning. Literature about LLL is, however, scarce in engineering education and since other disciplines (e.g. medicine) are more evolved in this domain of LLL, this scoping review will not exclusively include studies published in engineering education research. This scoping review will provide an overview of which LLL interventions have already been implemented in higher education and aims to answer the question: How can HEIs support the development of students' LLL competencies?

2 METHODOLOGY

2.1 Defining inclusion criteria

Search terms were created to find papers that met the following criteria:

(1) The intervention involved higher education students.
(2) The intervention was evaluated to a certain extent.
(3) The intervention had a clear connection with lifelong learning.

2.2 Search term

Based on the inclusion criteria and the research question a first search term was used. This search term was refined based on preliminary screening of abstracts and discussions with colleagues. The used search term is presented in Table 1.

Table 1. Search term

TITLE-ABS-KEY (*"lifelong learning"* OR *"lll"*)	AND TITLE-ABS-KEY (*"train"* OR *"empirical"* OR *"effectiveness"* OR *"intervention"* OR *"pilot"*)	AND TITLE-ABS-KEY (*"competenc*"* OR *"skil*"* OR *"attitude*"*)	AND TITLE-ABS-KEY (*"universit*"* OR *"higher education"* OR *"HEI"* OR *"student"* OR *"undergraduat*"*)

In addition, it was decided only to include journal articles, written in English, and published in the last 20 years. Via Scopus 247 records were returned, which were sorted on relevance. Since this is only a scoping review it was decided to stop screening abstracts when only 2 out of 20 consecutive hits were retained. As a result a total of 169 abstracts were screened, of which 31 full papers were retained [10]–[41].

2.3 Analysing the included studies

To analyse the included studies, a spreadsheet was created to provide the following information for each study: (1) Type and content of the intervention, (2) Duration of the intervention, (3) Target audience, (4) Used research design, (5) Effectiveness of the implemented intervention, (6) Efficiency of the intervention, and (7) the link with LLL competencies. These seven aspects will be discussed in the results section.

3 RESULTS

3.1 Link with LLL

A third of the included studies (n=13) linked the intervention (a method or tool) directly to lifelong learning competencies. Whereas other studies clearly defined the underlying competencies, related to LLL. A majority of the studies made a clear link with Self-regulation, Self-reflection, or Self-directed learning (n=12). Other, less frequent, underlying competencies were information literacy (n=2), clinical reasoning (n=1), and self-efficacy (n=1).

3.2 Type and content LLL interventions

When analysing existing LLL interventions in HEI, four main types can be identified: (1) Focus on self-regulation via (e)Portfolios, personal development plans, specific sessions, online material or personal learning environment & network (n=8), (2) Reflective journals or practice (n=3), (3) Student-centred teaching methods such as Problem/Project Based Learning (PBL), flipped classroom, team based learning, networked learning, work integrated learning (n=11), and (4) Use of Peer and Self-assessment (n=4).

3.3 Duration of the interventions

Most interventions are relatively short. A couple of studies (n=4) have a very short duration ranging from one session to two months. More than a third of the studies included the LLL intervention during a specific course (n=15). One study implemented PBL in four courses during one year, and six studies implemented their interventions in one or two semesters.

3.4 Target audience and discipline of the interventions

The target audience, if specified, of most LLL interventions are older students (n=23), ranging from second year students to final year students. Only two studies focused on first-year students. Both of these studies implemented an intervention for first-year students focusing on reflective behaviour regarding their study results or approach.

Half of the studies (n=16) focus on students in health care related study programmes (e.g. medicine, nursing, midwife, and dental). Other, less frequent disciplines are accounting & economics (n=4), teacher education (n=3), and engineering (n=2).

3.5 Used research design to measure effectiveness

In general, most of the studies adapted a mixed method approach, combination of e.g. interviews, focus group discussions, self-designed surveys, and validated surveys, to measure the effectiveness of the interventions. If quantitative measurements were used, a pre and post-test set-up was very often selected. Some of the studies also used a quasi-experimental design and thus used a control and treatment group.

3.6 Effectiveness of LLL interventions

Overall, almost all the studies have the potential to lead to successful and effective LLL interventions. Their conclusions are not always inconclusive, however, students' perceptions were positive.

3.7 Efficiency of LLL interventions

Only a few studies (n=3) mention something about the efficiency of the implemented interventions. The ones that do mention it, state that the interventions or methods used are more time consuming (e.g. PBL and reflective journal). Only one study sees an improvement in efficiency, because thanks to the use of technology it is possible for every student to learn where and when they want at their own pace.

4 DISCUSSION AND CONCLUSION

LLL is very often used as a buzz word or key word, even when the study does not focus on LLL at all. This was the case in many of the excluded studies. There is no clear agreement yet about what LLL exactly entails and how it should be assessed. A coherent framework would therefore be an added value in both research and practice.

Overall, when looking at the types and the content of the LLL interventions there is one major common feature: almost all interventions focus on a student-centred approach, either via a specific teaching method, or via the focus on self-regulation and reflection, or via the use of peer and self-assessments. This is not unusual, since being prepared for lifelong learning is indeed a personal matter which starts from the individual. It is the task of the HEIs to support their students during this journey.

Most of the interventions are rather short and longitudinal interventions are scarce [8]. Longitudinal interventions and studies are particularly interesting since competency development is a continuous process, where knowledge, attitudes, and skills become more and more intertwined [42].

It is also no surprise that most of the research is related to the medical field, since this field already has a large and explicit emphasis on LLL. These studies are an important source of information for engineering programmes. Most of the LLL interventions focus on older students, however [10] argue that LLL should be included in the curriculum as early as possible.

Measuring effectiveness of educational interventions is not easy, especially since there are many confounding and uncertain variables. The most preferable set-up is a quasi-experimental design with a control and treatment group, using a pre and post-test setup with validated measurement tools and a mixed method approach to capture both the quantitative as the qualitative results. Some authors also mention that there is a gap in the research about how to foster and measure LLL to obtain a deeper and more detailed understanding of students' LLL competencies.

Sustainable interventions, not only have to be effective but also efficient. An intervention is efficient when the observed outcomes are produced at the lowest cost in terms of resources. Existing literature about educational interventions, does not focus on this aspect [43] . Indeed, of the included studies only a few mention something about efficiency. This is an important aspect, that should be given more attention in future intervention studies.

When linking the intervention to lifelong learning competencies, many studies just make the statement that the used method or tool is important to improve LLL. It is, however, even more interesting to look at the underlying competencies of LLL. According to the included studies self-regulation is a very important one. Based on the literature around LLL, it can be concluded that self-regulation is a core competency of LLL. Longitudinal interventions, starting in the first-year and focusing on self-regulation, have the potential to be effective for engineering students.

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STUDENT PERCEPTIONS ON A COLLABORATIVE ENGINEERING DESIGN COURSE

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ABSTRACT

To adequately prepare engineering students for their professional career, educational institutions offer projects in which students collaboratively solve engineering design problems. It is known from research these projects can lead to a variety of learning outcomes and student experiences. However, studies that provide insights in the influence of different features of an educational design are rare. In the current study we use Cultural Historical Activity Theory (CHAT) as analytical framework to understand how different elements of an educational design affect students' experience. Additionally, we use the notion of contradictions to identify opportunities

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for structural course improvement. Focus groups were conducted with 12 Master students in Aerospace Engineering, that participated in a collaborative engineering design course. During the course, students applied Systems Engineering (SE) and Concurrent Engineering (CE) and worked in the Collaborative Design Laboratory (CDL), which is a state-of-the-art facility that holds a variety of industry relevant tools. It was found that students valued the guidance of their coach and experts, co-located collaboration and the freedom to structure their own process. However, they perceived challenges with regard to adoption of tools in the CDL, sharing their progress with their supervisor, coordination of collaborative efforts and scheduling issues. An analysis using CHAT revealed what contradictions caused these challenges. Finally, recommendations are given on how course structure can be structurally improved.

1 INTRODUCTION

Engineering problems grow increasingly complex, and the ability to design solutions to these problems in a team environment is essential for 21st century engineers [1], [2]. To adequately prepare future engineers for industry, educational institutions adopt pedagogical approaches, such as Project- or Challenge-Based learning, in which students collaboratively solve open-ended problems. However, only providing students with the opportunity to engage in collaborative engineering design activities, does not necessarily lead to effective learning and can lead to varying experiences. According to Cultural Historical Activity Theory (CHAT) [3], an educational activity can be described in terms of interrelated elements that influence outcomes. Contradictions within and between these elements explain how an activity develops over time. Still, studies that reveal how specific elements of an educational design affect students' learning trajectory are scarce [4]. We aim to add to the body of knowledge by conducting focus groups to investigate the impact of different elements of an educational design on student's learning trajectory. We use CHAT to perform a systematic analysis as it not only enables us to outline the elements that mediate an educational activity, but also addresses the complex interrelations between these elements. Additionally, its notion of contradictions provides a tool to identify areas for improvement in a course design.

2 THEORETICAL FRAMEWORK

2.1 Collaborative engineering design

Engineering projects grow increasingly complex [2]. In order to systematically manage this type of problems, Systems Engineering (SE) has been widely adopted in industry. SE can be defined as "*an interdisciplinary approach and means to enable the realization of successful systems*" [5, p. 21] and offers processes, methods and tools that can be leveraged to manage the design and integration of a system thereby taking into account a variety of realistic constraints, such as economic factors, safety, and reliability. In traditional process models, experts design sub-sets of a system relatively independent, while using stand alone tools. However, this separated approach makes it more difficult or even infeasible to integrate the system and find optimal solutions which include insights of the multiple technical and non-technical disciplines involved [6]. To overcome these limitations, industry increasingly makes use of Concurrent Engineering (CE), which is "*a system design practice that encourages immediate collaboration between groups working on interrelated subsystems, so that the whole system can be integrated seamlessly and quickly"* [7, p. 1]. Additionally, tools have been developed to support the continuous integration of a system. Examples are in the Concurrent Design Facility of The European Space Agency (ESA) [6], which provides tools that support the creation of a model that integrates different sub-sets of a design, enable experts to share and present work, and facilitate co-located as well as distributed collaboration.

Educational institutions have to prepare the next generation of engineers for industry by developing education in which they simulate (parts of) professional practices. They increasingly adopt team-based design courses in which students solve complex problems while using industry relevant approaches and tools. In our research we aim to support the design of these courses based on CHAT, which provides a framework for understanding how collaborative engineering design activities can lead to learning.

2.2 Cultural Historical Activity Theory

In CHAT learning is conceptualized as an improved ability to participate in existing cultural practices [8]. For this, learners (subjects) engage in an activity that already exists in a community, because they have a common motive (object). The actions of subjects cannot be understood without the cultural context in which they take place [3]. While acting on the object, the subjects' actions are mediated by interrelated elements. First, there are tools, which are the means that subjects use to work on the object. Furthermore, subjects are mediated by implicit and explicit cultural norms and rules (rules), responsibilities, tasks and power relations (division of labour), and the community that shares the same object (community). These elements and their relations form an activity system (Figure 1). The mediational structure of an activity can be leveraged to promote learning, for example, through letting learners interact with more knowledgeable others [9] or through implementing tools that provide support [10].

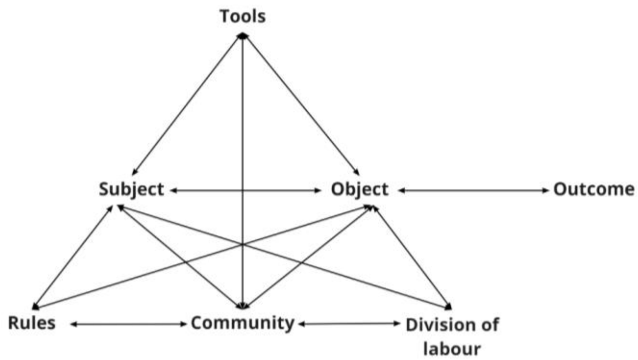

Figure 1. Activity system adapted from Engeström [3]

Activity systems are dynamic in nature and change over time. The source of these changes are contradictions, which are defined as "*historically accumulating structural tensions within and between activity systems*"[11, p. 173]. Analysing contradictions is an essential step toward understanding how activity systems evolve. Moreover, disruptions in the activity systems that are caused by contradictions provide fertile ground for structural improvement. There are four types of contradictions:

1. **Primary contradictions** exist within an element of an activity system, for example, a conferencing tool that cannot be used because the sound bar is not working properly.
2. **Secondary contradictions** emerge between different elements of an activity system for example, when CE rules require experts to integrate their sub-sets of a system in an early stage, but the tools they use do not allow for such integration.
3. **Tertiary contradictions** occur when the object of an activity is more culturally advanced than the dominant form of an activity. For example, when students go to

class their object might be to obtain a good grade, while their teachers instil the more culturally advanced object of skill development.

4. ***Quarternary contradictions*** exist between the central activity system and its neighbouring activity systems. For example, when the learning objectives of a certain course do not match the skills required by industry.

CHAT provides advantages for research on collaborative engineering design education. First, features of an educational activity cannot be examined in isolation as it is a system with complex interrelations. CHAT provides a framework that can help to understand an entire activity system and the interrelations between its elements. Second, the notion of contradictions can be used to trace opportunities for structural improvements in a course design.

In the current study we aim to first identify the benefits and challenges that students perceived during a collaborative engineering design project. Next, we trace back which elements of an activity system are central to challenges and which type of contradiction caused the challenge that was perceived by students. Our study is guided by the following research questions: 1) What benefits and challenges did students encounter during a collaborative engineering design course? 2) What contradictions underlie the challenges that students perceived?

2.3 Study context

The study was conducted within an elective course for Master Students in Aerospace Engineering at Delft University of Technology coined the Collaborative Space Design Project (CSDP). CSDP is a 5EC course that takes place within a period 8 weeks. A mid-term review in week 4 and a final review in week 8 form two major milestones. In this section the activity system of the course will be described (Figure 2).

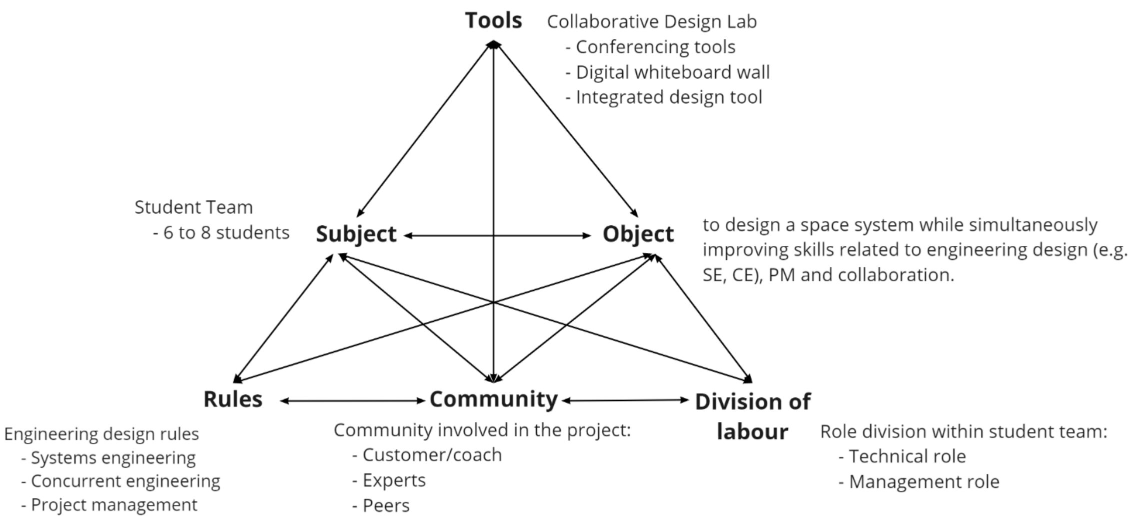

Figure 2. Activity system of CSDP

The ***subjects*** of the activity are three teams of 6 to 8 students. In the CSDP the object is to design a space system while simultaneously improving skills related to engineering design (including SE and CE), project management (PM) and collaboration. Teams work in the Collaborative Design Lab (CDL), which is an environment inspired by ESA's Concurrent Design Facility [6]. It holds a variety of industry relevant ***tools*** that facilitate CE, including: 1) conferencing tools, that allow hybrid meetings, 2) a digital whiteboard wall, which can be used for collecting, organizing and presenting information, and 3) an integrated design tool that allows for the creation and continuous integration of different sub-sets of a design. Teams were offered workshops on CE, SE, and PM, to support the application of these ***rules*** that are used in professional collaborative engineering design practices. Students were free to choose their approach to **division of labour**. However, they were encouraged to assign technical and management roles to each team member. During the process, students interacted with a **community** in several ways. Each team had one or two coaches who also fulfilled on the role of customer. Additionally, experts from industry and peers were invited to the mid-term and final review.

3 METHODOLOGY

3.1 Study design

We conducted focus groups, which are focussed discussions with a small group of people to provide qualitative data to help understand a certain topic [12]. Focus groups can guide the development of an educational program, as it provides insights from the perspective of the target audience.

3.2 Participants

In the academic year 2021-2022, three teams engaged in the CSDP. All teams were invited to participate in the study and 12 out of 21 students enrolled, respectively 3, 4 and 5 for each team. All students were Master Students in Aerospace Engineering, but there were variations in prior experience, study background and nationality.

3.3 Instruments

A semi-structured interview protocol (Appendix A) was constructed. The first part was based on Mwanza's Eight-Step-Model for interpreting the elements of an activity system [13] and addressed the role of each element of CHAT in students' design process. The second part addressed the benefits and challenges that students' encountered during their process, in order to explicate possible contradictions.

3.4 Procedure

Participants engaged in two focus groups; one after the mid-term review and one after the final review. Focus groups were conducted with members that were in the same project team. This led to a total of 6 focus groups. All focus groups were conducted by the first author of this paper and had a duration between 50 and 70 minutes.

3.5 Analysis

Our analysis constituted of two phases. In the first phase, we mapped development of students' activity by identifying features of the course they valued as well as the main challenges they encountered. For this, all focus group recordings were transcribed and analysed in Atlas.ti. We coded all interviews using a coding scheme based on CHAT elements (Appendix B). Next, we collected all benefits and challenges and performed a thematic analysis to cluster them. Only the ones that were mentioned during multiple focus groups were included in the results. In the second phase, we used CHAT as a framework to understand why challenges have emerged. We connected the elements of CHAT that were associated with a certain challenge and assessed what type of contradictions caused the challenge.

4 RESULTS

In this section, we provide an overview of the features of the CSDP that are perceived as beneficial and challenging. Next, we use CHAT's notion of contradictions to understand why these challenges emerged and to identify opportunities for structural improvement of the course.

4.1 Benefits

The design of an activity system can be leveraged to improve learning. In this section, an overview is given of elements of the educational design that were perceived by students as beneficial for learning.

4.1.1. *Freedom to make mistakes*. All student teams appreciated the freedom they were given during the CSDP. This not only gave them the opportunity to pursue a direction that was aligned with their own interests, it also created a valuable learning environment. Students had to choose their own directions and structure their own work processes. They felt that this led to making 'mistakes' that were in hindsight the most important learning moments. One student explained: "*I still think that making the mistake was a learning experience. Tripping over the stone is like: 'Hey, this stone is there*.'" As such, students perceived the way rules were embedded in the activity as positive, as they were given the freedom to choose, try and evaluate their own approach rather than having an imposed set of rules.

4.1.2. *Communication with coach and experts*. Teams mention that they benefitted from the interaction with their coach and experts. One team indicated that they especially valued the informal character of the conversations they had with their coach. It was also mentioned that the mid-term and final review that were attended by the coaches, experts and the other project teams were very useful for collecting feedback. Involvement of the community gave them the opportunity to learn from others that were already more advanced in collaborative engineering design practice.

4.1.3. *Co-located collaboration*. Two teams mentioned that working co-located in the CDL was beneficial for their collaboration. Being together in one room smoothened communication and coordination of tasks among team members. Students perceived that the facilities that were offered positively influenced the division of labour.

4.2 Challenges

The design of a learning activity can also be sub-optimal and elicit challenges for learners. This section provides an overview of these challenges and connects them to CHAT elements.

4.2.1. Technological issues. Two teams mentioned that technological issues made it difficult to use some of the tooling available in the CDL: “*you have to fix problems, they don't work the way you want them to (…) and it slows down things and it is frustrating*.” This challenge applies to the tools element of the activity system.

4.2.4. Coordinating cooperative efforts. The process of dividing and integrating work was perceived as challenging by all teams. Team 2 and 3 both indicate that it was difficult to monitor group progress, as there was no formal process for coordinating and organizing work. “*We didn’t really have a formal way of tracking tasks. (…) I think the problem was we didn’t really have somebody in charge of running these meeting in which you ask: ‘how are you doing on this task? And how can we move it forward and all?’.*” This shows that there was a lack of rules on how to organize the division of labour. Team 2 attributed the difficulties in convergence to the fact that they did not have a shared goal in mind: “*The biggest challenge for me during this course was, we split work at the beginning and then that was it for me. So I had the things I said for myself in relation to my part of the thing, but I didn't have a common goal of which I said: ‘Okay we need to get there because we are all coming here’.*” This indicated there was division of labour without having clarity on the object of the activity.

4.2.3. Interaction with coach. Teams had the freedom to organize the interaction with their coach. Team 2 struggled with talking about ‘the bigger picture’ rather than separate issues. Their coach saw their complete design only short before the mid-term review and initiated major revisions: “*I think updates were not exhaustive in that sense, right? (…) I must say, we never showed her what we were actually doing and then she saw everything at once and then she said so many things.*” Team 3 indicated that they had not been pro-active in approaching their coach in the early stage of the project. As a reaction, their coach visited them on his own initiative and asked questions they had not prepared for. Both teams mentioned it was a challenge to provide an overview of their work in early stages of the design. This indicates that teams (subjects) struggle to communicate their work in relation to the project goal (objective) to their coach (community). This challenge disappeared after the mid-term review, where teams presented an overview of their work that provided common ground in later stages.

4.2.2. Adoption of tools. The tools that were available in the CDL were not used extensively by teams. Teams mention that learning to use the tools is a time intensive process and that investing the required time did not feel worth it. In particular the concurrent engineering tool had a steep learning curve and it was more attractive to use familiar tools: “*We haven’t really used [the integrated design tool], because we felt it was easier to use Excel. Learning a new software cost time, and we needed more time to focus on our design options and selecting the optimal design*”. Meanwhile its application felt inappropriate in early stages of the design, because the number of calculations that needed to be performed and integrated were limited: “*(…) the more in-depth we go in the design, the more useful [the integrated design tool] gets. At this moment we are that shallow that a special tool has no use.”* Elements of the activity system, might not resemble the ways of working that are employed in industry and allows subject to rely on familiar tools and rules they know from previous practices.

4.2.1. Course schedule. All teams mentioned that the time frame for the CSDP was tight and the workload was high, especially in combination with other courses. Also, there was overlap between workshops and other courses, which made it impossible for students to attend some of the workshops. The cause is beyond the CSDP activity system and involves activity systems of other courses.

4.3 Contradictions

Challenges that were identified in the first stage, are now understood more thoroughly through the notion of contradictions. For each challenge we have identified an underlying contradiction. Moreover, insights are provided on how to change the activity system in order to improve the course design. A mapping of challenges, contradictions and suggestions for improvement can be found in Appendix C.

First, tools in the CDL did not always work. This is a primary contradiction, thus a solution can be found within a single element, for example replacing malfunctioning software. Second, there is a secondary contradiction between division of labour and rules or object, as some teams have not agreed on rules related to work division or clarified the object of the activity. In addition, there appears to be a secondary contradiction between subjects, community and object, as students struggle to provide an overview of overarching work and goals to their coaches. Solutions to these secondary contradictions should target the interaction between elements. In this specific case subjects should be supported in explicating rules on division of labour. Moreover, the object should be clarified within the group as well as to their coach. A solution is to provide scaffolds that help students to explicate rules and goals. Students indicated that the mid-term review helped in integrating and showing their work. To establish this in an earlier phase of the project, a baseline review can be added in the beginning of the course. Fourth, during the CSDP tools were offered to enable students to simulate (parts of) CE practices from industry. However, students perceived that these did not have sufficient advantages over tools that students were already familiar with, while learning to use them was time consuming. As such, a tertiary contradiction emerged by the activity system of the course and the more advanced activity system in industry, where similar tools are deeply embedded in engineering design practices. Solutions should aim to make the activity system of the course better match the more advanced activity systems of industry. For example, by choosing an object that requires more in depth analysis with elaborate calculations, an integrated design tool could offer more advantages. Finally, a quarternary contradiction emerged as there was overlap between courses and a high combined workload at certain times. A solution requires coordination between multiple activity systems. However, if this is not feasible, it would be possible to record workshops and make the content available for students who could not attend.

These suggestions for improvement can provide support to students to overcome the challenges they perceived during the CSDP. However, it should be taken into account that these attempts should not interfere with the features of the educational design that are currently perceived as beneficial by students. Specifically, students indicated that being able to make mistakes contributed greatly to their learning process. Providing students with more directions, such as scaffolds, could also take away the opportunity of 'tripping over the stone'.

5 SUMMARY

In the current study we aimed to investigate how elements of an educational activity affect students' experience during a collaborative engineering design course using CHAT. It was found that students valued the freedom of choosing their own approach (rules), having a room for co-located collaboration (tools) and interacting with their coach (community). However, students also perceived challenges. Technological issues occurred, which indicated a primary contradiction within the tools element. Other challenges were caused by contradictions between elements. This included difficulties with explicating rules on division of labour and the object within the team and between the team and the coach. Support should target the interrelations between the elements involved. Additionally, tertiary contradiction between the activity system of the course and the more advanced activity system of industry caused hesitance among students in adopting tools in the CDL. A solution should be found in aligning elements of the CSDP's activity system with professional practices. Finally, challenges with conflicting schedules were caused through contradictions between activity systems of multiple courses, and should be solved through coordination between these activity systems.

The current study has some limitations. First, conclusions are based on the redescriptions of events by participants. This is useful for the collection of perspectives, but might not give an accurate reflection of the actual activity. To investigate the impact of different features of an educational design in more depth, methods such as observations could be used to complement focus group results. Second, the results of this study are tied to a specific course and therefore highly context dependent. Similar features in a different course design, might lead to different experiences for students. Therefore, it is important to expand this research to different collaborative engineering design courses, to see if generalisations can be made. Finally, some recommendations are given for course improvement. However, these suggestions are not yet tested in practice. It is important to follow up on these suggestions in order to assess whether they have the desired impact on students' experience.

Despite these limitations, we have shown how CHAT can be used as conceptual framework to address complex interrelations of elements in a course design. Moreover, the notion of contradiction can be used to understand the challenges that are perceived by students and to systematically trace opportunities for course improvement.

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APPENDIX A – INTERVIEW PROTOCOL

Question	**CHAT element covered**
- Which Bachelor degree did you finish before starting this Master - For which Master's track you are currently enrolled? - How much experience do you have with projects that involve both collaboration and engineering design?	Subject
- What did you expect to learn from the CSDP? - What have you learned during the CSDP?	Object

- What phases did you distinguish in the design process? - What activities did your team perform in each of these phases? - Why did you perform these activities? And why this order?	Rules
- How was the work distributed during these activities? - How did you keep up to date with eachother's progress?	Division of labour

- Where there people involved in the project from outside of your team?
    o Who where those people?
    o How did they contribute to the project?
	Community

- Did you use tools during the project?
    o When did you use those tools?
    o For what purpose did you use these tools?
	Tools

- Which parts of the course did you perceive as beneficial? o Why was this beneficial to you?	Activity system
- Which parts of the course did you perceive as challenging? o Why was this challenging to you?	Activity system/ contradictions
- How could you be supported during these challenges?	Activity system
- Do you have any other recommentions to improve the course? - Is there anything else you would like to share that we have not yet discussed?	Activity system

APPENDIX B – CODING SCHEME[2]

Code	**Applies to quotes that relate to:**	**Example**
Subject	characteristics of one or more students that participate in the project (i.e. the subjects)	"And for another, for me this is a completely different country, with completely different communicative cultures."
Object	the motive to participate in the activity. As the activity is an educational activity, the motive can relate to learning objectives as well as project objective.	"For me it was more about the software and the facilities we could use. So I thought it was nice we could learn something about concurrent facilities that is also used in industry and get experience in it."

[2] Version of coding scheme dated 2022-04-29

Tools	the means that students have used to achieve their objectives.	"We haven't really used [the integrated design tool], because we felt it was easier to use Excel because learning a new software cost time, and we needed more time to focus on our design options and selecting the optimal design"
Rules	the implicit and explicit rules in a community that mediated the activity.	"Yes for example for the orientation [phase],there is of course a certain structure to it when it comes to systems engineering."
Community	the community members that were involved in the activity.	"We invited a couple of other people to the review so at the review those people helped us and we've also scheduled meetings with them this week"
Division of labour	how work and responsibilities were divided among students during the activity.	"In the planning phase we gave each of us, how do you call it? A role, so (..) I was the cost person and [another team member] was the propellant management guy, so each had a subsystem or technical role, so later in the design we picked up those roles"
Contradiction	the indication there might be a contradiction	"the biggest challenge for me during this course was, we split work at the beginning and then that was it for me. So I had the things I said for myself in relation to my part of the thing, but I didn't have a common goal of which I said 'Okay, we need to get there because we are all coming here".

APPENDIX C – CHALLENGES, CONTRADICTIONS AND IMPROVEMENTS

Challenge 1: Technological difficulties when using tools		
Examples of evidence	**Contradiction type**	**Suggestions for improvement**
Team 2. "Yeah I mean because it is hardly even an intuitive thing" (…) "Some of the screens you have no idea where the control comes from" "Yeah, sometimes it is that pc, sometimes it is that pc, you don't know" Team 3. "you have to fix problems, they don't work the way you want them to (…) and it slows down things and it is frustrating."	Primary, tools	Replace malfunctioning software.
Challenge 2: Teams struggle with coordinating cooperative efforts		
Examples of evidence	**Contradiction type**	**Suggestions for improvement**

Team 1. "I think, where we are at this moment working on, is that it [work] is a bit hard to track, to back log so to say." "Yes when we were working on our presentation (…) that gave a good overview. I do not have that overview in our [Google] Drive." Team 2. "The biggest challenge for me during this course was, we split work at the beginning and then that was it for me. So I had the things I said for myself in relation to my part of the thing, but I didn't have a common goal of which I said: 'Okay we need to get there because we are all coming here'." Team 3. "We didn't really have a formal way of tracking tasks. (…) I think the problem was we didn't really have somebody in charge of running these meeting in which you ask: 'how are you doing on this task?"	Secondary, between division of labour and rules or object	Scaffolds by tools or community
Challenge 3: Teams struggle with showing an overview of their work to coaches and experts		
Examples of evidence	**Contradiction type**	**Suggestions for improvement**
Team 2. "I think updates were not exhaustive in that sense, right? (…) I must say, we never showed her what we were actually doing and then she [coach] saw everything at once and then she said so many things." Team 3. "So that is something we probably should have done better, actively communicating with him [the coach] a bit more." (..) Yeah, there was this dynamic that we certainly didn't reach out to him as much as we should have and what i think that happened is that he showed up to our working sessions which was actually nice to get that communication going. But then, because we weren't actually reaching out we could control how and when we actually wanted to have these feedback sessions."	Secondary, subjects, community and object.	Implementing a baseline review
Challenge 4: Teams do not adopt tools that are offered in the CDL and stick to familiar tools.		
Examples of evidence	**Contradiction type**	**Suggestions for improvement**
Team 1: "(…) the more in-depth we go in the design, the more useful [the integrated design tool] gets. At this moment we are that shallow that a special tool has no use." Team 3: "We haven't really used [the integrated design tool], because we felt it was easier to use Excel. Learning a new software cost time, and we needed more time to focus on our design options and selecting the optimal design"	Tertiary, between activity system of current engineering design courses and more advanced engineering practices in industry	Restructure activity system of course so that it is more similar to engineering practices in industry.

Challenge 5: Courses overlap with each other and combined workload is high.		
Examples of evidence	**Contradiction type**	**Suggestions for improvement**
Team 1. "For me it was also a very big challenge that there was an overlap with other subjects." Team 2. "In my case I had a lot of classes at the same time as the workshops and they were important classes." Team 3. "I think the workshops on the tools, they are great to expose us to these tools and these ways of working, but in a way I felt a little overwhelmed by some of them. Especially with [the concurrent design tool] I actually missed the first one [workshop] and then it felt like there was no point in trying to get it now and catching up because we had to manage all our other classes."	Quarternary, between CSDP and other courses' activity system	Coordination of schedules between courses, record workshops

DEVELOPING FUTURE WORKING LIFE COMPETENCIES WITH EARTH-CENTERED DESIGN

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ABSTRACT

Integration of sustainability in the curriculum of higher education creates a demand for bringing the theme into concrete development projects. Sustainable and proactive development have been identified in Finland as key generic competences in higher education. Capability to innovate and create sustainable solutions and services for future are key skills in producing novel sustainable solutions. We experimented with master's level students the use of a novel design method, Planet Centric Design (PCD), to create sustainable system and service concepts for the future. The trialed method combines systems thinking with service design to solve sustainability related challenges. It has been developed by a software company to support practical sustainable solution development jointly with their customers. Companies have

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recently been active in developing their own approaches to support design related activities. Trialing, benchmarking, and learning the use of the topical industry-lead methods during their studies, provides students practical hands-on experiences of using the methods and confidence to use the methods. The participating students found using an industry-developed design method valuable. Learning about sustainability was perceived to be applicable both for working and personal life and have impact in both areas. In the student's self-reflection reports on their learning and experiences, the collaborative teamwork in multidisciplinary teams and the creative confidence gained through the learning to use a novel design approach, were the most most often described positive themes.

1 INTRODUCTION

1.1 The need for new sustainable future related working life skills

Sustainable development related working life skills are increasingly part of competencies of software engineering curricula. This development is driven by, e.g., the UN 2030 Agenda for Sustainable Development [1].

In Finnish universities of applied sciences generic sustainable development competence related skills on bachelor's level include familiarity with the principles of sustainable development, ability to promote their implementation and acting responsibly as a professional [2]. For graduating bachelors, ability to find sustainability related information and solutions, and apply them in practice, as well as understand sustainability related challenges and issues are described as possessed skills. On master's level sustainable development compentences call for ability to develop and manage sustainable and responsible operating methods in work, and support sustainable change in work community and society [2]. Furthermore, the abilities of graduating master's level students include creation of sustainable solutions and analysing and assessing systemic dependencies of complex challenges.

Future competencies include also proactive development. On bachelor's level a graduating student seeks and implements solutions that anticipate the future and can apply existing knowledge and methods [2]. On master's level student can manage the development of new solutions that anticipate future by using various research and development methods to create new knowledge [2]. In addition, creative problem solving collaboratively in multidisciplinary teams, design thinking related customer centricity, sustainable and viable solution seeking and development, as well as future anticipation are needed skills for proactive development [2].

This pair of competencies calls for novel approaches to integrate the skill acquisition into the curricula and course implementations. Concrete development projects, where development methods used in industry are applied in practice to solve real-life problems have proven fruitful in learning the status quo industry practices [3]. Software companies are increasingly digital agencies providing not only software development, but also consultation and collaboration based on design thinking and service design. They provide as services not only solution identification, design and development, but also strategic planning, e.g., including business model innovation. Therefore, companies are active in developing approaches that support their wider spectrum of provided services.

1.2 Design approaches to solve sustainable future related challenges

As sustainable development goals increasingly drive innovation activities in organisations, new practice-oriented design approaches have emerged. As Papanek [4] in 1972 called for design that is revolutionary and radical to be ecologically responsible and socially responsive, Design for Sustainability as an approach emerged to address the sustainability and responsible design activities [5;6].

Designers themselves have recently globally joined to create an initiative and community around so called Earth-Centered Design [7]. The idea is to move from starting the design process from individual level to planetary ecosystem level. Earth-centered design has sparked practical design approaches, some of which are called planet-centric design. They are offered as consultative services for organizations to create sustainable solutions and business models. As the approaches are novel and industry-developed for practical purposes, the research on earth-centered and planet-centric design is still practically non-existent at the time of writing this article.

Design Council has also been active in creating a new framework for designing for the planet. Design Council's well-known Double Diamond model [8] for innovation is originally based on practitioners' design thinking approaches and has been widely applied in software engineering projects in industry as well as by academia. Recently Design Council has published for sustainable design a Systemic Design Framework [9] that combines the Double Diamond model with systemic thinking and puts planet and people in the center of design activities.

The Systemic Design Framework has six principles that guide the design activities [9]. These include the following: 1) People and planet centred to focus on shared benefits of all living things, 2) Zooming perspectives in and out - from a human to the wider system, from present to future, from root cause to vision, 3) Testing and growing ideas, 4) Inclusive and welcoming difference by creating safe and shared spaces to include various perspectives, 5) Collaborating and connecting as a project is one element in a wider system, and 6) Circular and regenerative by re-use, nurturing and growing existing physical and social assets. Systemic design includes the following activities: 1) Exploring throughout the design process, 2) Reframing the problem in different ways to support the creation of new ideas, 3) Creating bold, radical or provocative ideas as well as interventions at different levels of the system, adopting a circular mindset and prioritising most valuable actions, and 4) Catalysing by testing prototypes and consequences, by measuring by created metrics the environmental and social impact, by using sustainable business models to avoid negative consequences, and identifying similar ideas to create a bigger movement for change. The methods used in the Systemic Design process can be applied, e.g., from service design or from organisation's own or other suitable toolkits.

As an example of a planet centric design (PCD) toolkit developed by a company, a Finnish technology company Vincit openly shares their PCD toolkit to be used in sustainable design activities [10]. The approach combines systems thinking with design thinking to support creation of sustainable service or product concepts as well as business models. Design is done collaboratively and using a creative mindset. Toolkit consists of 19 canvases and a handbook to support the design process. The canvases are used to analyze, design, and evaluate different aspects of the sustainable solution development and the outcomes of the design process. The approach consists of five phases, with each phase having 2-6 canvases to support the design activities. The five phases of the PCD process are prepare, understand, envision, create, and release. We chose this method to be used in our course implementation, as it was at the time of planning the course implementation one of the few openly available toolkits and provided both the handbook as well as the canvases to be used in a concrete design project.

2 TRIALING PLANET CENTRIC DESIGN APPROACH

2.1 Learning goals

Problem-based learning (PBL) as a pedagogical approach emphasizes working on open-ended real-life problems to enable acquisition of desired skills and transferring learning to real-life [11]. We found it fitting as an approach to acquisition of competencies in sustainable and proactive development. To enable the development of the two competencies, we searched for novel approaches and practical methods that supported developing and trialing new pedagogical implementations. To address the goal of our master's level course "Creation of Future – Out of the Box" where sustainable development goals (SDG) were set as the driver for design and innovation activities, we decided to utilize an openly available industry-developed approach and toolkit for sustainable design, that is, the previously described Planet Centric Design (PCD) approach by Vincit.

As problem-based learning was chosen as the pedagogical approach in our course, we chose seven business fields in which the students as teams explored the sustainability challenges in their business field and chose the challenges to address in their team work. The learning goals of the course included understanding sustainability and sustainable development goals, mastering skills needed in creative collaboration and working as multidisciplinary teams, as well as applying design and systemic thinking related principles and development skills in practice.

2.2 Preparation and used learning technology

At the time of starting the planning of the course implementation and using PCD as the design approach, we contacted the technology company who had developed and openly shared their PCD approach and the related toolkit. The company experts, who had been designing and developing the PCD approach, gave the teachers support in planning the use of the toolkit and choosing suitable canvases (i.e., templates supporting design activities) from the toolkit to be used in the course implementation.

Materials of the course for self-study prior to and during the course were selected, created, and shared on a learning platform (Moodle) on the PCD toolkit, SDGs, creativity, systems thinking, as well as on business model design. These were chosen to support the students' self-paced learning. Miro boards containing the chosen canvases from the toolkit were created for each of the student teams to work on. Miro (miro.com) is an online collaboration tool that provides support for distributed cooperation synchronously and asynchronously by providing a whiteboard as a workspace. A group was created in MS Teams for the course and channels for each of the student teams were created to support their team work in terms of joint meetings and workshops, communication, and creating the team assignment outputs. The teachers of the course followed up and gave mentoring support in the design process by following up the activity of the teams in Miro, and on MS Teams channels, by the chat function of the channels.

2.3 Course implementation

35 master's level students enrolled to the course. Students were simultaneously actively working in their own organizations and primarily worked on the team assignment after work in the evenings or during weekends. The learning activity consisted of following parts. First, in a pre-assignment they chose on first come, first serve basis one of the seven business fields to work on as five (5) member teams: 1) Buildings and homes, 2) Green energy, 3) Tourism, 4) Transport and mobility, 5) Health and wellbeing, 6) Food, and 7) Online shopping. After choosing the theme, the students were asked to explore digital services or products in their chosen business field individually. Each of the students reported online intheir joint discussion forum in Moodle their findings on the exploration of solutions and identified gaps related to sustainability. This pre-assignment was aimed at supporting further working as a team during the first joint contact session online as well as during the later phases of the design process.

Three experts from a technology company facilitated an ideation workshop in Zoom for the student teams in the first contact session. This activity was based on the findings of the pre-assignment and self-study materials on SDGs. Student teams ideated solutions using a Planet Centric Ideation canvas in Miro to a question "*How might we deliver [value] responsibly, systemically and transparently by 2030?*" related to their business field. "*How might we*" questions are typical questions used in service design processes as the question to which solutions are ideated for.

First, the student teams needed to identify for the question the "value" to be delivered. Then the value to be delivered was asked to be brainstormed taking into account each of the three viewpoints. The students were encouraged to ideate in this phase freely, without criticism, to generate as many ideas as possible. The three viewpoints – responsible, systemic and transparent - were defined as follows. Responsible covers causing harm to the planet, systemic refers to collaboration between different partners, organizations, and other collaborators, and transparent stands for opening up the processes to end users and providing sustainable choices when using the service or solution.After ideation all the teams came together to discuss the ideas. The company experts discussed with the students the identified problems and value propositions, and the ideas for the three sustainability related areas. Experts also raised questions and helped the students in formulating and refining the value propositions and ideas.

After this session, each student team continued their PCD process online at their own pace during a one-month period. Miro board was used as the ideation and development platform, and MS Teams as the communication and collaboration channel synchronously and asynchronously. The process required the students to work as a collaborative team synchronously when brainstorming and developing solutions on the Miro board. This differed from many of the earlier course implementations during their master's degree studies where they could do group work asynchronously and divide the work between the group members for independent working. The details on the used eleven canvases from the total of nineteen PCD canvases in the design process are reported elsewhere [12].

In the end of the course, the students were asked to report their design process with its phases and outcomes with a short 10 min video and write a blog post on the learnings on the creative process, the use of the method as well as reflect on the ideas and thoughts on applying the learnings and methods in their worklife. In the second, final joint 4-hour learning session in Teams at the end of the course, each student team was asked to moderate a 15-minute discussion based on the 10-minute video presentation by one of the other teams. Instructions for how to prepare and run moderated discussions were given to the students to help them prepare their moderation. The moderation included introductions to the theme and the presenting team members and their video, preparing questions to the presenting team, and leading the discussion based on the video using the prepared questions.

2.4 Questionnaire for students on learning process and learning experience

In the end of the course, students were asked in a self-assessment questionnaire to reflect their own learning process focusing on skill development related to creative thinking, sustainability development, and future readiness. They also were asked to describe their learning experience – what was easy, what was hard for them, as well as what skills they would like to develop further, and how they could apply what they learned during the course and while applying the PCD process. The collected data was qualitative, and it was analysed by thematic analysis.

3 RESULTS

3.1 Design outcomes from the PCD approach

As outcome of the PCD process in its fourth phase, i.e., the Create phase, each of the seven student teams created one digital service or an IoT solution concept taking into account the sustainability aspects and using the results from the earlier phases of the process, including the third phase, i.e., ideation of solutions. The Planet Centric Concept canvas was used to transform ideas into concepts and identify what makes the concept sustainable. Idea was analysed with the following questions: What does it do? What is the planet positive impact? How can you measure success? What are the risks? How can it be improved?

For the created concept teams also analysed the systemic touchpoints by considering the positive and negative impact from the point of view of economy, society, and environment. For economy the question to answer was: How does the concept change the value of key resources? From the point of view of society, the questions to consider were: How do lifestyles change? Do new behaviors emerge? Who are the winners and loosers? Finally, for the environment, the impacts on environment were collected with the question: How does value of resources and new behaviors impact nature?

To enable concrete business to emerge, a business model canvas was used to address what the business model would be like with sustainable goals. Specific questions related to sustainability related issues guided the creation of the business model. As in traditional business model canvas, customer segments and value proposition were the starting points of filling in this canvas. Furthermore, the key strategic partners were identified that would enable the concept to develop into a real service. These were identified in terms of amount of influence, and on the other hand, who is in favour and who is resisting and holding back the initiative. These could be both internal and external partners.

Finally, in the fifth phase, i.e. Release, teams were asked to address how they could get their message across about the sustainability of the created solution to their target audience using the Sustainability Storytelling template. Teams considered first, what would be the metrics, i.e., the facts, related to sustainability that are communicated to the target audience. Teams then picked the tone of their message, that would represent the brand personality, and created the message to share the facts. Teams reflected on the possible perceptions of the target audience on the message, and impact of the message on their behaviour. Also risks related to the created message were analysed. If risks emerged, message could be iterated.

The concepts created by the teams included the following. A mobile application concept for mobile phones was created to support saving energy in buildings. Another team created a concept platform for green energy market for those selling energy and for consumers. Team focusing on food, identified sustainability related gaps in the current model of food delivery service Wolt, and created new features to the service based on their findings, thereby renewing the concept and business model. Online shopping platform Wish was analysed by one team, and they found a number of sustainability related issues in the operation model to address, including the returning of products. The new concept addressed several SDG's to create a more sustainable online shopping experience. The team focusing on tourism created a novel mobile application concept to support sustainable travel and related choices. New requirements were also idenfitied for developing smart watches, including materials and batteries, and related digital services. One of the teams created a novel digital service concept for sustainable citybikes.

To address the quality of the outcomes of the process, the following can be concluded from the perspective of the teachers. Firstly, quality of the outcome was affected by how the team committed to working as a team synchronously in joint workshops, and how well organized the planning of the joint team workshops were. If someone took charge of planning and facilitating each of the team workshops, this affected positively the quality of the ideas, the created concept, the business model, and the message to be delivered to the audience. Secondly, the more focused the problem to address was by the teams, how many SDGs were chosen, and how clearly the value could be identified, the more desirable and viable the concept and business model appeared, and the more clearly the message could be conveyed.

3.2 Fun and inspiring – Student experiences from the trial

The most often mentioned positive theme in the students' reflection of the course and using the PCD approach in the questionnaire was collaborative teamwork to solve the problems together as a multidisciplinary team. Furthermore, students described the creative nature of the PCD process, and many described that their creative confidence was boosted while learning and using the PCD approach collaboratively. Focusing on sustainability was considered challenging, but the canvases were mentioned to help in taking it into account in the process. Most of the students mentioned spontaneously that they took after the course more into account the different aspects of sustainability in their own working and personal life, although they noted that making the choices was not always easy. In addition, the systemic approach of the method that revealed the complexity and interconnectedness of issues, was described as valuable. Learning to use the industry-developed PCD approach and gained knowledge of sustainability issues was described as an asset and giving practical skills to be applied not only in the worklife, but personal life as well.The challenges of using the method raised by the students were primarily related to understanding the use of the canvases or the process itself, but as the process advanced, this was described to become easier. Overall, the students reflection revealed that the learning and experiences were positive.

4 CONCLUSIONS

We described the use of a novel Planet Centric Design method in higher education while using problem-based learning approach in a course implementation. The collaboration with the software company that had developed the method and applying the method was perceived fruitful and valuable by the students. In order to ensure both work-orientation and value of acquired competencies in studies for working life, experiments with new methods should be carried out as well as trialing the use of industry-standard methods in higher education. This would also allow a further comparison of the methods and the results obtained in these experiments in terms of competence and skill development as well as their applicability in working and personal life.

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ADVANCED MATHEMATICAL SKILLS AND THE RELATING FACTORS OF ENGINEERING APPLICANTS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Higher education institutions assess applicants with entrance examinations as a way to identify and rank those applicants with adequate ability to proceed in their studies. Engineering students form a significant group of higher education students, both in Europe and Finland. Finnish universities of applied sciences (UASs) developed and harmonised their student selection in the Development Project in 2017–2020. In the Development Project, a new national digital universities of applied sciences entrance examination (UAS Exam) was developed. In the current study, a cross-sectional design was used to assess advanced mathematical skills and related factors of the bachelor-level engineering applicants performing the newly developed UAS Exam. The advanced mathematical skills exam section contains mathematics and physics problems. The data were collected via the digital exam system. Altogether, 1205 engineering applicants consented to the study and performed the exam section. The data were statistically analysed. The applicants' mean scores were 4.8 (SD 5.2, median 3.9, range -4.9–20 pts) out of 20 maximum points. Over 20% of the applicants failed. Some of the background variables explain the applicants' exam results, indicating that older applicants scored better than younger ones, males better than females, and high school graduates and applicants with previous higher education degrees better than those with vocational diplomas. The results indicate that engineering applicants' advanced mathematical skills were rather poor, indicating that it may be possible that engineering applicants lack the basic skills in mathematics and physics, but this may vary between applicants.

1 INTRODUCTION

The admission of new students to universities can be described as a process of matching, guidance and selection enabling the graduation of students with the adequate skills needed in their future working life (1). Therefore, higher education institutions (HEIs) assess their applicants using entrance examinations and other selection methods to identify and rank applicants with a high probability of programme completion (2). The assessment of applicants should aim for equity and fairness, which challenges HEIs to use objective and valid selection methods (2; 3). However, student selection practices vary within and between countries (1; 2).

In Europe, engineering students form a significant group of higher education students. In 2019, there were 10.9 bachelor-level engineering graduates per thousand inhabitants in the European Union (EU) area. In Finland, there were 15.6 engineering graduates (bachelor level) per thousand inhabitants in 2019, which was the second highest number of graduates on the Eurostat list of the European countries (4). However, engineering educational systems differ across the world (5). In the Finnish educational system, higher education has a dual model consisting of science universities and universities of applied sciences (UASs) (6). In science universities, the basic degree is a master's degree, whereas UASs offer more pragmatic education and in where the basic degree is a bachelor's degree. Both university sectors offer engineering education programmes in Finland. In UASs, the duration of bachelor-level engineering education is four years, covering 240 ECTS (7).

In Finland, higher education is free of charge for citizens in EU member states and the European Economic Area (5). However, entry to Finnish HEIs is limited, so there are more applicants than study places available. Until 2016, entrance to the bachelor-level engineering education to Finnish UASs was based on success in earlier studies (matriculation examination scores) or work experience (concerning applicants with vocational diplomas) and entrance exams testing applicants' basic skills in mathematics and physics or chemistry. To be qualified as an eligible applicant, the applicants had to get enough points from the entrance exam (about one-third of the total). The final selection decision was based either on a combination of certificate scores/work experience scores and entrance exam scores or only on the entrance exam scores. Since 2017, entry to bachelor-level engineering education in Finnish UASs has been possible with certificate-based selection as well.

Finnish UASs have developed and harmonised their student selection in the Development Project for Student Selection in Finnish UASs 2017–2020. A new digital national universities of applied sciences entrance examination (UAS Exam) was developed and used for the first time in autumn 2019 (8). The UAS Exam is intended to be used in all study fields, and it includes exam sections common to all applicants and those common to applicants in specific study fields. The exam section of advanced mathematical skills is performed by all bachelor-level engineering applicants.

The purpose of the current study was to assess the advanced mathematical skills and related factors of the bachelor-level engineering applicants (to UASs). The research questions were: 1) What is the level of advanced mathematical skills of engineering applicants? 2) What factors are related to advanced mathematical skills of engineering applicants?

2 METHODOLOGY

2.1 Design, setting, participants and data collection

A cross-sectional study was conducted. Altogether, 20 UASs that were geographically spread out and that used the UAS Exam in autumn 2019 participated. Engineering applicants (bachelor level) who answered the advanced mathematical skills section in the UAS Exam and gave their consent were included. The collected data comprised the applicants' automatically calculated exam scores from the digital exam system and background variables of age, gender, previous education, socioeconomic background (according to mother/father), place of birth (own/parent) and study programme/field of an applicant. The applicants performed the UAS Exam under supervision at the participating UASs using their own devices between 29 October 2019 and 1 November 2019. Approval to undertake the study was granted by the UASs, and ethics committee approval for the study was obtained (27 September 2019).

The advanced mathematical skills exam section assesses applicants' abilities in mathematics and physics. The problems concerning mathematics involve simplifying algebraic expressions, solving equations and problems involving plane geometry and trigonometry, for example, a right-angled triangle. Physics problems involve conclusions and calculations based on the given physical models or basic knowledge related to physical phenomena, as well as interpreting charts and graphs. Unfortunately, the more specific presentation of the concrete exam questions is beyond the scope of the current paper. In autumn 2019, there were altogether seven exam questions (multiple choice). The maximum scores were 20, the minimum pass score was 1, and penalty scores were used to avoid guessing behavior.

The validity evaluation of the advanced mathematical skills exam section was conducted as part of a larger research project (8). In the research project, the exam questions were evaluated by an expert panel and pilot tested, and psychometric testing utilising both classical test theory and item response theory methods was conducted (8).

2.2 Data analysis

The data were analysed using the Statistical Analysis Software (SAS 9.4®). Descriptive statistics were used to describe the applicants' success in the advanced mathematical skills section (exam scores) and describe the demographic characteristics. The relating factors were analysed from two perspectives: by analysing the associations between the background variables and exam scores and between the background variables and failed exam results (i.e., the applicant scored below the minimum pass score limit). Analysis of variance with Tukey's test in post hoc multiple group comparisons was used to analyse those factors related to the applicants' exam scores. Logistic regression analysis was used to explain applicants' failed exam results and related factors. The data were analysed as part of a wider research analysis focusing on the exam results for the entire UAS Exam and its sections. Therefore, all the background variables were included in our analysis. However, the variable of 'study field' is not reported in the current study because its practical importance was considered minimal because only the engineering applicants performed the advanced mathematical skills exam section.

3 RESULTS

3.1 Applicants' demographic characteristics

Altogether, 1205 out of 1756 engineering applicants participated in the study (response rate 68.6%), thus performing the advanced mathematical skills section in the UAS Exam. Most of the applicants were 20–24 years old, and less than 10% of the applicants were younger than 20 years old (Table 1). Two-thirds of the applicants were male. Most of the applicants were high school graduates or had a vocational diploma. Applicants' parents were most often manual workers by their socioeconomic background. Most of the applicants were born in Finland. (Table 1.)

Table 1. Demographic factors of the participants (n=1205).

Demographic factor	**f**	**%**
Age		
< 20	108	9.0
20–24	479	39.8
25–29	261	21.7
> 29	357	29.6
Gender		
Male	866	71.9
Female	339	28.1
Previous education		
High school	469	38.9
Vocational school	431	35.8
Double qualification (high school and vocational school)	43	3.6
Higher education degree	93	7.7
Other	169	14.0
Socioeconomic background (father)		
Self-employed persons	215	17.8
Upper-level employees (with administrative, managerial, professional and related occupations)	202	16.8
Lower-level employees (with administrative and clerical occupations)	193	16.0
Manual workers	417	34.6
Students	27	2.2
Pensioners	114	9.5
Others (Unemployed)	37	3.1
Socioeconomic background (mother)		
Self-employed persons	115	9.5
Upper-level employees	154	12.8

(with administrative, managerial, professional and related occupations)		
Lower-level employees (with administrative and clerical occupations)	297	24.6
Manual workers	476	39.5
Students	25	2.1
Pensioners	73	6.1
Others (Unemployed)	65	5.4
Place of birth (own): born in Finland		
Yes	1107	91.9
No	98	8.1
Place of birth (parent): one parent or both parents born outside Finland		
Yes	156	12.9
No	1049	87.1

3.2 Applicants' advanced mathematical skills and related factors

The applicants' mean scores in the exam section of the advanced mathematical skills were 4.8 (SD 5.2, median 3.9, range -4.9–20 pts) out of 20 maximum points. Over 20% (n=299, 24.8%) of the engineering applicants failed (scored less than +1 points). The score distribution of the applicants is presented in Figure 1.

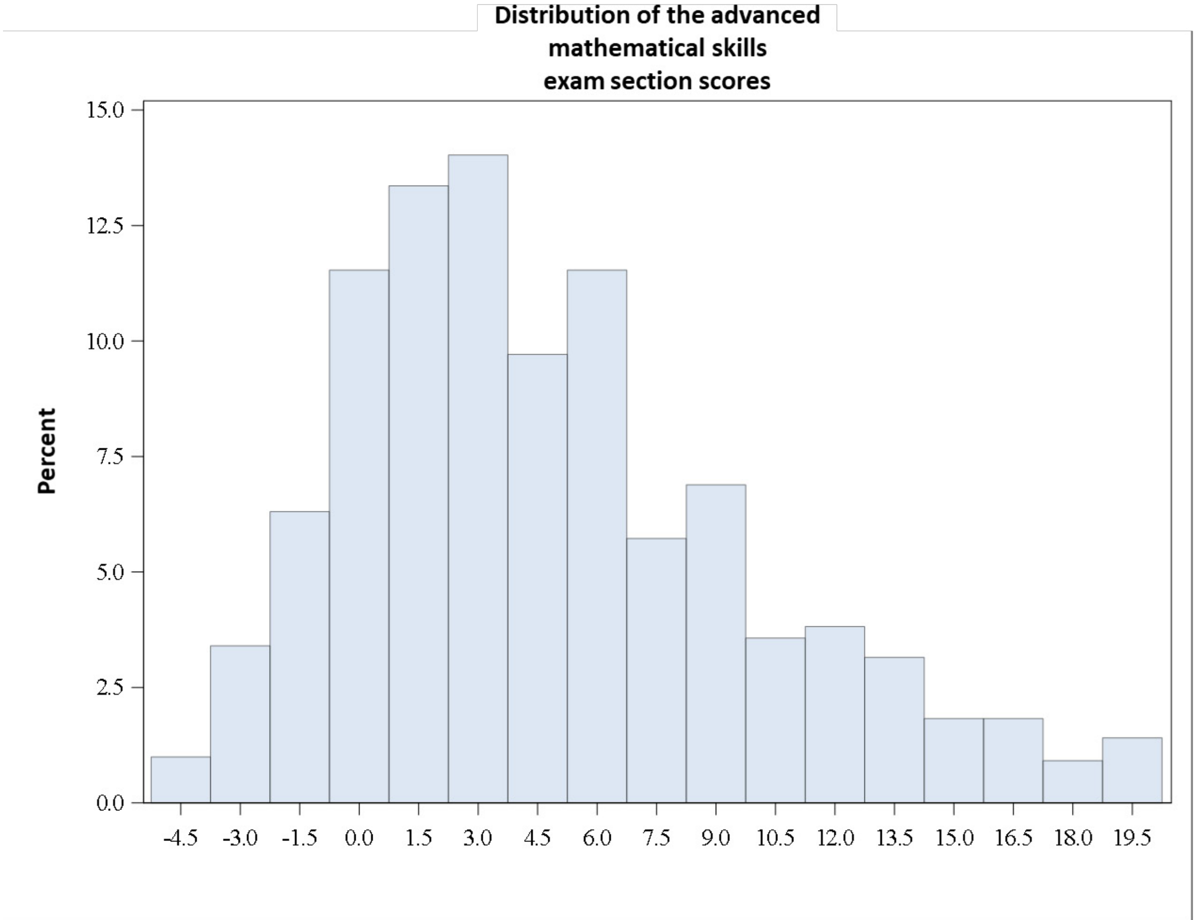

Figure 1. Score distribution of the advanced mathematical skills exam section.

Age, gender and previous education explained the applicants' success in the advanced mathematical skills exam section (Table 2). The oldest applicants (> 29 years) scored better than the youngest age groups (< 20 years and 20–24 years), and male applicants scored better than female applicants. Concerning previous education, the main result was that those applicants with previous higher education degrees and who graduated from high school scored better than the applicants with vocational diplomas. (Table 2.)

Table 2. Factors related to engineering applicants' (n=1205) advanced mathematical skills.*

BACKGROUND VARIABLES	**TOTAL SCORES** Difference between means (95% confidence interval), **p-value**/NS = not significant
Age	
20–24 vs. > 29	-1.44 (-2.41– -0.46), **0.0009**
< 20 vs. > 29	-1.64 (-3.09– -0.18), **0.0201**
Gender: Male vs. female	1.79 (1.13–2.44), **<.0001**
Previous education	
Vocational school vs. higher education degree	-3.75 (-5.37– -2.12), **<.0001**
Vocational school vs. high school	-2.69 (-3.63– -1.75), **<.0001**
Higher education degree vs. other	3.54 (1.70–5.39), **<.0001**
Other vs. high school	-2.50 (-3.78– -1.22), **<.0001**
Socioeconomic background (father)	NS
Socioeconomic background (mother)	NS
Place of birth / own	NS
Place of birth / parent	NS

*Only the statistically significant results in group comparisons are presented.

Gender and previous education were the only background variables explaining the failed exam results (Table 3). Female applicants were more likely to fail than male applicants. Applicants with vocational diplomas were more likely to fail than those with previous higher education degrees and high school graduates. (Table 3.)

Table 3. Background variables explaining engineering applicants' failed exam results in the advanced mathematical skills section (n=299/N=1205).

	OR*	**95% confidence interval**	**p-value**
Age	-	-	NS
Gender: Male vs. female	0.48	0.36–0.65	**<.0001**
Previous education			
Higher education degree vs. vocational school	0.39	0.21–0.71	**0.0024**
Other vs. vocational school	1.06	0.71–1.59	NS
High school vs. vocational school	0.54	0.39–0.75	**0.0002**
Double qualification vs. vocational school	0.64	0.30–1.37	NS

Socioeconomic background (father)	-	-	NS
Socioeconomic background (mother)	-	-	NS
Place of birth / own	-	-	NS
Place of birth / parent	-	-	NS

**OR = Odds Ratio. When the OR is higher than 1, there are more failed exam results in the group on the left than in the right one. When the OR is lower than 1, there are less failed exam results in in the group on the left than in the right one.*

4 SUMMARY

The purpose of the current study was to assess advanced mathematical skills and the related factors of the bachelor-level engineering applicants (to UASs). A new objective and digital assessment method (UAS Exam) was used. The results indicate that engineering applicants' advanced mathematical skills were rather poor and that a considerable number of applicants failed the exam section. In Finland, advanced mathematical skills, such as mathematics and physics, have been assessed for years in engineering student selection. Previously, it has been reported that entry-level engineering students lack the basic abilities in mathematics and physics, and the failure percentage in engineering entrance examinations can be very high (9). According to recent educational statistics in Finland, the number of UAS applicants who have included the physics test on their matriculation examination (a national examination taken at the end of Finnish upper secondary school) is rather low (10). Based on the results of the present study, it is possible that many UAS engineering applicants lack the basic skills in mathematics and physics, but there may be a large amount of variation between applicants and, thus, between prospective students' skills. These results should be acknowledged both in the upper secondary level when preparing students for higher education studies and in the entry/first semester of the UAS studies to find solutions that can help in filling the gap in new students' skills. Overall, it is not ideal to fail a high number of applicants in student selection. However, it is possible that the applicants' low exam scores may also relate to the difficulty level of the exam and use of penalty scores. Therefore, the scoring technique and difficulty of the advanced mathematical skills section should be further evaluated. The study results indicate that some background variables may explain engineering applicants' success and failed exam results. Male applicants scored better than females, but men were the major applicant group. An important result is that high school graduates scored better than applicants with vocational diplomas. Upper secondary education (11) should prepare students for higher education studies, but it seems that high school graduates are better prepared than those applicants with vocational diplomas. The results of the current study highlight the importance of preparing upper secondary students for higher education studies, especially in vocational education. The results can be used in further development of the UAS Exam and of fair and objective student selection practices. Furthermore, the results have international implications because HEIs are encouraged to develop their student selection practices (3).

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COMPASS: addressing the challenge of Digital Skills skilling from the Regional Ecosystem Perspective

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ABSTRACT

This is a position paper presenting the scenario and main conditionings that delimit approaching the technological and digital (re/up)skilling problem by also enhancing the role of the university as a regional ecosystem key player. This is the main objective of COMPASS, an initiative initiated to face actual challenges on the labour market related to the digital skills mismatch. COMPASS goal can be stated as the development of a regional ecosystem-based training platform and associated methodologies for effective and efficient skilling pathways. COMPASS as a guiding tool is conceived to a) guide individuals and companies to get a closer idea of the skills-gap they need to cover, as well as to b) help universities as training providers to elaborate their offer on the basis of the detected regional needs. This will definitively help to make the overall ecosystem more efficient. On the other hand, COMPASS is also conceived as a learning & training environment, in the sense of a) dynamic micro-learning environment providing easy and mobile interaction between the learners and the content and b) micro-credential system linked to the achieved skills.

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1 INTRODUCTION

Today we are experiencing what has come to be called the Fourth Industrial Revolution or Industry 4.0, in which digitalisation is one of its most important pillars, while at the same time we are on the verge of a green transition towards a decarbonised and environmentally friendly economy. This is the so called Twin Transition to a green and digital economy firmly grounded in the objectives of the European Green Deal. Digitalisation can go further than is currently planned by facilitating the shift to a more sustainable production. Technologies such as blockchain, automation, machine learning, additive manufacturing, digital design, digital twins allow additional degrees of freedom for designers and engineers to create products that emit less CO2 during their manufacturing phase, use (and re-use), and more value creation across the whole value chain, including wide based manufacturers. This twin transition is imposing urgent challenges to individuals and companies that need to face nowadays on the labour market. However, are companies prepared for this twin transition? What enablers they need? These facts, jointly with the COVID-19 pandemic have put a renewed focus on the core question: What will be the future of work, workers and workplaces? [1]

In this communication we present the drivers that motivated out university to face the technological and digital (re/up)skilling problem, specifically for adult population, as well as the conception of COMPASS as a platform to enhance the role of the university as key player on its regional ecosystem. On that respect, COMPASS, an initiative lead by the university but with the engagement of different societal players. Main purpose is to face some of the needs society 4.0 is facing for adult learning specially with respect to the engineering education related to technology ans digital skills. Those needs are basically related to the skills needed to surf the Twin Transition; for an appropriate career guidance as well as an effective and efficient upskilling & reskilling formation offer. Career guidance can facilitate re-employment by identifying new job opportunities and proposing relevant training. However, coordination of the many actors involved in such career guidance is a challenge. Career guidance is a fundamental policy lever to help adults successfully navigate a constantly evolving labour market through advice and information on job and training opportunities. Most adults who do not train say that there was no training offer that they wanted to take up. This may reflect a lack of understanding of the importance of training in today's labour market, or difficulties in identifying suitable training opportunities. The concept of adult himself is changing, who are today's decision makers and voters sustaining or influencing change in Europe. Their knowledge, capacity and learning build the groundwork to address the urgency of recovery, to decrease the burden for next generations and to pave the way to the future that Europe anticipates.

The rest of the communication is intended to present the elements that constitute the scenario as well as the proposal approach for the COMPASS platform. The scenario includes considerations about the future-proof education, the role of the universities and the considerations about a platform for appropriate reskilling/upskilling. Finally the components of COMPASS are presented. It is worth to say that in its actual stage, COMPASS is a project under development that is focused on the digital skills

FUTURE-PROOF EDUCATION

One of the indisputable consequences of the covid19 pandemic crisis is the acceleration of changes that were on the agenda of almost all universities but remained at the horizon. The crisis has motivated an urgency for teaching online and this has brought new ways of teaching and learning, look for innovative uses and new ides with respect to the adoption of technology as a key educational tool. Much of those changes have proven to be really useful and will definitively stay as the crisis is remitting. Therefore, modernizing the on-campus learning.

The mass adoption of technology has clear benefits, as it will allow universities to reach more people, provide new communication channels and the use of a wide variety of educational resources. However, personalization and human interaction are important, too. Those are key aspects to consider when looking for a future-proof education.

In his communication *on a European strategy for universities* (Strasbourg, 18.1.2022),[2] the European Commission clearly delivers the message that Universities have to adapt to the rapidly evolving situation regarding skill needs: *The green and digital transitions require future-proof education, research and innovation, in close cooperation with the related industries and stakeholders and the significant disparities in digital skills across the EU must be overcome*. Therefore, universities need to be put at work to tackle those needs as a societal challenge. The reference to future-proof education is not a minor issue and introduces some considerations (constraints?) to highlight for universities to face educational needs for the coming future. So whatever the adopted solution, the educational approaches should take into consideration:

- **Embrace technology:** The adoption of technology has made possible the continued delivery of education even the challenging situation we faced during the last two years. This fact has lead digital transformation of educational tasks at an incredible pace. Among them, the hybrid learning approach has opened new doors and made students' expectations to grow because of added flexibility.
- **Optimize human interaction:** Even technology provides means for a distance learning of improved quality, it is needed to put special attention to the added value of student and teacher meet face to face and spent time together, interacting. This time window should be focused on probing questions, look into student understanding, finding areas needing more clarity and having meaningful discussions and dialogue. Students can use recorded videos. Those are now a well-established resource (widely used, for example,

in the flipped classroom approach). They can review it at their own pace, on an asynchronous way, but they will not completely replace in-person time

- **Personalize content:** The use of online learning based on Learning management systems (LMS) either as a complement to presential on-campus education, hybrid-based approaches or on full on-line education, constitutes an unprecedented opportunity to use data analytics to understand individual learning and to tailor education for that learning. This allows learning and content to be adapted to evolve with the learner much more quickly. The use of interactive elements such as polls or questions, with informed, tailored personalized support can accelerate learning. As data reveals content that students find most challenging, the lecturer, tutors, and teaching algorithms can focus instruction in these key areas to improve learning outcomes.
- **Reach more people:** This has been one of the clear benefits the adoption of technology has put on the table during the pandemic crisis: being able to reach larger audiences than on pure presential formats. There is no discussion on this. The world's population is shifting, internationalisation is increasing, and in a closer future, our students will be coming from different places than they are now. We expect to see increasing demand for higher education from students in places such as India and Africa and it is becoming much easier to reach those students and make further learning more equitable.

All the presented factors, put on the shelf considerations that should be taken into account when desgining training and learning approaches. Specifically for specific targets such are, in this case, adult people. Therefore, by combining our use of technology, optimizing our human interactions and personalizing our instruction will allow us to stay relevant and in demand through the changes ahead.

2 THE ROLE OF UNIVERSITIES

Future jobs will be more diverse, demanding, flexible. There will be more entrepreneurs and more people working in small and medium size enterprises. This complex future is driven by the new roles that will be (in fact are being) created by the Fourth Industrial Revolution, shifts in the global economy and industrial transitions towards sustainability. Those shifts are the drivers for the EU Skilling Agenda. How will University prepare himself for this complex future? Whatever will be the adopted strategy, there is no doubt in that this preparation will need to take place in coexistence with the complex world to which people is being prepared for. What is the role of university in this new ecosystem? [3]

There are clear positionings at governance level that points the central role of higher education systems in this new panorama. The World Economic Forum, The World Economic Forum launched in 2021 the *Reskilling Revolution* [4], an initiative to provide people with better education, skills and jobs by 2030. The scheme aims to future-proof workers from technological change and help economies by providing new skills for the Fourth Industrial Revolution. This is reinforced by the European

Higher Education Area (EHEA) Rome Communiqué 2020 [5] that has already brought reskilling and upskilling to the forefront of the debate on changing the tertiary educational offer. This excerpt from the EHEA Rome Communiqué is a clear statement of this positioning "*higher education institutions have the potential to drive major change – improving the knowledge, skills and competences of students and society to contribute to sustainability, environmental protection and other crucial objectives. They must prepare learners to become active, critical and responsible citizens and offer lifelong learning opportunities to support them in their societal role*."

The report *Upskilling for Shared Prosperity* [6] finds that dual vocational training systems are particularly effective in emerging and developing countries – by combining theory and training embedded in a real-life work environment. Despite these encouraging trends, the global education and training sector remains fragmented and would benefit significantly from the emergence of a more comprehensively interconnected ecosystem.

The previous situation is reflecting the starting point of a changing higher education landscape where some fundamental questions, not appeared nor raised before, are appearing. With this perspective in mind, learning demand is shifting to a fundamentally new paradigm. What is the best way of tackling this uncertain and complex future is a question with no answer. However, for these situations it is worth to devise plausible scenarios that stimulate university leaders to formulate appropriate questions, to analyse global trends and detect opportunities and threats. There will be the need for a continuous criticism regarding the resilience of current strategies regarding new patterns and emerging trends.

One of the clear positionings that the University should redefine himself is that of collaboration with local or regional social, cultural and economic stakeholders. This is usually seen less significant than research or international collaboration. Too often also, about associating university with the world of work. There is therefore the need for a shift in perspective from the university governance with regard to the societal compromise of the university. This applies specially for what matters to lifelong learning for adult people when we refer to technology and digital skills.

3 MICROLEARNING AND SKILLING PLATFORM CONSIDERATIONS

The constant and rapid evolution of knowledge, specially within the technological domains, requires workers to adapt to this new context in order to maintain their productivity. Therefore, increase opportunities within a new more dynamic labour market. Micro-learning comes into play to facilitate this process to potential learners by breaking down new concepts into small fragments or pills of content, also called micro-content. These small learning units are given to learners progressively and in a way that is suited to them [7].

The combination of several factors has stimulated the development and the positive reception of the micro-learning paradigm: i) the human capacity to stay focused on a single item, avoiding distraction and inattention, has decreased; ii) very quick changes in all areas, especially in technology, have resulted in workers needing to update their training constantly; and iii) traditional training is not proving to be a good method to train workers effectively and efficiently.

In any case, offering adequate environments that can be totally integrated into the working processes is not a trivial aspect. An inappropriate training environment may result in high drop-out rates. This is clearly reflected in the use of MOOCs (Massive Open Online Courses) as a complement to daily work activity, with more than 90% of dropouts in this context, due to a range of reasons [7]. Accessibility is the main motivation of many students, who use the platform at their convenience for training without following the guidelines of the course in an exact way. Definitively this puts a very interesting challenge on the table of trainers, specifically at HEI. In fact, the difficulty in designing training content that is adequate for learners is not constrained to the field of continuous training for adults/employees, but it can also be used in other areas such as the university. Therefore, it is clear that the university itself will experiment a clear benefit of dealing with continuous learning as a direct multiplier effect.

These small lesson plans are gradually given to students in a way that is tailored to their needs, with the aid of telematics devices. For those employees who must be trained as an indispensable process in their professional career, micro-learning perfectly fits in by introducing short units of content, usually in audiovisual format, which can be digested in downtimes between activities. According to the main recommendations found in the literature, we consider that each unit of micro-content must be composed of three elements: a brief introduction or description, the development or explanation of the content and a small section to assess knowledge acquisition.

In order to support a micro-learning approach, it is necessary to provide activities and to facilitate the design of adequate training sequences. The Microlearning materials should be able to draw attention to very specific and clear aspects; besides, there should be complementary materials which enable learners to directly participate in their generation, assembling and modification. It is important to find a balance between brief format and complementary information. Finally, it is especially interesting to promote the micro-learning for communities, where materials derived from the training activities themselves are accessible for the student community in a manner that they can serve as a basis for debate, as support material for new activities or simply as a reference to consult.

The composition of micro-content to elaborate or define training sequences requires a system which can provide solutions to store, to locate and to compose micro-content. The cloud computing paradigm fits in perfectly with the concept of micro-learning, since if the latter is characterized by the use of brief educational resources upon request, the cloud computing paradigm is also supported by the flexible use of resources (hardware, software, storage, computation, etc.) whose amount dynamically varies depending on what is needed at each particular moment. Consequently, the application of this paradigm to the provision of micro-learning environments can be considered as a natural evolution from the first platforms based on web environments, which would allow the availability of storage, backup services and computer services, elastically provided depending on the needs at each moment, and at a more affordable cost.

There is a wide range of options when deploying a micro-learning platform. In spite of the difficulties they must face, some proposals have proved successful in this context. The appearing of some commercial solutions providing the explicit characteristics that, especially for corporate training, workers do need because of the difficulty of combining training and their normal work. On the other side, Universities do conduct formal education lying on Learning Management Systems (such as Moodle, edX, etc). Those environments where not initially been designed to support the features needed to develop, manage and deploy micro-content and implement micro-learning solutions.

At this point is where a hybrid solution comes into the table to be explored. In a similar way such as formal education is not considered an appropriate option for the corporate context, a hybrid approach that combines formal training, work experience and informal training has proven to be effective, why not to analyse an integration of micro-learning activities in traditional distance learning frameworks?

The advantages of using an existing learning platform include (i) familiarity with the environment on the part of both technicians and professors, (ii) a range of tools to manage users, profiles, permissions documents, etc. and (iii) continuous updates and improvements in terms of security and functionality.

There are however some of the essential features of micro-learning that deal with the interaction between the learners and the content. This needs further analysis and, probably, some developments. For example, since one of the relevant aspects of micro-learning is the active participation of learners in the process of co-creation and distribution of micro-content there is the need to ensure the environment is providing the mechanisms to allow both students and professors to have a more collaborative role in the creation and learning processes.

4 METHODOLOGY

From the methodological point of view, COMPASS as a skills guiding tool will be elaborated incorporating regional ecosystem activity, sector-based skills taxonomy and introducing technological trends as a source for pointing at the near future needs. Therefore, the tool is conceived from the regional ecosystem detected needs and from a transnational point of view for what matters to implementation of the learning platform. This approach will foster expertise synergies among EU HEI that will collaborate in the joint micro-learning offering. The development is conceived in terms of the following steps and activities.

4.1 Skills Taxonomy

Methodological approach to skills characterization in the technological, digital and green domains from a taxonomical point of view. This encompasses some steps forward in the characterization of skills. The elaboration of a detailed skills taxonomy is intended to allow for a statistical monitoring of brain circulation and to establish a set of indicators to allow monitoring and statistical analysis of training needs to properly redefine current offer. For example, defining a taxonomy of skills for the green transition, which will allow the statistical monitoring of the greening of our professions. This skills taxonomy should be developed jointly with the complicity of the regional ecosystem. Therefore, regional industry associations have been contacted and will take part on the skills taxonomy definition. This is a key point because ethe establishment, denomination and definition of the skills should be understood from both sides of the equation, academy and potential recipients.

4.2 IT Tool for Skills Taxonomy Management and Data Gathering

This It tool is intended to feed a database defined in terms of the previous taxonomy. The data will be collected from the regional ecosystem and will provide a data base to enable decision making regarding training offers. The fact of facing training offers in terms of a skills-based approach will enable new pathways to employment by allowing a more tailored training offer in terms of the detected gaps (actual skills map, technological trends, regional job market, etc)

4.3 Ecosystem Engagement

Once the Skills Taxonomy is established and the IT tool for management implemented, ecosystem engagement will be worked out by means, for example, of a series of sessions organised by umbrella assciations and joining companies, work placements, regional governments, adult organisations, etc. Main purpose is to present the faced problem on career guidance as well as the prospective for the COMPASS tool will be presented. These sessions will contribute to elaborate a radiography of the skills status of a region/economic area/company/etc. Allowing for trends in economy and technology to be introduced, skills gaps will also be reflected, and skilling pathways based on similarity profile.

4.4 Ellaboration of the Carreer Guidance tool

This career guidance tool will be elaborate to operate on the skills taxonomy dabase that refects the state of the region. On the basis of actual challenges, desired skills, individuals as well as companies can test heir position with respect to the needed skills. The detected gap will suggest the most appropriate training. As per the university concern, what is relevant is the picture of the detected skill gaps at regional level. This should drive the university on what is the more suitable offer on lifelong learning if it has to impact on the region.

5 COMPASS CONCEPTION

COMPASS is conceived as the development of a regional ecosystem-based training platform and associated methodologies for effective and efficient upskilling and reskilling.

COMPASS as a platform is conceived as integrated by two key elements: a) skills guiding tool and b) a dynamic micro-learning based training offer. COMPASS as a skills guiding tool will be elaborated incorporating industrial activity, sector-based skills taxonomy and introducing technological trends as a source for pointing at the near future needs. COMPASS guiding tool is conceived to:

- Guide individuals and companies to get a closer idea of the skills-gap they need to cover.
- Help universities as training providers to elaborate their offer on the basis of the detected regional needs. This will definitively make the overall ecosystem more efficient.
- Provide a skills monitoring dashboard to facilitate a dynamic micro-learning based offer to cover the actual and forecasted needs.

On the other hand, COMPASS as a micro-learning based training environment:

- Dynamic micro-learning environment providing easy and mobile interaction between the learners and the content.
- Micro-credential system linked to the achieved skills.
- Incorporation of a challenge based system to help drive the learning pathway to the appropriate micro-modules

The tool is conceived from the regional industrial ecosystem detected needs and from a transnational point of view for what matters to implementation of the learning platform. This approach will foster expertise synergies among EU HEI that will collaborate in the joint micro-learning offering.

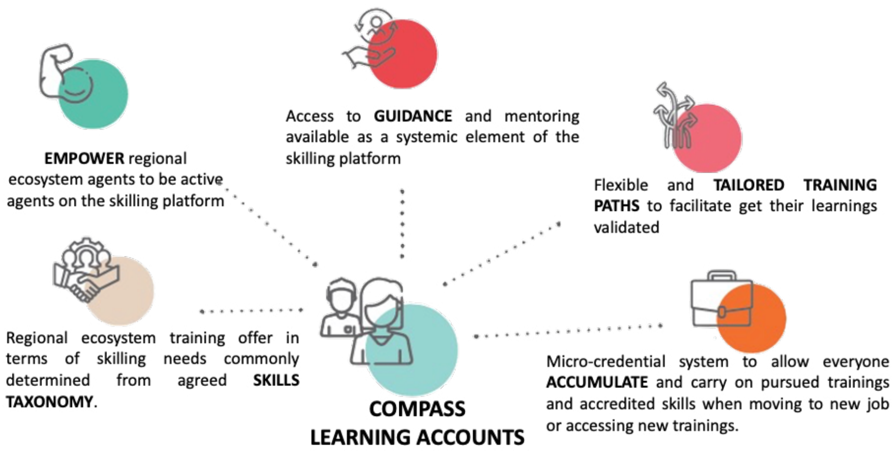

Fig. 1. COMPASS

6 SUMMARY AND ACKNOWLEDGMENTS

This communication has presented the scenario that drives an higher education institution to be involved into the training activities oriented to increase the labour effectiveness of the surrounding ecosystem. The settings are the ones linked to the COMPASS initiative that is focused on the technological, digital and green skills. The overall picture has been presented and the key role universitie should play into those regional ecosystems highlighted. The point of introducing a shift into the perspective of better valorising education in front of just doing research will by sure have a mid-long term impact on a more global level.

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THE ETHICAL UNDERSTANDING OF ENTRY LEVEL ENGINEERING AND COMPUTER SCIENCE STUDENTS

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ABSTRACT

Ethics is considered an essential aspect of tertiary computer science and engineering education and forms a core part of professional accreditation for degree providers. The authors have been unable to locate a study in New Zealand on computer science and engineering students' ethical beliefs, making this study an important exploration in this field. This study investigates the incoming first-year

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cohort's beliefs and understanding of ethical issues across three areas: students, future employees and members of society. We conducted the study over two consecutive years to investigate cohort beliefs. For most questions, the students provided high ethical responses, except in the areas of "software piracy and copyright" and "misuse of computer resources". In one year a small but significant number of female students indicated very low agreement that plagiarism is unethical. This research identified the importance of gaining an insight into student ethical beliefs as cohorts can differ in opinions. The findings challenge the common practice of teaching the same material over multiple years with the recommendation that teaching is adapted to address differences in students' ethical beliefs.

1 INTRODUCTION

1.1 Background

In both engineering and computer science education there is a recognised need by professional bodies and tertiary institutions to educate students in ethical responsibility and reasoning [1]–[3]. Despite this goal, the international literature indicates that there is widespread differences in approach and limited evidence on the effectiveness of many existing curricula [4]–[5]. In the New Zealand case there is no significant body of literature that looks at effectiveness of teaching, students ethical beliefs, or relevant context.

Our School of Engineering and Computer Science programme at Victoria University of Wellington, New Zealand (VUW) teaches a Bachelor of Science (BSc) and Bachelor of Engineering with Honours (BE) in digital technology fields. There is no instruction on ethics in the first-year programme and both degrees share many technical courses. Ethics education within our programme is primarily delivered via second- and fourth-year professional engineering courses in the BE.

2 METHODOLOGY

2.1 Survey, Data Collection and Analysis

This study aims to identify the strength of ethical belief of our incoming BSc and BE students from three perspectives: as students, as employees and as members of society - asking from different viewpoints allows identification of features in the responses indicative of the character of student understanding of ethical issues. We used a modified version of the survey instrument developed to assess ethical perceptions by Omosalewa Aderonmu, Cheryl Aasheim, and Paige Rutner, from Georgia Southern University, USA [6]. The full survey can be found here: https://bit.ly/35wjty4. The VUW ethics committee approved this research (ref. 0000027448). Questions are grouped into the three perspectives and responses are requested on a 5 point Likert scale where 1 is "strongly disagree" and 5 is "strongly agree". Table 1 in section 3 lists the survey questions. The surveys were distributed in paper form in the courses COMP103 "Introduction to Data Structures and Algorithms" in trimester 2 of 2019 and in COMP102 "Introduction to Computer Program Design" in trimester 1 of 2020, within the first three weeks of the courses.

These courses were chosen because all BE and BSc students are required to pass both of these courses. The response rate was 45% in both years and the results were manually entered into Qualtrics [7]. In our analysis we divide responses into "buckets" with scores of 4 and 5, indicating positive agreement with the ethical position described in the questions, while grouping responses in the range 3 – 1 into a "bucket" indicating the student needs ethical education ("needs education").

3 RESULTS

3.1 Average responses on the Likert scale

How a student answers the survey questions, as a student, employee or member of society, reveals their ethical understanding. The overall results indicate generally high (> 4.0) average agreement with the ethical statements, but differences between responses within each viewpoint reveals evidence of ethical relativism on issues which should be important for students studying toward careers in digital technology. Table 1 shows the average response to each survey question in 2019 and 2020 surveys; the full results of the surveys are available online.

Table 1. Average responses to questions in 2019 and 2020

Question	Text	2019	2020
As a student I believe it is unethical to:			
Q6.1	Take credit for someone else's work	4.5	4.5
Q6.2	Hire someone to write an essay	4.5	4.3
Q6.3	Purchase or submit a research or term paper from the internet to a class as one's own work	4.6	4.5
Q6.4	Cheat on a graded assignment	4.5	4.5
Q6.5	Cheat on an exam	4.5	4.5
Q6.6	Plagiarize other people's work without citing or referencing the work	4.4	4.4
Q6.7	Add the name of a noncontributing person as an author in a project/research study	3.9	4.0
Q6.8	Copy and paste material found on the Internet for an assignment without acknowledging the authors of the material	4.1	4.3
Q6.9	Deliberately provide inaccurate references for a project or research study	4.2	4.3
Q6.10	Knowingly permit student work done by one student to be submitted by another student	4.2	4.4
As a student I believe it is unethical to			
Q7.1	Surf the internet for personal interest and non-class related purposes during classes	2.4	2.6

Q7.2	Make a copy of software for personal or commercial use	3.2	3.2
Q7.3	Make a copy of software from a friend	3.0	3.1
Q7.4	Download pirated software from the internet	2.8	3.4
Q7.5	Distribute pirated software from the internet	3.2	3.7
Q7.6	Buy software with a single user license and then install it on multiple computers	3.6	N/A
Q7.7	Share a pirated copy of software	3.3	3.6
Q7.8	Install a pirated copy of software	3.2	3.3
As an employee I believe			
Q8.1	Providing unauthorised access to other people's personal information to be unethical	4.7	4.7
Q8.2	I have an obligation to respect and protect the integrity of intellectual property and confidentiality agreements	4.5	4.6
Q8.3	Using social media networking as a tool for cyber bullying to be unethical	4.6	4.6
Q8.4	It is unethical, and potentially unlawful, to take an unathorised copy of someone else's work	4.5	4.5
Q8.5	Ethical behaviour is better understood by students in your major than students in other majors	2.8	3.0
Q8.6	Education has an influence on one's ethical behaviour	4.0	3.8
Q8.7	Being ethical is important in the information technology sector	4.4	4.4
As an employee I should			
Q9.1	Not disclose confidential organisational information to co-workers without authorisation	4.6	4.6
Q9.2	Uphold and abide by the laws, code of conduct, ethical and moral principles of my organisation	4.6	4.6
Q9.3	Not violate the privacy and confidentiality of information entrusted to me to further personal interest	4.7	4.7
Q9.4	Not surf the internet for personal interest and non-work related purposes at work	3.3	3.4
Q9.5	Not involve in the act of phishing (unathorised stealing of people's valuable data)	4.8	4.8
Q9.6	Not involve in the act of email spoofing (deformation of email phishing purposes)	4.7	4.8
Q9.7	Not violate other people's privacy with the use of internet	4.7	4.7

	monitoring devices		
Q9.8	Not use technology to infringe on other people's privacy rights	4.7	4.7
Q9.9	Adhere to strict confidentiality rules regarding privacy and proprietary matters	4.7	4.6
As a member of society, I should			
Q10.1	Advise in an honest and trustworthy manner to enable people to behave ethically	4.5	4.4
Q10.2	Be ethical in my behaviour in all aspects of life	4.3	4.3
Q10.3	Protect fundamental human rights	4.7	4.6
Q10.4	Respect the diversity of all cultures	4.7	4.6
Q10.5	Abide by and not violate the laws of the country and community	4.4	4.5
Q10.6	Not misuse computing or technology resources	4.3	4.3
Q10.7	Report and violations of ethical regulations to an authority	4.1	4.2
Q10.8	Protect against the act of piracy (downloading or copying copyrighted music/video/books/software or any electronic materials)	3.4	3.5
Q10.9	Take action if I catch someone involved in unethical use of computing resources	3.6	3.8
As an employee, I believe			
Q11.1	Establishing an organisational code of ethical standards encourages employees in that organisation to behave ethically	4.2	4.3
Q11.2	Establishing a code of ethics for professionals encourages professionals to behave ethically	4.3	4.3
Q11.3	Students acquire and develop their ethical standards by taking ethics as part of the curriculum	3.6	3.6
Q11.4	Ethical standards are important in programmes. Ethical standards should always be included in the curriculum	3.8	4.0

Questions 6 and 7 ask, from the perspective of a student, for an assessment of matters related to academic integrity and software piracy and copyright violation. The contrast in responses is stark: most Q6 responses are greater than 4.1 while most Q7 responses are less than 3.7; the distributions are explored in detail in section 3.2.

Questions 8 and 9 ask for the ethical perception from the perspective of an employee, regarding obligations to society and their employer with respect to privacy, confidentiality, copyright, intellectual property, and ethical behaviour. These two questions consistently received the highest average responses. Both cohorts rate the ethical understanding of their peers in other majors as neither better nor worse than their own (Q8.5 “neutral” 3.0 average.) The influence of employment vs.

academic context may also be seen in the results of question set 11 regarding codes of ethics, where higher average responses are given to organisational importance (Q11.1, Q11.2) than academic importance (Q11.3, Q11.4).

Question 10 is asked from the perspective of a member of society regarding personal behaviour. The majority of responses to these questions indicate a sentiment of high ethical obligation to society from both cohorts. The exceptions are questions 10.8 and 10.9, regarding copyright violation and the unethical use of computing resources, and are notable because they are consistent with context-sensitivity displayed in the lower average responses to Question 7.

Ethical relativism is where ethical belief is attributable to context, be it cultural or social norms while in contrast, ethical absolutism holds that ethical situations have definitive answers regardless of context [8]. The absolutist response to the survey would be "strongly agree" to every question. We find in the results consistent ethical relativism related to the personal identity as a student, reflecting the students understanding of social norms in their peer group. This relativism is most pronounced in question set 7 but also discernible in several other questions, for example, a reluctance to report peers visible in the response to Q10.9, or the different average responses to Q6.1 and Q6.7 which ask the same fundamental ethical question. The dichotomy seen in the average responses to question set 11 is also consistent with a relativist interpretation that ethical understanding is acquired in the context of employment rather than learned in an academic context.

3.2 Distribution of ethical sentiment within the Likert scale

Question Q6.7 was identified receiving the lowest average response in the Question 6 set regarding academic integrity, despite its close relationship to Q6.1. Question Q6.1 asks whether it is unethical to take credit for someone else's work while Q6.7 effectively asks whether it is unethical to give credit for someone else's work. Both are violations of academic integrity by the misrepresentation of authorship. The distribution of responses for these two questions is revealing and are shown in Table 2. In both years 90% of students agree, with around 80% strongly agreeing, with the statement that taking credit for someone else's work is unethical. In contrast, around only 37% – 43 % of students strongly agree with the statement that giving credit for someone else's work is unethical and 26% – 30% are neutral or disagree. Question Q6.7 provides an example of clear differences in response between the 2019 and 2020 cohorts, with a shift of around four percentage points toward stronger sentiment that "gift authorship" is unethical in the 2020 cohort.

Table 2. Distribution of responses for Questions 6.1 and 6.7 in 2019 and 2020

Question 6 As a student I believe it is unethical to:	Bucket	2019	2020
Q6.1 Take credit for someone else's work	Needs education	10.8%	11.0%
	Somewhat agree	8.9%	11.0%

	Strongly agree	80.4%	78.0%
Q6.7 Add the name of a noncontributing person as an author in a project/research study	Needs education	30.4%	26.0%
	Somewhat agree	32.9%	31.5%
	Strongly agree	36.7%	42.5%

This is perhaps the single strongest result pointing toward ethical relativism by first-year students and indicates that further education is required for both cohorts on this specific aspect of academic integrity, particularly in degrees such as the BE which place emphasis on group project work.

Question set 7 received consistently low average responses compared to all other question sets, and the distribution of responses is shown as Table 3.

Table 3. Distribution of responses for Question 7 in 2019 and 2020

Question 7 As a student I believe it is unethical to:	Bucket	2019	2020
Q7.1 Surf the internet for personal interest and non-class related purposes during classes	Needs education	82.8%	80.2%
	Somewhat agree	14.0%	12.7%
	Strongly agree	3.2%	7.1%
Q7.2 Make a copy of software for personal or commercial use	Needs education	56.4%	63.2%
	Somewhat agree	26.9%	20.0%
	Strongly agree	16.7%	16.8%
Q7.3 Make a copy of software from a friend	Needs education	62.6%	60.8%
	Somewhat agree	27.1%	22.4%
	Strongly agree	10.3%	16.8%
Q7.4 Download pirated software from the internet	Needs education	65.4%	50.8%
	Somewhat agree	24.4%	27.8%
	Strongly agree	10.3%	21.4%
Q7.5 Distribute pirated software from the internet	Needs education	60.5%	43.7%
	Somewhat agree	19.7%	21.4%
	Strongly agree	19.7%	34.9%
Q7.6 Buy software with a single user license and then install it on multiple computers	Needs education	40.8%	N/A
	Somewhat agree	24.8%	N/A
	Strongly agree	34.4%	N/A
Q7.7 Share a pirated copy of software	Needs education	51.0%	43.7%
	Somewhat agree	24.8%	27.0%
	Strongly agree	24.2%	29.4%

Q7.8 Install a pirated copy of software	Needs education	58.3%	56.3%
	Somewhat agree	21.2%	23.0%
	Strongly agree	20.5%	20.6%

Almost every question received a response indicating neutrality or disagreement with statements that software piracy is unethical from more than 50% of respondents. The only exception is Q7.6 in the context of licensing – a legal term – where only 40% or respondents are neutral or disagree that violating the terms of a software license is unethical. In 2019 only around 10% of respondents indicated strong agreement with the statements "as a student I believe it is unethical to download pirated software from the internet" and "as a student I believe it is unethical to make a copy of software from a friend."

These sentiments are incongruent for students to hold, whose career pathway is employment in the software industry in which their livelihood will depend on compliance with legal and ethical obligations to observe software copyright and licensing. Some awareness of this issue is revealed in the responses to questions Q8.2, Q8.4 and Q8.7 as employees while apparently not applying to themselves in the academic context [9]-[10]. Identifying this manner of ethical reasoning in the students indicates that significant classroom discussion of ethical relativism [8] should be incorporated into the professional engineering courses for these cohorts.

A trend of a small but significant number of female students responding with very low scores on the ethical understanding of "plagiarism" was observed in the 2020. For example, Q6.6: in 2019 there were 115 respondents identifying as male and 39 identifying as female, of whom 6.7% and 5.1% "strongly disagreed" with the ethical statement. In 2020, 84 respondents identified as male and 40 as female, of whom 3.4% and 17.1% "strongly disagreed" with the statement. Other questions in this set showed a similar relatively high "strongly disagree" response from female students in 2020, with differences statistically significant at the $p=0.05$ confidence level. A complete statistical analysis of this trend is unfortunately beyond the scope which can be accommodated by this Research Paper.

4 SUMMARY

We find evidence in the survey results consistent with relativist ethical reasoning [8], particularly in relation to software piracy and copyright violation [9]-[10]. Our professional engineering courses teach the same ethics material over multiple years from a predominantly absolutist perspective – which student relativist reasoning perceives as less effective (Q11.3; Q11.4). We recommend, and will implement in our courses, that teaching is adapted to address incoming students' surveyed ethical beliefs. It is clear from the data that our courses need to address the idea that ethical understanding is equally important across the three boundaries: student, employee and member of society. Our courses must address the connection between being a student and an IT professional and in doing so it may be possible to utilise the discussion around ethical relativism as a means of exploring ethical case studies.

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Reflection in action: a critical reflection tool to help students deal with uncertainties in designing solutions for complex problems

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ABSTRACT

At Delft University of Technology (DUT) in the Netherlands, multi-disciplinary teams of students collaborate with professionals in living labs to design solutions for real-life complex problems in technological innovation processes. Students are guided by a lecturer through the four phases of design to “cut through” the complexity of the problem. However, in these 'ill-defined wicked problems' nobody has an overall picture of the problem and students face many uncertainties. These uncertainties are often perceived as a barrier for decision-making within the design process.

A reflection tool, based on theoretical insights in transformative and triple-loop learning, is developed to help students critically reflect in action, providing them with options to deal with their uncertainties. We distinguish between task, social, and individual uncertainty. In this study, the central question is: How can the reflection tool help students deal with their uncertainties in solving complex problems in DUT living labs. By means of surveys and interviews we monitored students in two living labs, one with bachelor and one with master students. We focused on what kind of uncertainties they encountered, how they dealt with these uncertainties and how the reflection tool supports them in this regard.

Analysis of the data shows that students perceived all types of uncertainty in the various phases of the design process. By means of the reflection tool students gradually became aware of the many options they have in dealing with uncertainties, and particularly how these pertain to their decision-making in the design process.

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1 INTRODUCTION

1.1 Problem

Major socio-technical problems require that many people from different disciplines, angles, and expertise generate new knowledge and solutions together. Living labs have been set up at Delft University of Technology to integrate complex problem-solving in higher education. In the living labs, students work together with academics and professionals. In the minor and master program of Communication Design for Innovation at TU Delft, this is done in the so-called 'C-Labs'. In this, teams of multi-disciplinary students work together with a commissioner and stakeholders (professionals) to analyse and design for complex socio-technical problems. Students do this according to the design-based learning methodology, under the supervision of a lecturer and student teaching assistants.

With these ill-defined, so called 'wicked' problems, neither the students, commissioner, stakeholders or lecturer has a clear view of the problem or what to design for. Following the design process, the actual problem and subsequent design emerges from the collaboration between the different actors. Wherein the commissioner and stakeholders provide in-depth content knowledge, and the lecturer knowledge concerning systems (thinking), collaboration and decision making. The lecturer also provides tools for design and facilitates the process. It is up to the students to combine these different inputs in order to make design decisions. Decisions that on one hand must take into account the design process, and on the other the needs and wishes of their commissioner and stakeholders. This causes students to face a lot of uncertainty, which can be a barrier for their decision-making, and subsequently, their learning process.

1.2 Research goal and question

Since uncertainty is inherent to learning, it is not the intention to resolve or remove uncertainties in the C-labs, but rather to teach students how to deal with uncertainty to prevent that it negatively influences their decision-making and learning process. For that, we started a two-year study (funded by the 4TU Centre of Engineering Education in the Netherlands) with the aim of gaining insight into how students can be supported in solving complex problems in living labs.

Part of the research project is specifically aimed at critical reflection and is divided into three phases: In the first phase, the focus is on the question: To what extent do students experience uncertainties and how do they deal with them? The second phase focuses on the question: How can a critical reflection tool help students with this? and in the final phase, the question is: How can the tool be embedded in living labs such as the C-lab?

In this paper we will discuss the first two phases. The overarching question of this paper is: How can the reflection tool help students deal with their uncertainties in solving complex problems in DUT living labs?

2 THEORETICAL FRAMEWORK

2.1 The C-lab

The concept of the C-labs is based on **authentic learning** and **design-based learning** (DBL). Authentic learning is learning by being involved in real-world problem solving [1]. DBL is described by Gomez Punte, van Eijck, & Jochems [2] as “an educational approach where students gather and apply theoretical knowledge to solve design problems” and rooted in “active learning methods that facilitate students' learning processes" (p.14). Within C-labs, design-based learning is used to approach the problems in a structured way; a creative, disciplined and decision-oriented inquiry, carried out in iterative cycles. Basically, DBL is a teaching approach similar to, and often compared with, problem-based learning; however, in DBL the design process is of main importance. The iterative cycles in design-based learning follow the four stages of the double diamond: discover, define, develop, and deliver [10].

A crucial skill in design-based learning, due to its decision-oriented inquiry nature, is **coping with uncertainty** [3]. We distinguish **three types of uncertainty** that can inhibit the decision-making process of students in design-based learning [4] [5]. First, task uncertainty, wherein the uncertainty is caused by a lack of overview of information necessary or the complexity of the task. Second, social uncertainty, wherein uncertainty is caused by a lack of necessary information exchange or collaborative action. Within social uncertainty we distinguish uncertainty attributed to fellow students, lecturer, and commissioner. The third type is individual uncertainty, wherein uncertainty is caused by a perceived lack of competence of the individual student.

2.2 Critical reflection

As dealing with uncertainty requires students to become aware of how they experience it, it seems necessary for students **to critically reflect** on their uncertain experiences within their learning process. Given this design-based learning process involves many actors from different (technological) backgrounds: diverse students, professionals and lecturer, everyone can perceive uncertainty differently. This research therefore holds a **constructivist view on learning**, seen as using previous interpretations to construct new interpretations of the meaning of one's experience. Both transformative learning [6] [7] and triple-loop learning [8] follow this constructivist view and focus on critical reflection to achieve transformation [7] [8] or profound change [8]. Both theories indicate various levels on which an individual might reflect to deal with a mismatch or disjunction with their current way of viewing the situation. Daalhuizen et al. refer to these situations as non-routine situations wherein the individual experiences uncertainty in the decision-making process [5]. This also warrants a focus on the type of reflection, where this research looks at both reflection in-action: reflecting while doing to change the current situation, and reflection on-action: retrospective reflection to influence future situations [9].

2.3 Perspective Pyramid

This research integrates the above-mentioned theories into a framework for an individual's perspective on which an individual might reflect to become aware of and deal with experienced uncertainty. The framework, called **perspective pyramid** (see figure 1)**,** is grounded in one's perception of knowledge (epistemology), reality (metaphysics) and value (axiology). At the bottom of the pyramid lies one's *frame of reference* - the structure of cultural and psychological assumptions which assimilates past and shapes future experiences. One's frame of reference comprises *habits of mind* - ways of feeling, acting, and thinking based on previous assumptions, which is shown as the second layer from the bottom. One layer above holds the *points of view*, which express the habits of mind. These are constellations of beliefs, feelings, attitudes, and judgments. These are further comprised of *meaning scheme clusters* (the layer above), sets of immediate specific expectations, beliefs, feelings, attitudes,

and judgments. The top layer is then one's *interpretation* of reality – the culmination of the layers into how one experiences a situation.
The perspective pyramid is operationalised as a critical reflection tool used to reflect in-action while students experience uncertainty, by taking the following steps, see figure 1. First, students are asked to classify their uncertainty (task, social, or individual uncertainty). Second, students use the reflection tool to critically ask themselves why they are experiencing uncertainty, going through the different layers of the pyramid from top to bottom. Third, having identified their uncertainty, students are asked to generate options for decision-making in dealing with their uncertainty. The tool was implemented as a paper booklet in phase 2 (see 3.2 Methodology).

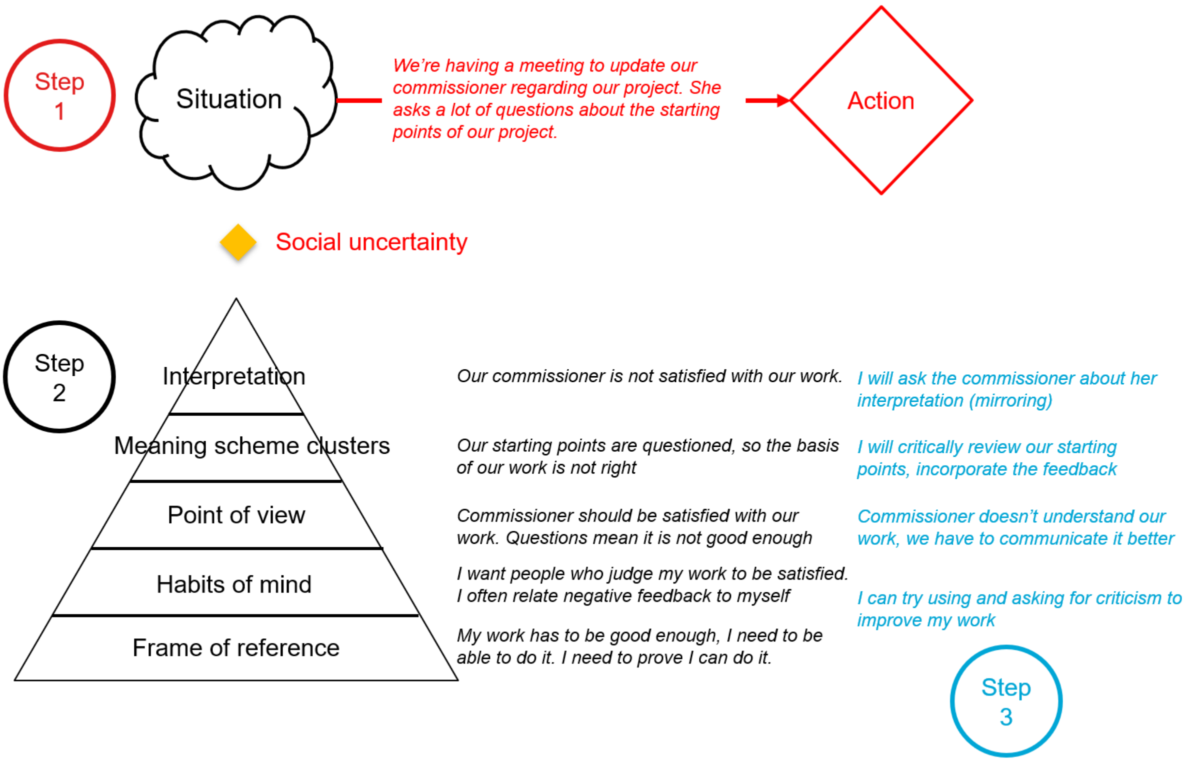

Fig. 1: Example of reflection tool in use

3 METHODOLOGY

3.1 Phase 1

The focus of the first phase was to explore to what extent students experience uncertainties and how they deal with them. In this study, 35 BSc students participated, who all signed the consent form. The students had a wide variety of technical backgrounds, where most came from computer science, mechanical engineering, architecture, and industrial design. Criteria for group composition were based on students' bachelor programs: every team consisted of students with different backgrounds. The students worked in teams of 4-7 and each team focused on a different case; all complex socio-technical problems from practice. The cases were submitted by government, industry and non-profit organizations. These professionals ("commissioners") were actively involved during the entire process, from problem definition to the presentation of the final product. They were available

for input and feedback; at set times and when students had specific questions. The minor included 8 cases with 8 student teams, spread across 9 commissioners.
The C-lab course (15 ECTS) took one semester (September 2021 – February 2022). Students worked on the case from day one. The lectures and supervision by the lecturer and student assistants were aimed at getting students to go through the design process in a systematic way, as explained in section 2.1 of this paper.
During the course students filled out weekly surveys with open- and closed-ended questions. The survey asked participants to reflect on which type of uncertainty they experienced that week, how they dealt with it, and what they would need to deal with such uncertainty throughout the design process. All data was anonymised, and the mentioned uncertainties were coded via pre- and open coding and divided into three categories: uncertainty attributed to the individual, the social context and the task. Additional measurements were used to specify and interpret the data from the weekly student-surveys, like introductory and final student surveys, learning style assessments, and interviews with lecturer and commissioners. Due to the limited size of this paper, this is not discussed in detail here.

3.2 Phase 2

The focus of the second phase was to validate the reflection pyramid as a tool. Four MSc students , all with different technological backgrounds, participated in this part of the research. They took part in a C-lab project in an international context that was compressed in one full week (November 2021). The students filled out daily reflection booklets in which the perspective pyramid was integrated (see figure 1). First students reflected on each type of uncertainty (task, social, individual). Next, each type of uncertainty experienced was further reflected on, using the layers of the perspective pyramid. Lastly students were prompted to formulate potential follow-up actions with respect to their reflections on uncertainty.Students filled out the booklet individually at the end of each day, in a facilitated reflection session.

Retrospective semi-structured interviews on basis of the reflection booklets were held with each individual student: questions related to their process and output of the week, their use and experience of the reflection tool, their awareness and ways of dealing with uncertainty, and possible improvements to the reflection tool.
The 4 interviews with master students in this second phase of the research were transcribed and coded via open coding.

4 RESULTS

4.1 Phase 1

In the monitored living lab with bachelor students, all types of uncertainty were reported. Task uncertainty, social uncertainty regarding collaboration and communication with fellow students, lecturer, and commissioner, and individual uncertainty, see figure 2. Throughout the course, task uncertainty was the most prevalent, and fellow students and lecturer uncertainty were mentioned the least. Individual uncertainty was reported more often, peaking in week 13, where students indicated they were stuck in the design process.

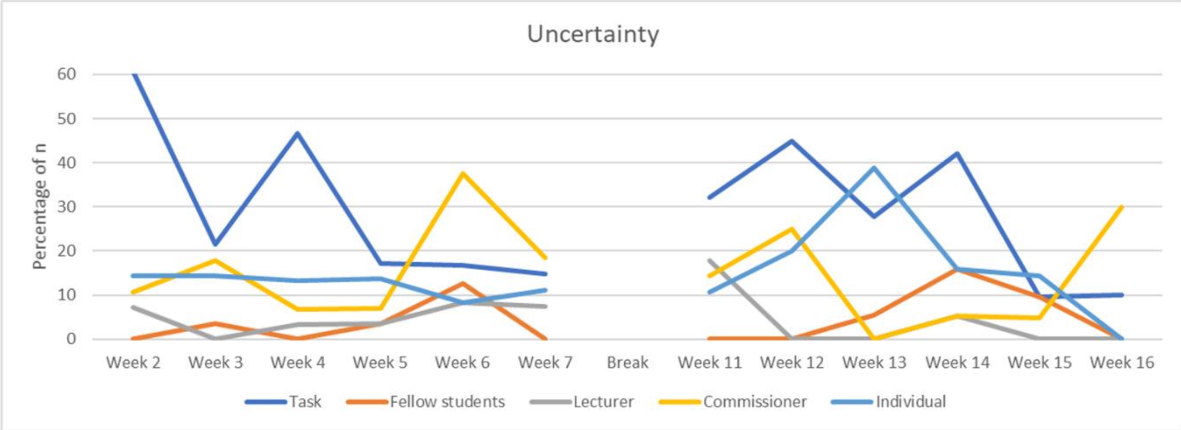

Fig. 2: Perceived uncertainty types throughout C-Lab

To some extent, students were aware of the **causes of their uncertainty**, which changes throughout the course. In weeks 2-4 (discover phase) the cause of uncertainty among most of the students was associated with an unclear task, goal, or unclear next steps to take. They attributed their task uncertainty with causes outside themselves. In weeks 4-7 (define phase), they perceived the cause of their uncertainty having more to do with difficulties in their communication with the commissioners and stakeholders. From week 11 onwards (develop and deliver phases), students took more ownership in dealing with the complexity of the case, basing their decision-making on integrating different perspectives from stakeholders and their commissioner. This required actively asking practitioners critical questions in a practice that is new to most students, causing both task and social uncertainty. Moreover, the introductory survey and interviews with the lecturer showed that bachelor students have little experience with critical reflection, and a limited critical mindset.

> *"Students struggle with developing a critical mindset, to accept different perspectives."* (lecturer)

Students reflected on what they would need to **deal with** their experienced **uncertainty** in continuation of the course. In the first phase of the design process, the following options were mentioned: better task description, clearer goals, (clearer) stakeholder input, better communication with commissioner and stakeholders. These options for improvement all seem to be attributed external to the student. In the later phases of the design process, students suggested more internally attributed options to deal with their uncertainty. The following options were mentioned: improving communication, be open-minded, take initiative, ask for help, improve teamwork. The weekly reflections of students showed that they gradually took ownership of dealing with their uncertainty.

4.2 Phase 2

Results from the retrospective interviews with master students regarding the use of the reflection tool indicate to what extent the tool supports students in dealing with their uncertainties.

In **using the tool**, students were aware of their uncertainties and it supported them in gaining insights into dealing with their uncertainties as learning opportunities. When being asked how a student experienced task uncertainty, she mentioned she had difficulty trusting the design process, finding it difficult to embrace the fuzziness of design. When asked how she reflected on this uncertainty she mentioned:

"The more often you convince yourself it is part of the process, the more it becomes a baseline for yourself. From conscious to subconscious." (#1)

One student mentioned he was very judgmental to his teammates in the beginning of the process. By using the reflection tool, he mentioned the following regarding social uncertainty:

"The tool made me less judgmental to others, first trying to find out how I project things onto others." (#2)

When being asked about how the reflection tool contributed to his learning process, one student replied:

"When you become aware of how input fits in your frame of reference, everything becomes a learning opportunity." (#2)

Students indicated which **conditions** should be prevalent in dealing with uncertainty. The necessity of reflection and reflective discourse was recognized by all students. Two students remarked it especially helped them deal with individual uncertainty. Furthermore, all students were adamant about the importance of creating "common ground" within the respective teams, meaning they had a sense of bonding on a personal and professional level.

"You can reach common ground on both personal and professional level. It can be superficial or deep." (#3)

When asked how to create common ground the following aspects were mentioned: open-minded attitude, sharing vulnerabilities, shared social and informal activities, time and effort to form bonds. Two students mentioned that having common ground helped them to leave their comfort zone.

"Leaving your comfort zone, to not be afraid but open to new things." (#2)

Finally, students provided **recommendations** for improving the reflection tool.
In reviewing the reflection tool, all students expressed enthusiasm in exploring the lower layers of their pyramid:

"It helped me to think about things I would otherwise not think about." (#4)
"I quickly kept asking myself how to get to the bottom of the pyramid. This gave me individual insights." (#2)

This speaks to how the tool facilitates critical reflection through structural questioning. However, they also stressed the importance of how the tool had to be flexible enough to fit individual reflection styles.

"The tool should stimulate reflection in your own way." (#4)

5 CONCLUSION

The central question of this paper was: How can the reflection tool help students deal with their uncertainties in solving complex problems in DUT living labs? This research shows uncertainty is present throughout the design process in DUT living labs. Results from phase 1 show that systematic reflection helps students take ownership of the causes of their uncertainty and internalise options in dealing with their uncertainty. The critical reflection tool tested in phase 2 had similar results. Moreover, the tool stimulated relatively deeper reflection, providing insights and learning opportunities regarding students' habits of mind and frame of reference. Finally, retrospective interviews about the use of the reflection tool indicated certain conditions and recommendations for dealing with uncertainty in living labs.

6 DISCUSSION

Use of the reflection tool can admittedly lead to insights among students about the more personal 'lower layers of their perspective', but (behavioural) changes cannot always be realized within the context of the living lab.This is why attention should also be paid to critical reflection and personal development in other subjects in the students' curriculum, although dealing with uncertainties may play a less prominent role there.

The retrospective interviews with students indicated their desire for a personalised reflection tool. In phase 3 of this research project, our aim is to develop the reflection tool further to both maintain its structural and critical nature, while also being flexible enough to accommodate personal reflection styles.

The extent to which deeper reflection occurs and helps students deal with their uncertainties has been further researched, and will be discussed during the presentation of this study at SEFI 2022.

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Mind the Gap – Students' Perspective on Relevant Competencies Needed and Gained in Engineering Education

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ABSTRACT

There are numerous discourses about competencies of future engineers as well as the challenge to learn, teach and assess them. In particular, this applies for the question of which competencies – besides technical knowledge and understanding – are relevant for future engineers in order to responsibly address the needs of society. This paper contains the initial results of an ongoing research project which aims to investigate engineering students' competencies and their perception thereof. In the context of a recurring engineering master's seminar at RWTH Aachen University the participants conducted interviews with a total of 41 students from outside the course. The interview subjects were themselves master's students from diverse engineering programs. In the interviews, the subjects were asked by their peers, among other things, which competencies they consider relevant for engineers and to what extent they have acquired these in their studies. The answers to those questions are evaluated and discussed in this work. The results show gaps in the acquisition of competencies – from the students' point of view – and in particular a discrepancy

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between the perceived relevance of competencies and the acquisition of these in the study programs. Besides problem solving, and technical knowledge and understanding, students pointed out that social competencies, such as communication and teamwork are particularly relevant. At the same time, they saw a lack of acquisition of these competencies in their study. The same applies for missing integration of knowledge into practical application.

1 INTRODUCTION

Research and practice within engineering education are framed by growing discourses about competencies of future engineers. This goes along with the need for both student-centred learning and integrated curriculum development in order to synthesize students' knowledge and to prepare them as future professionals [1, 2]. Moreover, as future professionals, engineering graduates must acquire a broad range of interpersonal and personal competencies that go beyond siloed technical knowledge [2, 3]. This concerns competencies for sustainable development as well as professional identity with regard to responsibility and influence on society. However, those insights are well established. Already, 20 years ago, for example [1, 4] called for a more student-centred and outcome-oriented engineering education. The same applies for the CDIO initiative, which published its first syllabus in 2001 [5].

Several literature reviews focused on competencies engineering programs should emphasize and engineering students should gain [e.g. 6, 7]. Common findings are the need for personal and interpersonal competencies, especially with regard to communication, teamwork and problem solving. At the same time, surveys with engineering students showed that they do not feel well prepared for career entry, as those competencies are lacking in their study programs [8, 9]. Often, this also goes along with an education focused on putting theoretical knowledge before practical applications [10, 11] or a lack of knowing how to integrate knowledge into application [12]. For example, in the study by Miranda et al. [8] civil engineering students emphasized that they primarily learn technical knowledge and perceive themselves in a passive role, rather than having hands-on experience. Applying and integrating theoretical knowledge to real-world problems influences students' perceptions of their engineering profession, thereby reflecting on the need for interpersonal skills, such as teamwork – which surprised several students in the study by Hughes et al. [13]. The results show that students' perception about their engineering profession is often narrow and based on disciplinary and technical knowledge, which is also in line with the results of other studies [e.g. 11, 14].

Building on that and considering the lack of qualitative research about students' perception of their competencies [15], this study focuses on engineering students' perception with regard to the most relevant competencies needed for professional engineers and their acquisition within their study programs. The study aimed to answer the following research questions:

What competencies for engineers do master's students in engineering consider relevant – and why?

To what extent are these competencies acquired in their studies?

2 METHODOLOGY

In the context of a recurring engineering master's seminar at RWTH Aachen University the participants conducted an interview each with a total of 41 students from outside the course. The aim of the course was to find out, through student-led interviews, which competencies engineering students consider relevant to be able to cope with future challenges. The teaching concept is described in detail in [16] and will therefore not be discussed further. Instead, the following is a partial evaluation of the student-led interviews on relevant competencies of engineers.

The interview subjects were themselves master's students from diverse engineering programs (see Figure 1) and recruited by the students from the course. A majority of the interview subjects studied either civil or mechanical engineering. In the interviews, the subjects were asked by their peers, among other things, which competencies they consider relevant for engineers and to what extent they have acquired these in their studies. Here, the interviewed students answered freely without being given a prior choice of competencies. Note that this is a partial evaluation. In a next step, the competencies mentioned will be analyzed further with regard to the students' perspectives on engineering responsibility and identity. A notable limitation is that the interviews were not conducted by one person, but by 41 individual student interviewers. To address this, an interview guide was developed and provided for by the instructor. All interviews were recorded and the original audio files were used for further analysis.

All 41 students-led interviews were then analyzed qualitatively by the authors in order to answer the predefined research questions. In doing so, the interviews were systematically screened for competencies that students deemed relevant.

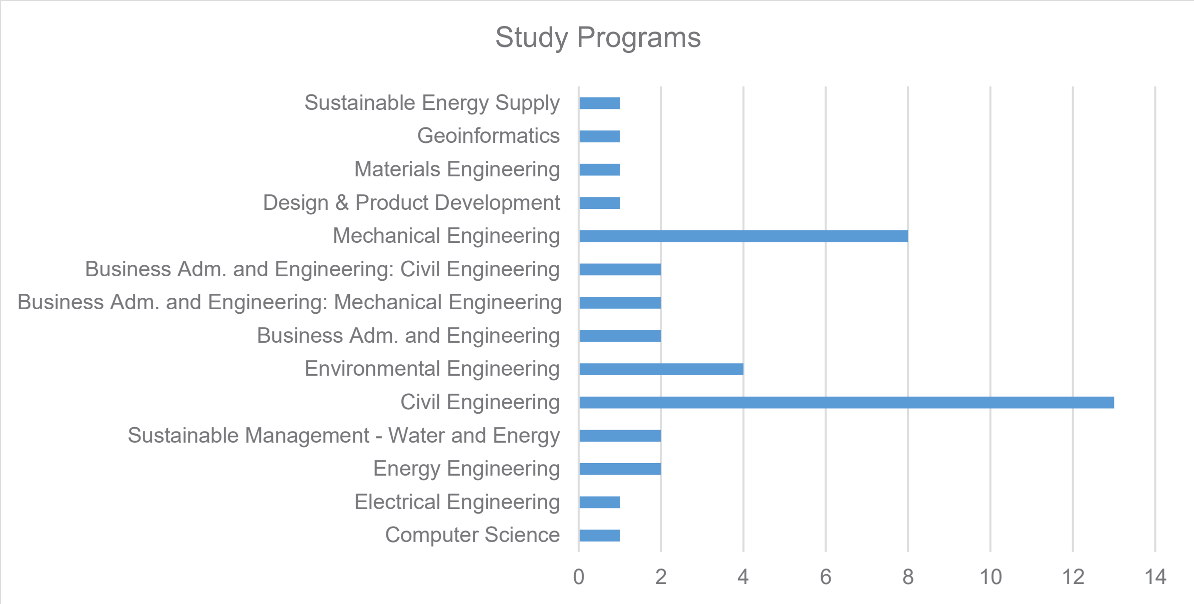

Figure 1. Study programs of surveyed master's students

3 RESULTS AND DISCUSSION

Table 1 provides an overview of both all competencies mentioned by the students as relevant for engineers and all competencies mentioned by the students as perceived as missing in their studies. The number of mentions does not serve as statistical analysis, but is intended to give an idea and to illustrate the respective distribution.

Note that the listed (translated) competencies were mentioned by the students *themselves* [16]. We deliberately did not categorize the competencies in order to transparently present the students' assessment and perception without any biases of the authors. However, there are several frameworks and studies that group teamwork and communication as social competencies, often described as interpersonal skills [e.g. 5, 13]. The fact that students name the respective competencies differently can be attributed to a lack of knowledge about them and the different ways of describing competencies [6, 7, 17].

Problem solving, and technical knowledge and understanding were mentioned most frequently as relevant competencies by students. In general, the students considered these competencies to be central characteristics of engineers, also with regard to their own perceived engineering identity. One student from business administration and civil engineering described that in the following way:

> *"A person who is very independent. A person who is so self-sufficient that when she/he has a problem, she/he has a good solution and can structurally go to this problem and solve this problem by providing certain tools, mainly related to the technical. The implementation of technical problems – this is for me an engineer."*

Note that all quotes were translated from German to English by the authors.

Table 1. Relevant and missing competencies for engineers – students' perspective

Rank	Relevant competencies for engineers (# mentions)
1	Problem Solving (33)
2	Technical Knowledge and Understanding (27)
3	Communication (19)
4	Social Competence (16)
5	Teamwork (14)
6	Analytical Thinking (8)
	Ethical Behavior and Understanding (8)
7	(Self-)Learning (7)
	Methodological Competence (7)
8	Creativity (6)
9	Responsibility (5)
	Interdisciplinarity (5)
	Holistic Thinking (5)
	Perseverance (5)
	Impact and Risk Assessment (5)
10	Leadership (4)
	Intercultural Competence (4)
11	Personal Competence (3)
	Sustainable Thinking (3)
	Economic Knowledge (3)
	Digital Literacy (3)
12	Willingness to Perform (2)
	Empathy (2)
	Presentation Skills (2)
	Recognizing Errors (2)
	Management (2)
13	Openness (1)

Rank	Competencies missing in studies (# mentions)
1	Social Competence (17)
2	Communication (8)
3	Teamwork (7)
4	Ethical Behavior and Understanding (6)
5	Interdisciplinarity (5)
	Holistic Thinking (5)
	Intercultural Competence (5)
6	Responsibility (4)
	Leadership (4)
	Presentation Skills (4)
	Digital Literacy (4)
	Problem Solving (4)
7	(Self-)Learning (3)
	Creativity (3)
	Impact and Risk Assessment (3)
8	Perseverance (2)
	Economic Knowledge (2)
	Willingness to Perform (2)
	Management (2)
9	Methodological Competence (1)
	Personal Competence (1)
	Sustainable Thinking (1)
	Empathy (1)
	Recognizing Errors (1)

In general, students' perceptions of relevant competencies for engineers go along with other studies [e.g. 6] and frameworks [e.g. 5]. In their systematic review, Passow and Passow [6] provided a broad overview of engineering competencies with regard to their importance, finding that problem solving, communication and teamwork are the three (ABET-mapped) competencies most important for work. At the same time, they concluded that "technical competence [here: technical knowledge and understanding] is inseparably intertwined with effective collaboration" [6, p. 491], which was also highlighted by the students, as, for example, one environmental engineering student stated:

> *"We engineers will most likely need to continue to work with people to solve problems collaboratively. In terms of that, I think maybe we should work more with each other [in our studies]."*

Moreover, social competence itself as well as teamwork and communication were mentioned frequently by the students as relevant competencies. At the same time, those were mentioned most frequently as missing competencies when asked whether students have acquired these competencies in their studies. To illustrate this discrepancy, these competencies are color-coded in Table 1. One environmental engineering student linked these competencies in the context of communicating technical solutions to the public, but also emphasized the relevance of reflecting on the impact of technical developments:

> *"I would say that social competence should be taken into account even more in education. That you don't just have this extremely specific technical training, but that you also learn a certain way of dealing, especially with people who are not so involved in this technical training. In order to have a better understanding of how solutions affect others, but also how I can present my solution in such a way that others can understand it."*

The competencies that were pointed out as missing most frequently were interpersonal and/or personal competencies. No student mentioned a lack or gap of technical knowledge and understanding, instead they criticized the amount of theory and technical knowledge in comparison to a lack of practical experiences and applications, as one environmental engineering student put it:

> *"Most of the subjects in my study program are far too theoretical and […] I think there is a great lack of practical experience in our study program."*

This goes along with a lack of interaction and teamwork, which was pointed out by a student of design and product development:

> "*I have already had a few bad experiences in the area of my bachelor's study program. On the one hand, there is a lack of any practical reference. A lot of theory is learned, but I missed this practical reference and also teamwork and this whole interaction, which has moved a bit to the back in the study."*

Moreover, students were afraid of not being properly prepared for professional life, as two civil engineering students stated:

"What is particularly difficult is the reference to practice. I don't really feel prepared considering how many theory subjects you've had during your study program and how much theory you retain from it. Although I'm sure these aspects were important, I don't feel that well prepared for later life. Everything I have learned so far and what I can apply are things that a program will do for me later. That doesn't make me very happy, but I can understand why people learn it."

"I don't have the feeling that I, as a whole, already stand in the market and would be ready to be able to solve more complex solutions independently, on my own responsibility. At the same time, I think that's also the competence that you have to have as an engineer: understanding complex situations, analyzing them and breaking them down into smaller packages so that you can then work on them and come up with a solution."

In the last quote, the student voices the feeling of not being able to solve complex problems independently, which students at the same time perceived as one of the most important competencies for engineers.

The lack of practical application and integration of knowledge into practice is a well-known and long discussed problem within engineering education, also regarded as traditional engineering [1, 3, 10, 11]. Thereby students have hardly any opportunity for deep learning experiences which could enable them to solve complex real-world problems [10, 12]. These findings go along with the study by Lermigeaux-Sarrade et al. [9], who asked master's students about their perceptions of gaining conceptual knowledge and professional skills. The results showed that students ask for more practice and interdisciplinarity in their studies, as well as for more teamwork. In comparison to the study by Miranda et al. [8], the results presented here represent students' perception of traditional teaching approaches in civil engineering. Students pointed out the exact lack of integrating knowledge, thereby feeling passive in their role as learners.

4 CONCLUSION

This study showed that there are significant gaps with regard to the competencies students perceive to be relevant for professional engineers and the competencies they believe to gain through their education. Especially, this concerns interpersonal and personal competencies, such as teamwork or communication. This becomes particularly relevant concerning the lack of integrating knowledge into practice, showing that this is still not the "center of their education" [1, p. 7]. The study also revealed that students' perception of relevant competencies is consistent with those discussed in engineering education research. This is novel insofar as qualitative studies from students' point of view are lacking. The results are particularly relevant as the interview subjects did not receive a predefined list of competencies, but answered freely and articulated competencies on their own. Moreover, the respondents were from different study programs, including both traditional technical engineering programs such as civil and mechanical engineering and study programs tending multidisciplinary, such as environmental engineering. However, their perceptions were very similar, especially with regard to the lack of practical application and missing interpersonal competencies. As this study is about students' *perception* of their knowledge and competencies, this does not necessarily imply *actual* gained knowledge and competencies. Therefore, an interesting next approach would be to investigate perceptions of both first-year students and graduates to get a deeper understanding of how the perception of both required and acquired competencies changes during the course of their studies. Even though the results represent the subjective perception of the students, the consistency and similarity to other studies is striking in every way. Therefore, on the one hand, the results confirm the emerging call for new and integrated curricula approaches [2], such as the CDIO approach [5, 18]. On the other hand, the results illustrate that despite existing efforts in terms of curriculum development and innovative teaching approaches, both are – in some areas – not yet applied sufficiently.

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THE POWERLESS ENGINEER: QUESTIONING APPROACHES TO TEACHING SOCIAL RESPONSIBILITY (RESEARCH)

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ABSTRACT

In recent years there has been growing emphasis on the requirement for engineers to contribute toward the complex socio-technological challenges confronted by society. The need for a more holistic understanding of the societal impact of engineering has been highlighted by government, professional institutions and industry, and has strengthened calls for a widening of engineering curricula. Despite this, there is evidence to suggest that the higher education (HE) sector is not producing socially responsible engineering graduates. This study explores potential barriers to the development of socially responsible, culturally aware engineers. In so doing, it draws upon student feedback and reflections from a UK based engineering

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design course which makes use of the Engineers Without Borders UK Design for People Challenge, and which focuses on human centered, sustainable design. The findings are discussed in the context of theories of reasoned action and planned behaviour. It is argued that engineering culture and curriculum act to discourage alternative modes of thought which leave students powerless in their ability to enact meaningful change. Alternative modes of teaching and learning are discussed.

1 INTRODUCTION

1.1 Motivation

The need for engineers to solve complex socio-technological problems has been highlighted by government bodies [1], professional institutions [2], [3], [4] and industrial stakeholders [5], [6], resulting in worldwide calls for curriculum changes. Within the UK, the latest edition of the Accreditation of Higher Education Programmes (AHEP) framework (AHEP4) has incorporated language around the social dimension of engineering, with one of the five areas of learning being referred to as “The engineer and society”, this including learning outcomes that refer to mitigation of security risks and supporting equality, diversity and inclusion (EDI), in addition to sustainability, risk and ethics [7]. Elsewhere, the National Academy of Engineering [2] call for engineers to “ethically assist the world in creating balance in the standard of living for developing and developed countries alike” (p. 51).

Despite the apparent consensus that the profession should engage more deeply with societal issues, several pieces of work suggest that higher education (HE) is not preparing engineering students to display social responsibility. For example, Bowen [8] describes “a tendency for engineering, as presently taught and practiced, to prioritize technical ingenuity over helping people” (p. 6). Zandvoort [9], Riley & Lambrinidou [10] and Bielefeldt [11] all note the absence of any clear vision of what serving society means for engineers.

Other work has focused on changes in the way engineering students perceive social responsibility, with both Cech [12] and Rulifson and Bielefeldt [13] reporting an apparent decrease in the value students place upon social responsibility throughout their undergraduate degree. Elsewhere, Smith et al. [14] reported that students taking classes with significant corporate social responsibility (CSR) content tended to express a greater desire to work for socially responsible companies. However, this improvement did not usually translate to their next course. Disengagement with societal issues has been claimed to have direct implications for the diversity of engineers [14], with several pieces of work claiming that women and racial/ethnic minorities are more likely to pursue engineering careers with an explicit sense of social responsibility [12], [15], [16]. It also limits the extent to which we can expect engineers to produce socially just and sustainable engineering solutions.

This mixed methods study explores some of the potential barriers to developing socially responsible engineers. Data is drawn from the Engineering Professional Responsibility Assessment (EPRA) tool [17] and a combination of student feedback and reflections from a UK based engineering course which makes use of the

Engineers Without Borders (EWB) UK Design for People Challenge. The findings are discussed in the context of theories of reasoned action and planned behaviour.

1.2 Theory of Reasoned Action and Theory of Planned Behaviour

The Theory of Reasoned Action, or TRA [18], [19] and the Theory of Planned Behaviour, or TPB [20], [21] are theories used to understand human behaviour, and have increasingly be used in relation to sustainability research [22], [23], [24], [25] as well as energy, green IT technology adoption, environment-friendly energy use, waste management, and vehicle use [26], [27], [28], [29], [30]. TRA (see Figure 1) offers a conceptual framework which proposes that behaviour is influenced by three factors. *Attitudes toward behaviour* and *subjective norms* are both claimed to inform a decision process which results in the deliberate plan to perform the behaviour, or the *behaviour intention*. Within the framework, the attitude toward a behaviour is influenced by two things: *outcome belief* and *outcome evaluation*. Similarly, *subjective norms* are affected by both *normative beliefs* and *motivation to comply*. TPB is an extension of TRA (see Figure 1) which includes *perceived behavioural control*, which relates to the degree to which people feel able to enact the behaviour in question, this being based on opportunity and/or capability. Such theories are of interest given the existence of work which identified a negative correlation between powerlessness and action on climate change [31], [32]. The same work also describes a relationship between action and the commons dilemma, a term originally used by the economist William Forster Lloyd [33], and which refers to a case when the benefit derived from an action accrues to the individual, but the cost is shared within the community.

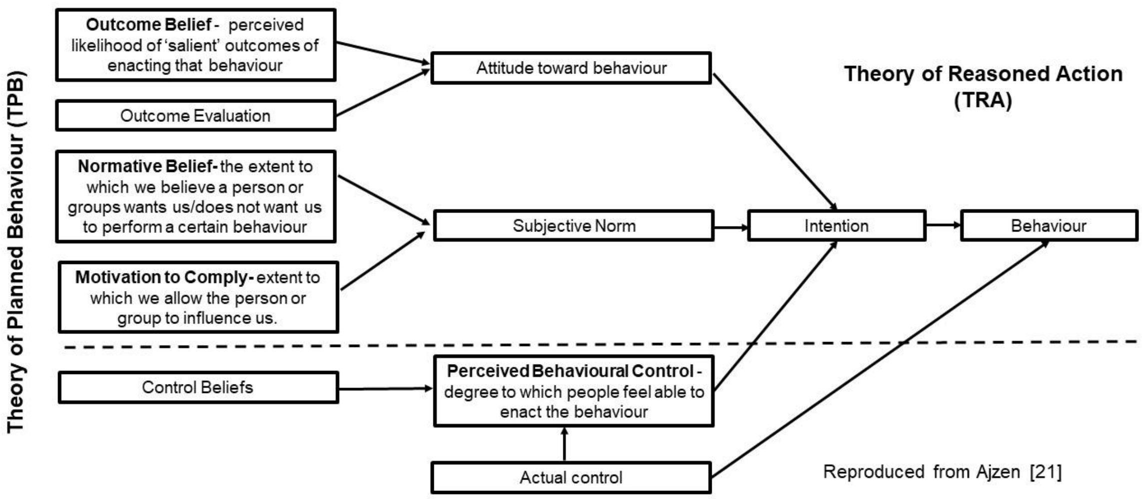

Fig. 1. Schematic showing the dimensions of the Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB) frameworks. Reproduced from [21].

2 METHODOLOGY

Data was obtained from first year (Civil, Electrical and Electronic, Materials and Mechanical) engineering students enrolled on a 10-credit module entitled

‘Engineering for People’. The module ran in the first semester of the academic year, for a duration of seven weeks from late September. The syllabus included: mindset and self-awareness; ethics and professional responsibilities; sustainability; design cycle; teamwork; positionality and personal design perspectives; and reflection. There were 2 hours of contact time per week including lectures and discussion. The module culminated in a week-long immersive design challenge during which all other modules were postponed. Students worked in small groups (5-7 students) to produce a design for the EWB UK Design for People Challenge.

Approval for use of student submissions for research purposes was sought from the Swansea University College of Engineering Ethics Committee. Students were provided with the research information sheet at the start of the module and were asked to complete a consent form to ‘opt in’ to the study. 105 of the 444 enrolled students consented to take part.

A mixed methods approach was adopted with the aim of understanding the attitude of engineering students toward social responsibility. Quantitative data was collected using the EPRA [17] which was administered to the students in the first week of the module. The EPRA has been demonstrated as being a reliable and valid measure of the social responsibility of engineering students and was developed by Canney and Bielefeldt [17] to operationalize their professional social responsibility development model (PSRDM). Their model assumes that, until university, experiences are limited to the personal realm of social responsibility development (realm 1: personal social awareness) when they are heavily influenced by friends and family. It is important to note that data was collected from first year students during their first semester, and it therefore likely that their views and behaviours reflect their personal social awareness. Throughout their degree programme, students learn about the professional realm of social responsibility, this referring to the values of priorities of the engineering profession (realm 2: professional development). The authors claim that students are likely to compartmentalize these two different realms unless they are given opportunity to engage in co-curricular activities that show them how personal and professional experiences can be integrated (realm 3: professional connectedness). The dimensions associated with each realm include: awareness (aw1-aw5), ability (ab1-ab4) and connectedness (co1-co4); base skills (ba1-ba5), professional ability (pa1-pa4), and analyze (an1-an5) and professional connectedness (pc1-pc19) and cost-benefits (cb1-cb4). The original tool therefore had 50 items in total. Following the recommendations of Canney and Bielfeldt [17], the number of items were reduced in the current work. Namely, the number of items related to the professional connectedness dimension were reduced and both the base skills and professional ability dimensions were omitted [17]. Answers were scored with a value of 1 being given for “strongly disagree” and a value of 7 given to answers of “strongly agree”. Negatively worded items (labelled * in Table 1) were reverse scored. For this work, only a basic analysis of data was conducted, and it would be interesting to investigate whether the results varied according to student characteristics, for example by gender, nationality or engineering discipline.

Qualitative data was drawn from several different sources including: written module feedback; lecture discussions; written reaction to the statement "Obsolescence is not only planned but forced and engineered", made by Professor Justin Lewis during a TEDx talk [34]; written reaction to a small extract from [35] which discusses the way in which engineering has focused on the needs of the richest in society, at the expense of other nations. Data underwent thematic analysis [36].

3 RESULTS

3.1 EPRA Results

The mean and standard deviation for each item of the EPRA tool is given in Table 1.

Table 1. EPRA Results

	Item	Mean(s.d.)
Realm 1	aw2: Some community groups within the UK need our (engineers) help	6.11 (0.83)
	aw4: There are members of society who have needs not being met	6.47 (0.97)
	ab2: I can have an impact on solving problems that face my local community	5.79 (1.02)
	ab3: My contribution to society will make a real difference	5.76 (0.99)
	ab4: I cannot have an impact on solving problems that face under-served communities internationally*	5.39 (1.22)
	co1: It is not my responsibility to do something about improving society*	5.80 (1.35)
	co2: It is my responsibility to take real measures to help others in need with problems	5.56 (1.24)
	co3: I feel an obligation to contribute to society	5.56 (1.14)
Realm 2	an1: Cultural awareness/ understanding is important for a professional engineer	6.14 (1.10)
	an3: I would not change my design if it conflicted with community feedback*	5.64 (1.05)
	an4: It is important for engineers to consider the broader impacts of technical solutions	6.26 (0.84)
	an5: It is important to incorporate societal context and constraints into engineering	5.93 (0.99)
Realm 3	pc1: It is important for professional engineers to volunteer and serve others	5.18 (1.14)
	pc3: It is important to me to have a career that involves helping people	5.50 (1.19)
	pc4: Service should not be an expected part of the engineering profession*	4.40 (1.31)
	pc5: I will use engineering to help others	6.05 (0.82)
	pc6: I view engineering and community service work as unconnected*	4.90 (1.45)
	pc7: I feel called to serve others through engineering	4.76 (1.48)
	pc8: Needs of society have no effect on my choice to pursue engineering as a career*	4.45 (1.75)
	pc13: Engineers should use their skills to solve social problems	5.39 (1.12)
	pc14: It is important to use my engineering abilities to provide a useful service to the community	5.70 (0.96)
	pc15: I believe I will be involved in social justice issues for the rest of my life	4.11 (1.61)
	pc17: I think people who are more fortunate in life should help less fortunate people with their needs and problems	5.67 (1.30)
	pc18: I believe it takes more than time, money, and community efforts to change social problems: we also need to work for change at a national or global level	6.10 (0.99)
	pc19: It is important to me to have a sense of contribution and helpfulness through participating in community service	5.27 (1.13)
	cb1: I would be willing to have a career that earns less money if I were serving society	4.48 (1.56)
	cb2: My engineering skills are strengthened through participation in engineering service	5.75 (0.91)
	cb3: I believe my life will be positively affected by the volunteering that I do	5.54 (1.14)
	cb4: I believe extra time spent on community service provides benefits for the community	6.10 (0.75)

The slightly higher values obtained for the awareness dimension, compared to ability and connectedness is perhaps unsurprising given the fact that statements are based on observation and general knowledge, as opposed to obligation [17].

When considering the professional connectedness dimension, the highest value was obtained for pc5, and it is possible that students assume that engineering, by its nature, helps society (e.g., by developing new technology) [17]. Lower values were generally obtained for items which referred to the individual (e.g., pc7, pc8, pc15) as opposed to the profession. One of the lowest values within the dimension was obtained for pc4 suggesting students feel they should have a choice in how they behave as engineers. In comparison, the highest value recorded for the dimension was for pc18. This perhaps indicates that students are aware of limitations in their ability to behave as socially responsible engineers.

It is interesting to note that one of the lowest mean values was obtained for one of the 'discriminating' [17] items, cb1.

3.2 Qualitative Results

Most students considered societal challenges such as climate change, energy security, water availability, over population, and poverty, to be the most pressing issues faced by the profession. Despite this awareness, it was possible to identify several potential sources of resistance to the inclusion of social responsibility in the context of the engineering curriculum. Table 2 presents representative excerpts organized by interpretive theme, alongside associated dimensions within the TPB.

Table 2. Representative excerpts and associated TPB dimensions organized by interpretive theme

	Subtheme	Excerpt	TPB dimension
Tensions between economic and social sustainability	Incentives	engineers focus on "how they can make the most money"; "…if we do not generate a profit then we will lose business and cliental"; if companies are "not releasing new products often enough a different company will"; "…the driving force of the modern world is economic growth and getting things done as quickly and cost-effectively as possible"; "isn't it weird that jobs helping people get paid less?"; "it's like we are being motivated not to help people"; Incentives are "predominately financial"; "…the majority of people will pursue monetary gain rather than social gain"; "…we live in a world where money is a huge factor in our thoughts and decisions making... in an ideal world…perhaps then an engineer would be more willing to pick a lower paying job which benefits the lower class of society"; preoccupation with "monetary gain or personal career development" means "the engineering profession does not attract people with humanitarian interests"; challenges within engineering include "Technology vs. Humanity, Economy vs. Environment, Globalisation vs. Community".	Outcome belief and outcome evaluation (perceived opportunity cost /commons dilemma, and influencing the career path that a student takes).
	Engineering Mindset	"…an engineer should be striving to be efficient in their solution and the cost of the solution" Reduction in financial incentives would lead to "far slower rates" of innovation "… best way to progress is to prove there is profit to be made"	Subjective norm (engineering culture)

	Culture/ "group behaviour"	"…the public's demand for newer things" which engineers don't "have control over". "…society aren't satisfied unless we see progression and improvement" "…a problem many people face is the inward view of success…our view of success drives us to be who we are, thus, in today's society, the brand-new, the fancy, the item everyone 'needs' is the message portrayed by every business, company, and store. We need to be better than we already are, all through physical items and price tags." "…the modern world is so consumed with economic growth and profitability that sometimes we lose sight of real reasons we should be striving to improve what we currently have".	Subjective norm (societal culture)
Sense of powerlessness	Limited impact	"…as an individual there is very little he can do". "…is this challenge one we will be realistically and physically taking action upon and possibly providing to their community or is it just another written assignment sort of thing?".	Perceived behavioural control
	Constraining factors	"…it is up to local governments and charities" "…many engineers…do not have the luxury to fully decide what industry they want to work in" "…empathise with engineers who feel trapped in an industry controlled by profiteering corporations" "…management as they control what products are being sold" "…just carry out orders from people higher up".	Perceived behavioural control
Inter-disciplinary	Respect for other disciplines	"Lads, we are doing engineering not political science" "Bruh, imagine failing an engineering course because you didn't revise social sciences" "RIP those of us that just wanted to build engines"	Subjective norm (engineering culture) Perceived behavioural control (expertise)
	Lack of understanding of systemic social issues	"…with a large population comes large differences…an inevitable inequality" "…the reason most engineering solutions have been developed for the richest people is because they have the knowledge and money to do such a thing… this doesn't mean engineering is only for them, this is just where solutions are developed. That doesn't matter to society though, who cares where or how it is developed?" "…poorer societies also experience large scale engineering…the fact they are poorer (means) they have a limited amount of what they can do.".	
	The self and personal motivations	"…future engineers may have different priorities…international students may focus on the problems facing poorer communities globally" "…the biggest issues I felt, were that many of my peers who have mostly come to Uni straight from school were not engaged in (the module content) the same way" "…the whole looking inside yourself…responsible engineering talks are preaching to the converted…we all know what we can and can't do at this point when it concerns the environment and climate change. University students are all too aware of the risks of climate change considering that we'll be the generation that has to deal with the consequences."	

4 SUMMARY AND ACKNOWLEDGMENTS

This paper has identified several possible sources of resistance to social responsibility. For example, it appears as though some students feel limited control over their ability to contribute towards social issues, something exacerbated by both existing within a consumer society and economic pressures. It therefore seems appropriate to equip engineering students with an awareness of alternative business models and no growth economics. This powerlessness seemed to be emphasised, for some, by the nature of the design challenge which focuses on theoretical solutions for distant communities, and in future it may be suitable to focus more on societal issues within the context of the local community.

In common with the themes identified during this work is a misalignment between personal and professional experiences and a lack of consideration for the ‘whole’ self, something which may not be surprising given both the early specialisation within the school system and valorization of STEM (science, technology, engineering, and mathematics) subjects that takes place in the British context, and the way in which our education systems utilise grades as a measure of student success. As Heywood [37, p.4] reminds us, the person is the base of the engineering process, saying that “Understanding how our beliefs and values (moral and otherwise) are formed is important to our conduct as engineers and individuals but it belongs primarily to the domains of philosophy and theology which are different languages”. In the absence of a ‘well-rounded’ education, students are unlikely to be aware of alternative modes of thought which may allow them to enact meaningful change in the face of complex problems such as climate change and social injustice, and which may allow them to “conceive a way of being outside this neoliberal worldview” [38] and they may, instead, be likely to become agents of cultural reproduction [39].

In what ways can we encourage students to explore their beliefs and motivations in a system, and indeed a society, which values academic success and how much money they make? Perhaps more importantly, to what extent should we try and address these issues? As Pawley [38] points out, as educators, most of us “indoctrinate students into neoliberalism” and fail to make students aware of alternative modes of thought which allow them to “conceive a way of being outside this neoliberal worldview”. Shor and Freire [40] describe how student resistance to liberative pedagogies was rooted in job anxiety and Freire [41] argues for the need to prepare students for the current (neoliberal, capitalist) state of the world.

It is clear we need to help students navigate complex tensions and feel comfortable sitting with uncertainties. This involves allowing ourselves to be vulnerable and admitting we do not know the answers. It necessitates us providing students with space and time, away from pressures of grading, to understand their beliefs and values, and to feel safe to express feelings of anger, guilt or confusion. It also means we need to understand how values and attitudes depend upon cognitive and ethical development [42]. How we best do this in a system which focuses on the cognitive domain over the affective domain, and which encourages disciplinary specialisation, is unclear and involves raising questions about our own learning and development, our own understanding of society and culture and of our selves. This may seem challenging for many of us trained within engineering and involves making choices which affect the way we are perceived by students, colleagues, and management. However, the benefit of the socially constructed nature of engineering is that it does allow us this choice.

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MAPPING THE ENGINEERING EDUCATION RESEARCH LANDSCAPE IN IRELAND AND THE UK (RESEARCH)

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ABSTRACT

The growth of Engineering Education Research (EER) has led to claims about it becoming a globally connected field of inquiry. This paper presents data on the development of EER within the UK and Ireland with the aim of contributing towards

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our understanding of the field. A computer-aided process was used to extract the names of authors, affiliated with UK and Irish institutions, that had published in a sample of 13 different EER journals in the years 2018 and 2019. We identified 122 UK authors and 17 from the Republic of Ireland.

Selected experts in both countries were contacted to obtain complementary data that were used to build a picture of the research landscape in which EER practitioners function.

Similarities and differences between EER in both geographic contexts were identified. In both there were few institutions listed as having EER centres, and it was more common for participants to refer to individual researchers. There also appeared to be a lack of formal PhD programmes and funding opportunities in EER within both countries. Whilst recognition for EER in the UK was primarily associated with teaching awards and fellowships, in Ireland EER outputs appeared to be as valued as disciplinary research activities.

The overall portrait that emerges from the data collected suggests that in both the UK and Ireland, EER does not benefit from a national support infrastructure but rather, is typically carried out by individuals or small groups of researchers.

1 INTRODUCTION

The last few decades have seen an increasing amount of research which focuses on the evolving nature of engineering education research (EER). The approach to such work varies. For example, Jesiek, Newswander, and Borrego [1] made use of observational data collected at the International Conference on Research in Engineering Education (ICREE) to examine how EER is variously conceptualized as a discipline, community of practice, and/or field. Froyd and Lohmann [2] make use of Fensham's [3] criteria for evaluating the maturation of fields of disciplinary-based education research to describe the state of EER.

Elsewhere, work has considered EER within the global context [4], [5], [6], with some making use of a comparative methodology when considering the approaches taken in different geographical locations. For example, Borrego & Bernhard [7] compared approaches to EER in the US and Northern and Central Europe. They concluded that the growth of EER depends upon understanding the perspectives of researchers within other contexts, as well as valuing diverse views on what constitutes quality.

Several pieces of research focus on the development of EER within different contexts including: the U.S.A. [2]; Portugal [8], [9]; Ireland [8]; Australia and New Zealand [10]; Europe [11]; as well as within three Nordic Countries [12].

More recently, this work has included the use of scientometric analysis to determine trends in the number of EER publications and is thus useful for quantitative comparison. This paper compares the development of EER within the UK (consisting of England, Wales, Scotland and Northern Ireland) and the Republic of Ireland. In so doing, a computer-aided process is used to extract the names of authors, affiliated with UK and Irish institutions. The findings are discussed in the context of complementary data obtained from selected experts within each location. Previous work [8] within the Irish context has described the status of EER, based on Fensham's [3] criteria. In the UK, two different studies have described low levels of engagement in EER, with a lack of peer reviewed articles [13], with most of the published research being single authored, or associated with single institutions [14].

2 METHODOLOGY

2.1 Publication data

This research adopts a case study approach, this being suited to the detailed and complex analysis necessary to answer questions about contemporary phenomena within real-life contexts [15]. We define our cases as the EER landscape within both the UK and Ireland. This includes EER centres within universities as well as national organisations that support, fund, and disseminate EER such as research networks. The research methodology was approved by research ethics committees at both Swansea University and TU Dublin.

A computer-aided process was used to extract the names of authors affiliated with UK and Irish institutions, who had published in a sample of 13 different EER journals in the years 2018 and 2019.

The journals were selected because they were indexed by Scopus and were established journals that had been publishing for at least several years. Related journals which focused heavily on technology aspects were not included (such as Computer Applications in Engineering Education and IEEE Transactions on Learning Technologies), as were journals that did not focus on a tertiary setting (such as Journal of Pre-College Engineering Education Research).

The thirteen selected EER journals were (i) Advances in Engineering Education, (ii) Australasian Journal of Engineering Education, (iii) Education for Chemical Engineers, (iv) European Journal of Engineering Education, (v) Global Journal of Engineering Education, (vi) IEEE Transactions on Education, (vii) International Journal of Electrical Engineering Education, (viii) International Journal of Engineering Education, (ix) International Journal of Engineering Pedagogy, (x) International Journal of Mechanical Engineering Education, (xi) Journal of Engineering Education, (xii) Journal of Engineering Education Transformations, (xiii) Journal of Professional Issues in Engineering Education and Practice (now Journal of Civil Engineering Education).

122 UK authors and 17 from the Republic of Ireland were identified.

2.2 Complementary data

This data was complemented by that obtained from the answers to five questions

1. Are you aware of any research teams/groups in the UK that focus on EER? If so, please name the relevant groups/leads/institutions

2. If there is no recognised EER team, are there individual active engineering education researchers? Can you share their names for the purposes of this study?
3. Are you aware of any institutions that have a structured programme, such as a PhD programme, which specialises in EER?
4. Are you aware of any incentives or recognition at your institution, or others within the UK, for publication within the EER community?
5. Is there funding or support for Engineering Education Research?
   Have any academics/researchers secured institutional, national or international funding for EER? If yes, could you provide source, objective and size of the funding?

In Ireland, the questions were emailed to all 17 of the identified authors. Nine authors who came from five different institutions, as well as one emeritus professor replied. In addition, the relevant deans of engineering and heads of engineering from 16 institutions in Ireland were emailed with the same set of questions. Eight deans/heads of engineering replied. Through this process, a further 17 academics were referred, with three responding. This resulted in a total of 21 individual participants from eight different institutions.

In the UK, where a larger number of authors were identified (122), a purposeful sampling approach was used whereby those contacted were considered to be "actor(s) who have been visible in the dominant EER communities" [12]. 12 individuals were approached, with nine replying. Through a snowball sampling approach, a further three participants were contacted, of which two replied. This resulted in a total of 11 participants who came from nine different universities. 10 participants answered via email, whilst one answered during a video call.

There was also an attempt to understand whether EER projects were funded within the UK. The Gateway to Research (GtR) website, which enables users to search and analyse information about publicly funded research, was used to identify work funded by UK Research and Innovation (UKRI) who are responsible for directing research and innovation funding provided by the governmental science budget. UKRI is composed of 7 research councils, including Engineering and Physical Sciences Research Council (EPSRC), and Economic and Social Research Council (ESRC), the latter being responsible for funding education research, as well as Innovate UK who support business-led research and innovation. Search terms included "engineering education", "engineering" and "education", "STEM education", "STEM" and "education".

3 RESULTS

3.1 Publication data

In quantitative terms we note a difference in the number of authors published from the two national contexts in the years 2018 and 2019 and that there were more from the Republic of Ireland relative to its population, as well as the number of academic staff employed by HEIs.

When considering these findings it is important to note that the computer aided process only considered articles published in 13 different EER journals in the years 2018 and 2019, and the extent to which findings represent long term EER activity within both the UK and Ireland is limited. It is also possible that the most common mode of dissemination is via conference papers as opposed to publications within journal, as has been noted as the case in previous work [13], [14].

Table 1: The number of authors, affiliated with UK and Irish institutions, that had published in a sample of 13 different EER journals in the years 2018 and 2019.

	Authors	Population (million)	Number of HEIs/ Academic Staff	Authors per million population	Authors per HEI/academic staff
Ireland	17	5.2	18/9,977 [16]	3.3	1.1/0.002
UK	122	67.1	214/ 224,530 [17]	1.8	0.6/0.0005

3.2 Ireland

Respondents from Ireland identified a small number of research groups, with the CREATE group at TU Dublin, which is typically made up of 20 individuals, being most commonly identified as directly focused on EER. Other groups noted include the Technology Education Research Group at the University of Limerick, the Sustainable Infrastructure Research and Innovation Group (SIRIG) at Munster Technological University, and the Engineering Education for Sustainable Development (EESD) group that is active in University College Cork. There were pointers to other looser networks and affiliations, such as the Irish Network for Gender Equality in Computing (INGENIC).

One distinguished researcher questioned whether EER is a disciplinary field, as it relies on engineering to exist. This researcher noted that the definition of EER coming from the US was too narrow to be useful, which was taken to mean that generating knowledge of engineering education through research and the EER agenda were not sufficiently broad. Certainly, in looking at the breadth of respondent comments, there were numerous indicators that activities can be interpreted as intending to inform practice, for example preparing students, improving engineering education, changing the nature of engineering, and impacting society [1].

There appear to be no restrictions or limitations on EER activity, and publications in this field count towards research active status, and support promotion applications. There was no evidence of structured PhD programmes in EER. However, a number of institutions clearly support PhD research projects in EER with numerous respondents confirming this. This occurs across the HE sector – within universities, technological universities and institutes of technology.

At a national level there was no evidence presented of targeted funding for EER. However, several funded projects were noted as addressing research questions within EER. At an institutional level, there appears to be some small local support (essentially seed money) for projects within the general definition of EER. One researcher noted receiving significant EU support for international collaborative projects to identify attributes that would inform the practice of educating engineering students.

3.3 UK

A small number of research groups were identified, the most commonly cited being the UK Engineering Education Research Network. UCL, Bristol University and Warwick Manufacturing Group were mentioned as institutions hosting EER groups by numerous participants, with one saying that “the only substantive group would have to be there at UCL. That’s about the only formal one”. There seemed to be confusion around whether some researchers were part of a group, with one participant considering that “because there's nothing formal within the university to promote that it will tend to be a loose, informal coming together of people…if they don't fit within the university structure, then it often it, you know it is built around individuals. So often it will fizzle and die people or move on”. It was therefore more common for EER activity to be associated with individuals within each institution, with one participant describing it as limited to “one or two people. Sometimes they work together, sometimes they don't.” The same participant claimed that it would be beneficial to “mobilize” individual researchers “around a national priority or something…you know, if you've got 50 institutions, you've got 50 contributions to your data set”.

Participants were unable to identify any formal PhD programmes, with one participant saying that this would imply “a more US approach to PhD than the UK individual scholar approach”. They added that “many of the interested academics have one or two PhD students” but that this would not “constitute a programme”. A different participant commented that such PhDs were “done within the typical the institutional PhD frameworks” and were often completed by international students who had financial support from their own governments, or those who had support of the department (especially in the case of candidates who were already staff) or through trusts. Some participants mentioned that the title of the PhD would be associated with the department and therefore, in the majority of cases, candidates would obtain a PhD in Engineering. This has implications for the identity of engineering education researchers, but also how their skills and expertise are perceived and the career opportunities that may be available to them. Other participants identified both UCL’s MSc Engineering and Education and the Engineering Education BSc from the University of Sunderland which both include some elements focused on conducting education research.

Views around incentives or recognition for publication were polarised, with answers being linked to both teaching career pathways and Research Excellence Framework (REF). Those who spoke about teaching pathway (the title given to those on education-focused career paths varied between institutions and included teaching fellows, teaching and scholarship academics or education and scholarship academics), mentioned the need to produce pedagogical research or scholarship in order to achieve promotion. Internal funding for education research and Fellowship of Advance HE and the National Teaching Fellowship awards programme were also mentioned as incentives.

Opinions about the role REF played in incentivizing researchers were mixed. For example, one participant believed “change in terms for 2021 REF enabled EER publications to be submitted for assessment in the engineering panel which gave them a little more status.” In comparison, a different participant believed engineering panels “won't understand what you're doing” and that was assuming that “you've got to get through all the institutional culture that's against it before you can even get to that point”. However, they did add that “REF could be such a facilitator for what we're doing” suggesting “that unless a discipline can demonstrate in the REF it is doing discipline-based education research it should be marked down”. A different participant claimed there were “more disincentives” associated with EER than incentives, which they considered to include a lack of “journals with sufficient rating for REF submission while at the same time being practitioner relevant”, something which they considered made it “difficult for newer researchers to use the field to advance their academic careers” and meant that for more experienced researchers “it can be a part time activity while also pursuing their core engineering discipline”.

Funding for EER was considered to be “very limited”. Some participants had access to internal funds from their own institutions. The Higher Education Academy (now called Advance HE), the Office for Students, QAA, the Nuffield Foundation, and Leverhulme Trust as well as the Engineering Professors’ Council (EPC) and the Royal Academy of Engineering were all named as possible sources of small amounts of money. However, opportunities were sporadic, and organisations were described as not “really properly commit(ing) to something a little bit more like a programme of work”. Obtaining funding was described as mostly “coat tailing on other grants” which looked at “tangential things”. The lack of availability of funding was considered, by one participant, to result in “pigs feeding at a troth (*sic*)” and dispersed efforts, as opposed to the development of a sustainable community.

In comparison, a different participant considered the lack of funding to be a “perceptual problem rather than a real one”, something which they attributed to education research not requiring a lot of funding, and many institutions having small pots of money available. They believed that “the real gap to people doing EER is their own skills and lack of understanding of social sciences research methods, but that often gets masked as lack of funding”.

Funding from UKRI (Identified using Gateway to Research) appeared to take three different forms. In the first instance PhD studentships focused on research within engineering education were funded through EPSRC Doctoral Training Partnerships (DTP), a type of funding provided to UK universities to support multiple studentships. The funding is allocated to universities with significant EPSRC research activity, by means of an algorithm and it is up to the university holding a DTP to allocate studentships within their organisation. This funding source is therefore dependent on the local environment. The second form of funding was for projects that focused on engineering outreach work. The third type of funding was for development of software for education purposes and was typically funded by Innovate UK.

Table 2 Comparison of EER landscapes in the UK and Republic of Ireland

EER Landscape	UK	Republic of Ireland
Research Groups	Small number of research groups, with UCL Centre for Engineering Education being the most established	Small number of groups, with CREATE at TU Dublin being the most established.
Degree Programmes	MSc Engineering and Education (UCL) and BSc Engineering Education (University of Sunderland) both include elements focused on conducting education research	PhD at TU Dublin, MSc at DCU
National Incentives	REF (both incentive and disincentive) Fellowship of Advance HE and the National Teaching Fellowship awards. Lack of sustainable sources of funding, with small amounts of money periodically being available from various sources.	No specific funding line for EER, but some relevant projects have received funding.
Institutional Incentives	Some small amounts of funding. Scholarship counts towards promotion for Teaching Pathway Academics.	Some small incentives. Research outputs count towards promotion.

4 SUMMARY AND ACKNOWLEDGMENTS

There do not appear to be any explicit differences between the EER landscapes that would explain the increased number of authors in EER in Ireland compared to the UK. In both contexts there are only a small number of established research groups and formal doctoral qualifications. There is also a lack of external funding with internal incentives consisting of small amounts of funding and progress toward promotion. It is possible that the smaller number of institutions within the Republic of Ireland means that it is easier to collaborate and that there is less competition for the scarce funds available. It is also clear that REF has an impact on the research culture and environment within the UK context and could explain why it is more likely for EER to be considered as research activity for academics within Ireland.

The assumed desire for the UK and Ireland to remain at the forefront of engineering education developments creates the need for clear strategies that focus on national needs and collaboration, something which could be further facilitated by the UK and Ireland EERN, which was mentioned as providing a vibrant community across both of the regions considered. The creation of a research agenda should be facilitated by conversations between all stakeholders including policymakers, professional institutes, as well as academia, industry and engineering students. Such an approach would allow for the critical mass needed to carry out ambitious and well structured projects with wider reaching impact. This, in turn, is predicted to attract interest from researchers from different disciplines, including education and the social sciences, as well as funding possibilities. Researchers within the UK and Ireland should also pursue opportunities to work with international colleagues, particularly those from contexts in which EER is more established. This will allow them develop their research expertise, take part in larger projects and contribute to international developments.

Policymakers should consider funding priorities. For example, as Malmi et al. (2018) point out, whilst the US National Science Foundation support EER, within Europe funding is difficult as it does not align with criteria set out by Horizon 2020 funding [18].

In the absence of external financial support it seems clear, particularly given the increased pressures placed on universities and their staff, that the development of EER within both the UK and the Ireland will be dependent upon both institutional and national recognition for the work involved.

Further work in this area should focus on comparing the trends in publication across a wider timeframe, and comparison with more countries within Europe.

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A LANDSCAPE REVIEW OF THE LITERATURE FOCUSING UPON THE USE OF TECHNOLOGY TO SUPPORT PROBLEM, CASE AND PROJECT BASED LEARNING IN HIGHER EDUCATION STEM DISCIPLINES.

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Keywords: *Systematic review; constructivist; problem-based learning; STEM; technology enhanced learning.*

ABSTRACT

A systematic approach was undertaken to locate and analyse empirical research examining the use of technology to support constructivist approaches to learning. In particular, this paper focuses upon Problem, Project and Case Based Learning and consults publications which have employed technology in Science, Technology, Engineering and Mathematics within on campus higher education settings. Four databases were searched and after applying relevant inclusion and exclusion criteria, 56 publications published during 2007–2021 were included in this review. In addition to systematically documenting the landscape of literature associated with this area of research, this paper offers an analysis of the contributions of the research in understanding the way in which technology affects efficiency, team effectiveness and inclusivity as part of the learning process.

1 INTRODUCTION

1.1 Problem, Project and Case based constructivist approaches in STEM

The disciplines of science, technology, engineering and mathematics are collectively and more commonly referred to as STEM. Constructivist approaches such as Problem, Project and Case based learning are often employed within these disciplines and involve students working collaboratively to resolve complex, authentic and real-world problems (Hmelo-Silver, 2004; Graham, 2010; Hanney & Savin-Baden, 2013; Harmer & Stokes, 2014; Kennedy & Odell, 2014). Autonomy in learning, team work, and an active approach to sharing knowledge and understanding as part of a problem-solving process are integrated across the STEM disciplines. The tutor undertakes the role of facilitator to support students when

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engaging in carefully selected real-world challenges (Wood, 2003; De Graaf & Kolmos, 2003; Allen, Donham & Bernhardt, 2011).

Distinctions between Problem, Project and Case based learning often relate to the discipline in which they are most often located, for example, medicine and related fields such as healthcare often use the term 'Case Based Learning' (CBL). Cases relate to clinical practice but draw upon features of Problem Based Learning (PBL) such as problem solving in small groups. In some instances, the term CBL can be used interchangeably with PBL (Azer & Azer, 2015) with both involving the ability to collaborate and communicate as key attributes. Such attributes may, in some circumstances, be referred to as graduate skills or attributes of employability (Gunn, Bell & Kaffman, 2010).

For STEM subjects, such an approach would be relevant as the ability to solve problems as part of a team relates to the context in which many of the students will ultimately work and, as such, would be attractive to prospective employers and valued by accrediting bodies. However, there are also potential barriers to PBL-related approaches which often cite resources which include facilities as well as staff time (Graham, 2010; Kokotsaki et al, 2016; Harmer & Stokes, 2014; Frambach et al., 2019) and can be classified under three broad areas, namely, efficiency, effectiveness and inclusivity.

1.2 Constructivist approaches and the use of technology

A wide range of technologies to support campus-based teaching and learning are currently available. These include, but are not restricted to interactive handsets, displays and mobile devices to support, facilitate and enhance constructivist approaches to learning (Ioannou, 2016; Wood & Shirazi, 2020); simulations, games (Vlachopoulos & Makri, 2017), augmented reality, (Ibáñez & Delgado-Kloos, 2018), computer supported collaborative learning environments, (Al-Samarraie & Saeed, 2018) and use of multimedia and video (Noetel et al., 2021).

Existing systematic reviews examine specific technologies in relation to constructivist or student centered approaches to learning, for example, the use of a web-based online environment (Jurewitsch, 2012); cloud computing (Al-Samarraie & Saeed, 2018); audience response systems (Wood & Shirazi, 2020); video (Aronis, 2016; Noetel et al., 2021) or perhaps the use of a specific technology within STEM subjects, for example, augmented reality, (Ibáñez & Delgado-Kloos, 2018); digital case scenarios (Gavgani et al., 2015). There are also studies which focus upon a specific subject or discipline within the overarching portfolio of STEM, for example, Car et al., (2019) and Jin & Bridges, (2014) who respectively examined literature focussing upon digital technologies and interactive whiteboards and virtual learning environments (VLEs) in PBL within health education. The former concluded that there was evidence that digital PBL appeared to be more effective than either traditional PBL or traditional learning in terms of students' skill outcomes and more effective or equal to traditional PBL where knowledge outcomes are concerned. Jin & Bridges' study found that authenticity and 'rich' opportunities for learning facilitated students' growing expertise. Technology offered structured learning and supported engagement in collaborative activities which allowed students to explain, discuss and reflect upon their understanding thereby making their thinking more explicit (2014). Flipped learning in engineering was examined by Karabulut-Ilgu et al., (2018) who concluded that studies generally reported increased effectiveness in student learning. However, Karabulut-Ilgu et al., also highlighted that there was 'a paucity of the report of theoretical frameworks guiding the development and evaluation of the flipped approach' (p. 406), and that quantitative methods of evaluation were favoured above qualitative. Benefits of flipped learning in engineering, particularly 'professional skills and increased interaction' therefore needed further investigation to understand why and how such interventions were beneficial to student learning. A more recent review signalled the potential value of digital games in STEM education and argued that learner types and the effect of different forms and designs of such games on student learning needed to be examined (Wang et al, 2022). The authors also highlighted the need to support students' developing understanding of 'abstract and multi-dimensional concepts' when working within STEM subjects and the potential value of games in achieving this (Wang et al., 2022 p. 10).

Context and Rationale

There is a noticeable rise in the use of blended learning within campuses across the higher education sector. The popularity of PBL and related challenges listed above, calls for a review of the research carried out to date that represents the use of technology to improve the key outcomes for which PBL is chosen. A particular focus is on campus PBL settings as STEM educators now face a high proliferation of technology in their practice. Researchers looking at the how and why technology can enable or enhance the key outcome will also benefit from this review. Rather than selecting a specific technology or subject within the STEM disciplines, this study reviews empirical research which employs digital technologies used within any STEM discipline as part of a constructivist approach to learning and teaching, for example PBL, PjBL and CBL. With constructivist learning providing a central, unifying focus, the findings of this research will be relevant to researchers focussing upon specific or combined disciplines within the field of STEM in higher education.

2 METHODOLOGY

2.1 Research Questions

This systematic landscape review provides an overview of empirical research which examines the use of technologies for CBL, PBL and PjBL in higher education. It focuses upon the meta-discipline of STEM and reports on the landscape of literature which, at the time of writing this paper, sought to present the way in which technology supported and enabled: team-working; the development of graduate skills and student learning.

The PICO framework (Schardt, Adams, Owens, Keitz, & Fontelo, 2007), was employed where key criteria involving Population (P), Intervention (I), Comparison (C) and Outcome (O) provided a means of systematically defining our research question, search clause, inclusion and exclusion criteria in order to identify relevant literature which would allow us to answer the research questions. The population was limited to STEM disciplines in on campus Higher Education (HE) settings and the intervention involved the use of any technology in order to study its impact on the three key outcomes: team-working, graduate skills and student learning.

The following overarching and sub-research questions were developed using the PICO framework:

1. How have learning technology interventions been used to support the key outcomes related to problem, project and, case-based approaches within on campus higher education STEM settings?
    a. What technologies have been used in relation to the identified outcomes?
2. What are the characteristics of these studies?
    a. Which disciplines within STEM education have employed such approaches?
    b. What are the methodological characteristics of the studies?
3. What are the main findings of these studies?

2.2 Search and selection

In order to locate relevant articles undertaking primary research, which corresponded to the area of interest described above, a systematic search of four databases: Scopus (Sco), Education Resource Information Centre (ERIC), Web of Knowledge (WoK) and ScienceDirect (SD), was undertaken.

Table 1

PICO Themes	Corresponding search term
Population: Case / *Problem / Project based*	("Problem based Learning" OR "Project based learning" OR "CDIO" OR or "case based learning")
Population: *Higher Education*	("higher education" or "university" or "graduate" or "bachelor" or "college" or "post compulsory" or "post secondary" or "third level") AND ("engineering education" or "medical education" or "health education" or "science education" or "computing" or "mathematics")
Intervention: *Technologies*	("technology enabl*" or "technology enhanc*" or "video*" or "collabor* technology" or "flip* class*" or "flip* learn*" or "learn* techno*" or "m learning" or "mobile learn*" or "e learning" or "electronic learn*" or "interactive whiteboards" or "forum*" or "Wiki*" or "blog*" or "MCQ*" or "vlog*" or "Network* learn*" or "scale-up" or "blended lear*" or "learning environment" or "interactive learn*" or "handheld" or "active learn*" or "active method*" or "game based" or "Gamifi*" or "Social software" or "CAL" or "Computer assisted*" or "Computer support*" or "CSCL" or "learner track*" or "social learn*" or "Web 2.0" or "authentic*" or "voting systems" or "clickers" or "audience response systems" or "interactive learning tech*" or "simulations" or "augmented reality" or "peer instruction")
Comparator: *Any*	None.
Outcome: *Learning, Team working and graduate skills*	("perform*" or "team management*" or "achievem*" or "pretest" or "posttest" or "team develop*" or "team dynamics" or "collaborat*" or "cooperat*" or "group cohesion" or "team cohesion" or "team work*" or "self-regulated learning" or "SRL" or "team perform*" or "social dilemma*" or "conflict*" or "graduate attri*" or "graduateness" or "graduate skill*" or "soft skills" or "employ* skills" or "learning gain")
Final search clause	Population terms AND Intervention terms AND Outcome terms.

Filters, where available, were applied in order to include articles published from January 2007 to June 2021 and which were written in English. The search was not restricted to journal articles or to those which were subject to peer review in order to ensure the returns encompassed as wide a range of sources as possible thereby reducing the risk of bias across studies (Schlosser et al., 2007). Hand searching and reference checking were undertaken after the screening of full papers had been completed, more specifically, an ancestral search of the reference lists of the 41 selected articles was conducted by the authors, who identified further 15 articles that met the inclusion criteria. The PICO framework, (see table 1), was also helpful in systematically defining search terms within this review.

2.3 Inclusion and exclusion criteria

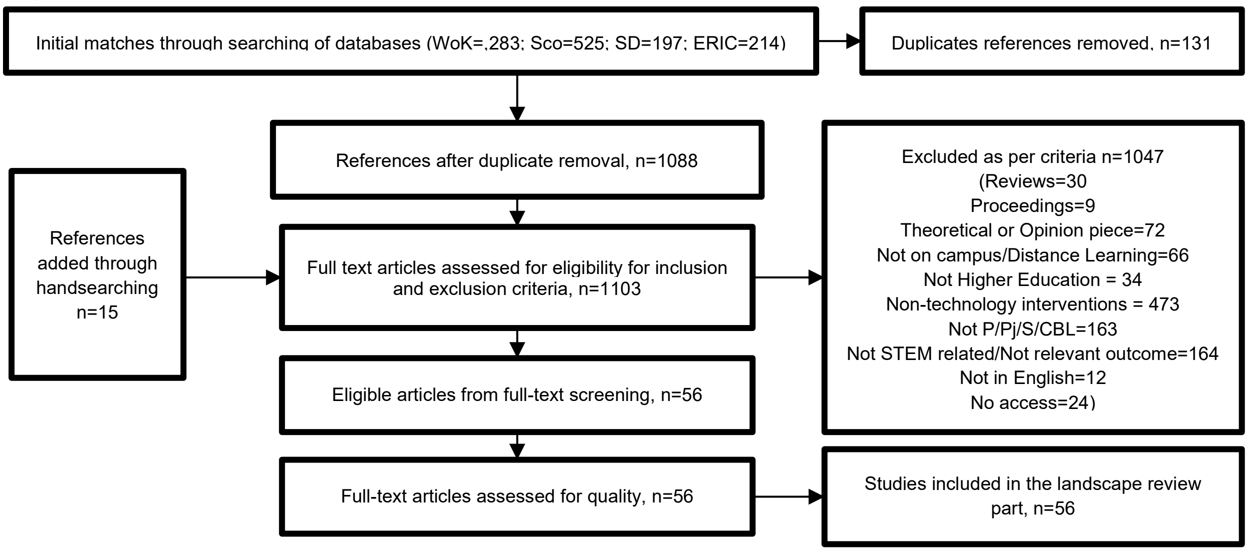
The PICO framework also helped in aligning our inclusion/exclusion criteria in a systematic way with the search terms and research questions. Table 2 shows details of the inclusion and exclusion criteria used.

Table 2

Inclusion Criteria	Exclusion Criteria
Population • HE-STEM Explicit mention of PjBL/PBL/CBL/CDIO. • On campus environments. **Intervention** • Any instance where technology has been used to support the selected population and outcomes. **Outcomes** • Team working • Learning gain • Graduate skills **Time Limit** • Publications between 2007 and 2021.	• All Subjects and Outcome not as stated in the inclusion criteria • Not on campus / Distance Learning. • All non-HE studies. • All studies not written in English. • All theoretical texts/ opinion pieces. • All proceedings • All reviews. • All studies published outside the defined date range. • All Non-Project / Problem/ case-based learning studies. • All Non-technology interventions. • No Access.

Following the recommendations from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, (PRISMA), (Moher et al. 2009), the landscape review of literature was undertaken through a three-stage systematic process of identifying and screening in order to arrive at the 56 papers included in this study (see figure 1).

Figure 1



During the first phase, a search resulted in 1219 results from the four selected databases. After removing the duplicates, attempts to access the full-text version were made on 1088 articles. To improve the reliability in the use of inclusion and exclusion criteria, each author and a third colleague read the titles and abstracts of 100 randomly chosen articles from the search results. Each researcher examined and assessed the articles independent of the others. A shortlist from each author was used to perform an inter-rater reliability check. The inter-rater reliability scores were calculated using Cohen’s Kappa calculation to consider any chance agreements between the researchers. As there were only 100 data points, the calculation was undertaken using a spreadsheet. Scores between the three pairs of researchers were: 0.70, 0.67 and 0.93 respectively. Scores ranging from 0.61 – 0.80 represent substantial agreement and 0.81 – 0.99 as near perfect agreement (HowToStats, nd). This allowed the authors to identify papers which needed further discussion and refining the use and definitions of the inclusion and exclusion criteria before progressing. The researchers then discussed the differences and agreed on the papers to include before phase two.

The second phase of the review process consisted of dividing the remaining papers from the search results between the researchers who reviewed these independently. This resulted in 41 papers being shortlisted from the search results. Handsearching, (Boland et al., 2017), of reference lists from those shortlisted yielded fifteen articles that met the inclusion criteria which were added to the shortlist. In total, 56 articles were retained for the landscape review.

A shared spreadsheet was used to extract key information, namely; (1) authors, (2) year of publication, (3) type of publication, (4) Population, (5) Intervention type, (6) Comparator / Control use, (7) Outcomes (8) aim of study, (9) country, (10) HE Level, (11) demographics, (8) research design, (9) research instruments, (10) data analysis procedures, (11) length of study and (12) Main findings of study. These are discussed further in the results section.

3 RESULTS OF THE LANDSCAPING REVIEW

The 56 selected studies are summarised in table 3 below. The papers are largely quantitative in nature reflecting the general focus upon the effect of the interventions on student performance. Of the studies that explicitly stated the methodology they had employed, quasi-experimental was the most frequently cited closely followed by randomised control trials. Qualitative data is sometimes employed within studies in combination with quantitative data, however, the emphasis is generally upon the quantitative with qualitative data occupying a minor role. Medicine and other health-related disciplines appear to make the most use of, and undertake research in, the use of technologies for PBL/CBL/PjBL. Alongside engineering and technology, these disciplines appear to contribute the most in terms of research publications. Interest appears widespread across the globe although there is a greater concentration of publications originating from North America and Europe.

Table 3 Landscape review of the findings included in this work

Authors, date of publication and source	**Population, intervention, outcome**	**Methods, instruments and duration**	**Main findings**
Aparicio, F., De Buenaga, M., Rubio, M. and Hernando, A., (2012). *Computers & Education*	medical, ITS, Performance	Quantitative Case study with comparator 90 mins Test and questionnaire	'computer tools created to facilitate and direct information searches on Internet are useful to enhancing the learning process in Health Sciences students.'
Arain, S.A., Afsar, N.A., Rohra, D.K. and Zafar, M.,(2019) *Advances in physiology education*	medical, video, graduate skills	Quantitative Quasi- RCT 1 semester Observations	'The study indicates that inclusion of AV aids improved students' engagement and classroom environment in electronic-PBL sessions, but did not improve diagnostic abilities based on the learned clinical skills'
Balslev, T., De Grave, W., Muijtjens, A.M.M., Eika, B. and Scherpbier, A.J.J.A. (2009*), Advances in health sciences education*	medical, video, team-working	Quantitative Case study with comparator 1 session Interview	An 'enhanced shared cognition through collaborative concept link formation' and 'Co-elaboration of concept formation is stimulated'
Barmaki, R., Yu, K., Pearlman, R., Shingles, R., Bork, F., Osgood, G.M. and Navab, N. (2019) *Anatomical sciences education*	medical, augmented reality, performance	Quantitative RCT 1 semester Test and questionnaire	'time on task, painting outcomes, and level of engagement with statistically significant outcomes' 'Statistical significance was established for most measures except long term knowledge retention.'
Bridge, P., Trapp, J.V., Kastanis, L., Pack, D. and Parker, J.C (2015) *Australasian physical & engineering sciences in medicine*	medical, virtual lab, performance and graduate skills	Mixed Cross sectional 1 semester questionnaire	Greater efficiency (student time and resource access), increased understanding, enjoyable learning, increased opportunity for experimentation and team working.
Chang, S.H., Chen, M.L., Kuo, Y.K. and Shen, Y.C., (2011) *IEEE Transactions on Education*	engineering, simulation and online, multiple outcomes (performance, team-working and graduate skills)	Mixed Case study no control 1 semester Questionnaire and test	Improved student conceptual understanding, design skills and allowed students to learn from one another (team working skills)
Chen, C.Y. and Teng, K.C., (2011), *Computers & Education*	engineering, collaborative system, team-working	Mixed Longitudinal 3 years Survey and interview	The use of a collaborative system introduced a macro-level meeting-oriented group process to guide collaborative work
Cole, D., Rengasamy, E., Batchelor, S., Pope, C., Riley, S. and Cunningham, A.M.,(2017) *BMC medical education*	medical, social media, team-working	Quantitative Cross sectional 1 year Survey and user metrics	Depending on a student's strategy (to use or not to use social media), students used SM to support collaborative learning
De-La-Fuente-	engineering,	Quantitative	Reduction in staff workload, reduction in student

Valentín, L., Pardo, A. and Kloos, (2013) Computers & Education	scripted learning, performance	Case study no control 6 weeks Test	dropout rate, sustained student effort, students valued the scaffolding despite increased workload
Ende, H.B., Lumbreras-Marquez, M.I., Farber, M.K., Fields, K.G. and Tsen, L.C., (2021) *International Journal of Obstetric Anesthesia*	medical, low fidelity sim, performance	Quantitative Quasi RCT 6 months Survey and test	No statistical difference between traditional approach and intervention
Eng, A.J., Namba, J.M., Box, K.W., Lane, J.R., Kim, D.Y., Davis, D.P., Doucet, J.J. and Coimbra, R., (2014), *American Journal of Pharmaceutical Education*	medical, hi fidelity simulation, performance	Quantitative Case study no control 1 semester Tests, survey	Improved confidence, evidence of improved patient care linked to performance, sim environment supported students' recall and skill application
Gisondo, C.M., Weiner, G. and Stanley, K., (2021), *MedEdPORTAL*	medicine (transport), video, performance and graduate skills	Quantitative Case study no control 30 mins to 2 months Questionnaire, pre/post test	Significant improvement in knowledge and confidence
Guariento, B., Al-Masri, N. and Rolinska, A., (2016), *American Society for Engineering Education*	engineering, blended, graduate skills and team-working	Mixed Case study no control 1 academic year Survey	Improved awareness of appropriate communication, processes of teamwork
Gurpinar, E., Zayim, N., Ozenci, C.C. and Alimoglu, M.K. (2009) *Turkish Online J. Educ. Technology*	medical, web-based learning (quizzes, links, search engine), performance	Quantitative Case study with comparison 8 weeks Questionnaire, computer log files and exam results	Significant improvement in exam performance
Hannig, A., Kuth, N., Özman, M., Jonas, S. and Spreckelsen, C.,(2012) *BMC medical education*	medical, game based, performance	Quantitative Quasi RCT 4 semesters Questionnaire and observation	Strong collaboration inspired by the competitiveness of the gaming aspects, increased willingness to learn
Harris, D.M., Ryan, K. and Rabuck, C., (2012), *Advances in physiology education*	medical, hi fidelity simulation, performance	Quantitative Case study with comparison One week 3 x 3 hour Pre/post-test and survey	Increased students' confidence in treatment strategy attributed to active learning involved in simulation
Hoic-Bozic, N., Mornar, V. and Boticki, I., (2008), *IEEE transactions on education*	technology, blended learning, management system, performance	Mixed Case study no control 2 terms questionnaire	Academic achievements were better than expected, dropout rate diminished, but students felt it was time-consuming
Jesus, Â., Gomes, M.J. and Cruz, A. (2016), *11th Iberian Conference on Information Systems and Technologies*	pharmacy, various tools performance	Quantitative Quasi RCT 10 weeks Test	Better exam results than traditional f2f.
Jou, M., Lin, Y.T. and Tsai, H.C., (2016), *Interactive*	engineering, mobile app and cloud computing,	Quantitative Case study with comparator 1 semester	the Mobile Learning APP provided a significant positive effect on learning performance and that most students showed favourable attitudes toward the

Learning Environments	performance	questionnaire	usage of the mobile learning system
Kish, G., Cook, S.A. and Kis, G., (2013), *Anatomical sciences education*	medical, simulation and online content, performance	Quantitative Case study with comparator 11 weeks (8 computer sessions) Exam	Significantly better anatomy curriculum student performance
Kleinert, R., Heiermann, N., Plum, P.S., Wahba, R., Chang, D.H., Maus, M., Chon, S.H., Hoelscher, A.H. and Stippel, D.L., (2015), *Journal of Medical Internet Research*	medical, simulation, performance	Quantitative Experimental 1 year Pre/post-test and survey	Impact shown on knowledge gain- increase in declarative knowledge, students were 'enthusiastic and motivated'
Kourdioukova, E.V., Verstraete, K.L. and Valcke, M. (2011), *European journal of radiology*	medical, computer supported collaborative learning scripting, multiple (performance, team working and graduate skills)	Mixed Survey and case study with comparison 3 weeks and 5 weeks survey and online interactions	Neutral to positive attitude to collaborative learning. CSCL developed students' medical vocabulary and reporting skills
LaRochelle, J.S., Durning, S.J., Pangaro, L.N., Artino, A.R., Van Der Vleuten, C. and Schuwirth, L., (2012), *Academic Medicine*	medical, video, performance	Quantitative RCT 2 years test	Increased authenticity of learning resources- mid level students' performance worsened (attributed to the possibility of cognitive overload)
Lee, M.J., Nikolic, S., Vial, P.J., Ritz, C.H., Li, W. and Goldfinch, T., (2016), *IEEE Transactions on Education*	engineering, video conferencing, graduate skills	Mixed Case study with comparator 2 semesters Test and questionnaire	'students became more confident and honed their presentation skills in preparation for their assessable pitches.'
Lin, J.W. and Tsai, C.W. (2016), *Computers & Education*	technology, scripting, team working	Quantitative RCT 14 weeks questionnaire	In an online PBL environment, GA has positive but temporary effects on low-SR students but positive and sustainable effects on high-SR students. In sum, an online PBL environment with GA support has different time length effects (i.e., temporary or sustainable effects) on different SR-level students.
Lu, J., Lajoie, S.P. and Wiseman, J., (2010), *International Journal of Computer-Supported Collaborative Learning*	medical, scripting, multiple (graduate skills, team working)	Mixed Case study no control 1 semester Observation	'..visualization and argumentation tools which supported goal setting, help seeking, time management, and planning. Students using interactive whiteboards demonstrated more adaptive problem-solving behavior than those using only traditional whiteboards. Interactive whiteboards mediated the teacher's scaffolding by increasing class participation'
Manogaran, E., (2013), *IEEE Fifth International Conference on Technology for Education*	technology, blended technologies, performance	Quantitative Quasi experimental Test and questionnaire	Decreased failure rate by approx. 50% with students performing significantly better
Martinez, M.L., Romero, G.,	engineering, collaborative web	Quantitative Case study with control	'The use of a collaborative Web environment has made it possible for students to work in

Marquez, J.J. and Perez, J.M. (2010), *IEEE EDUCON 2010 Conference*	environment, performance	1 academic year Survey and final marks	multidisciplinary teams' and 'enabled students to approach a problem from four different points of view'
McNamara, J., Sweetman, S., Connors, P., Lofgren, I. and Greene, G. (2020), *Journal of nutrition education and behavior*	agriculture, mind maps and T-Charts, graduate skills	Quantitative RCT 2 weeks questionnaire	'successful at encouraging students to use more CT-DM skills when compared with the control group.' 'better at making a decision and supporting that decision with a greater number of evidence-based reasons.'
Ng, O.L., Ting, F., Lam, W.H. and Liu, M. (2020), *The Asia-Pacific Education Researcher*	maths, interactive whiteboard, performance	Quantitative Quasi RCT 13 weeks test	students in the interactive group had almost twice the normalized gain of the traditional tutorial group.
Pearson, R.J., (2017), *Journal of Chemical Education*	chemistry, clickers, performance	Quantitative Longitudinal 2 years Exam score and survey	students think more deeply in-class and providing instant feedback are essential ingredients when creating an effective problem-based learning environment where students become more inquisitive learners. Combining a team-based model with clicker technology created a perfect blend, thereby allowing students to enter into peer instruction while maintaining a fun, interactive, and engaging environment in which to learn.
Peng, J., Wang, M. and Sampson, D., (2017), *Journal of Chemical Education*	engineering, various tools including visualisation, performance	Mixed Case study no comparison 1 year Survey, tests and interview	the participants made significant improvements on programming task performance and subject knowledge after completing the learning module. Their progress in programming performance was significant in all aspects (i.e., problem understanding, modular design, process design, and coding)
Peng, J., Wang, M., Sampson, D. and van Merriënboer, J.J., (2019), *Australasian Journal of Educational Technology*	technology, visualisation, performance	Quantitative Case study no control 6 weeks Test	the visualisation-based cognitive tool is more effective in improving students' programming performance and better perceived by students in terms of its support for scaffolding and articulating the complex project process.
Poulton, T., Ellaway, R.H., Round, J., Jivram, T., Kavia, S. and Hilton, S., (2014), *Journal of medical Internet research*	medical, simulation, performance	Quantitative RCT 1 semester Test	the use of Dynamic-PBL leads to better midterm learning outcomes than linear PBL (for questions related to D-PBL experiences
Prescott, W.A., Woodruff, A., Prescott, G.M., Albanese, N., Bernhardi, C. and Doloresco, *American Journal of Pharmaceutical Education* F., (2016),	medical, various tools including quizzes, performance	Quantitative Case study with control 1 academic year Exam and survey	improved academic performance and was well-received by students - students enrolled in the blended-learning model scoring better on the final examination and on aspects of the clinical skills examination, and achieving a higher letter and numeric course grade (poss due to watching/rewatching the videos)
Rodrigues Da Silva, A.N., Kuri, N.P. and Casale, A., (2012), *Journal of Professional Issues in Engineering*	engineering, various tools, performance	Mixed Case study with control 4 years Grades, questionnaires and assessments	increased student performance over the four years, evidence of greater knowledge and depth of understanding for PBL groups students took increasing responsibility for their own learning.

Education and Practice			
Sáiz-Manzanares, M.C., Escolar-Llamazares, M.C. and Arnaiz González, Á. (2021), *International journal of environmental research and public health*	medical- nursing, online interaction, multiple, (performance, graduate skills)	Quantitative Quasi RCT 9 weeks Test and questionnaire	Good results have been obtained in all assessment tests in the two types of blended learning. However, the type of blended learning that applied automated feedback and hypermedia resources obtained even better results
Sancho-Thomas, P., Fuentes-Fernández, R. and Fernández-Manjón, B. (2009), *Computers & Education*	technology, various tools, team-working	Mixed Case study with control Up to 2 years Questionnaire	Reduced drop out rate, increased pass rate, positive effect in knowledge acquisition, helped to develop team work skills
Saraç, L. and Ok, A., (2010), *Resuscitation*	medical, video, multiple (performance, graduate skills)	Quantitative Experimental with control 1 semester Test	Students performed less well than traditional approach- attributed to lack of hands-on practice and reinforcement from tutor
Saunder, L. and Berridge, E.J., (2015), *Nurse education in practice*	medical- nursing, simulation, graduate skills	Qualitative Case study no control 1 session Interview	Mostly focussed on design-divided student opinion opportunities to reflect on clinical practice and enhanced sense of competence but lack of realism, possible oversimplification and more student preparation were also listed
Selvi, S.T., Kaleel, D. and Chinnaiah, V., (2012), *International Conference on Recent Trends in Information Technology*	engineering, various tools, multiple (Team working and graduate skills)	Quantitative Case study with control questionnaire	TEL enhanced PBL approach revealed increase in skills (commitment, decision-making, confidence and collaboration) 2. increased competitiveness and 3. team spirit
Spinello, E.F. and Fischbach, R., (2008), *Public Health Reports*,	medical, simulation, performance	Mixed Case study with control 1 year Survey and exam	reported higher levels of cognitive learning in traditional than those in the Sim group, academic performance in sim higher particularly in needs assessment and intervention planning
Splichal, J.M., Oshima, J. and Oshima, R., (2018), *Computers & Education*	technology, scripting, team working	Mixed Case study no control 13 weeks questionnaire, observation	students were likely to self-regulate themselves or co-regulate other members when they encountered socio-emotional challenges such as inactive discussions, students who produced well-organized scripts shared the perceptions of challenges and progressively worked on them and used various regulation strategies.
Sun, C. and Qi, X. (2018), *World neurosurgery*	medical, simulation and scripting, performance	Quantitative Quasi RCT 1 year Test and questionnaire	Increased confidence, sense of accomplishment and individual judgement, the approach visually stimulated students' interest and enthusiasm and increased their self-confidence, pre/post test showed no significant difference between pSBL and non-PSBL
Topalli, D. and Cagiltay, N.E., (2018), *Computers & Education*	engineering, various tools, performance	Quantitative Longitudinal experimental 4 years Test	students' performance in the Senior-projects improved significantly; the game projects improve students' motivation
Tsai, M.H. and Tang, Y.C., (2017), *Library Hi Tech*	chemistry, various tools, graduate skills	Mixed Case study with control 1 semester Questionnaire	the experimental group was found to outperform the control group in terms of problem-solving attitudes, and the difference was statistically significant; authors suggest that lesson plan contents need to be designed based on problem-based learning theory, and reflect real-world conditions

Vivian, R., Falkner, K., Falkner, N. and Tarmazdi, H. (2016), *ACM Transactions on Computing Education*	technology, various tools, team working	Qualitative Instrumental Case study Duration not stated Online discussions	Most students employed content knowledge and discussed the problem- some metacognitive activities- solution focussed, rarely employed monitoring and regulation in favour of leadership and team-orientation
Weidenbusch, M., Lenzer, B., Sailer, M., Strobel, C., Kunisch, R., Kiesewetter, J., Fischer, M.R. and Zottmann, J.M., (2019), *BMJ open*	medical, video, performance	Quantitative RCT 90 mins Test and questionnaire	CCD approach is effective and sustainable approach for clinical reasoning. Higher efficacy of more interactive formats can be attributed to positive effects of collaborative learning.
Whelan, J.J., Spencer, J.F. and Rooney, K., (2008), *Rural and Remote Health*	medical, simulation, team working	Mixed Quasi experimental design 2 years Survey and focus group	1) student understanding of interprofessional practice in relation to quality of patient care increased 2) Broadened student understanding og professional roles-theirs in relatio to others 3) interactivity and authenticity of CNL scenarios well-received. Some not keen on role play but overall the experience contributed to collaborative and team-working skills
Williams, C., Familusi, O.O., Ziemba, J., Lee, D., Mittal, S., Mucksavage, P., Smith, A. and Kovell, R.C. (2020), *Urology*	medical, various tools (synchronous and asynchronous online), multiple (performance and graduate Skills)	Mixed Case study no control 4 weeks Questionnaire	course significantly increases students' scores in: self-perceived urologic knowledge, confidence in naming urologic conditions, comfort with performing urologic evaluations, and confidence placing consults for urologic conditions ($P < .05$).
Woltering, V., Herrler, A., Spitzer, K. and Spreckelsen, C., (2009), *Advances in Health Sciences Education*	medical, various tools, multiple (performance and team working)	Mixed Case study with control 3 years Questionnaire	The students described the blended PBL as "realistic", "descriptive" and "very practical" supporting memorisation and motivation of the students; flexibility the students emphasized the flexibility that was offered by the program, so that they were able to meet when they wanted to and to reconnect to the information after the first meeting; the use of a video was well-received For the tutors; no difference was perceived by tutors
WUa, C.P. and YONG, H.J (2013), *21st International Conference on Computers in Education*	technology, various tools, simulation, web-based resources, performance	Quant Quasi RCT Over 1 month Test	PBL group performed better than the traditional PBL group- authors suggest the worked example simulation of an expert's reasoning process with reasons given for decisions made helped students understand the process and to apply this to similar problems
Yaniawati, R.P., Kartasasmita, B.G. and Saputra, J. (2019), *Journal of Physics: Conference Series*	medical, various tools, online assisted, performance	Mixed RCT 7 sessions Test	The study showed positive impact of PBL and eLearning on Math skills / performance and on SRL to be statistically significant.
Yoon, B.Y., Choi, I., Choi, S., Kim, T.H., Roh, H., Rhee, B.D. and Lee, J.T., (2016), *Korean journal of medical education*	medical, video, graduate skills	Quantitative Case study with control 2 weeks Questionnaire	Standardised patients v video cases- SP more authentic and offer the most gains in terms of student learning (interaction, communication, attitudes and motivation to learn). SP more expensive and resource-heavy than video.
Zhao, J., Pan, S., Dong, Y., Ge, Q., Chen, J. and Dai, L., (2013), *Frontier and Future Development*	medical, video multiple (performance and team working)	Quantitative Self-controlled randomised crossover 2 days Pre/post -test/assessments	SBL and CBL can improve theory knowledge, practical ability and teamwork. Results suggest that a mix of SBL and CBL is effective, which has implications for course costs and feasibility of training.

of Information Technology in Medicine and Education			
Zhao, X. and Cong, L., (2019), *Nurse Education Today*	medical- nursing, scripting and wearable technology, graduate skills	Quantitative RCT (no within group comparison) Questionnaire	Intervention group had better scores in most of the preparedness and performance feedback. Group also made significantly better total score than “Conventional training” Group

4 DISCUSSION

There seems to be a wide distribution of research papers although these are concentrated across European countries, North America and Australia. An inclusive approach was undertaken to allow non-peer reviewed, conference papers and book chapters in addition to peer reviewed journal articles. However, language will have limited the distribution of papers which involve only those written in English and is an unavoidable limitation of this study.

Of the papers included in the final 56, there were variations in quality with some providing relevant theoretical frameworks allowing the author(s) to critically analyse the data collected. In many instances, the findings indicated that the technology had affected some change but this was largely unexplored with some problematic terms such as ‘motivation’ remaining unexplored. In some instances, studies did not articulate the research design or offer detail regarding the intervention which made it difficult to evaluate the quality of the research and its overall contribution to knowledge. Given the use of technology is often seen as innovative and that the range of technologies used is always increasing, the limited number of qualitative or mixed methods studies is certainly a gap in this body of literature. Recognising that there are strengths and limitations in each approach, it would be beneficial to address this imbalance in order to gain greater insight into the way in which interventions using technologies might support student learning and skills development. There were also instances where research was described as mixed methods in its approach but involved limited qualitative data with, for example, a single open question in a questionnaire.

In terms of efficiency, the use of technologies relieved pressures on physical resources such as specialised rooms and equipment and offered opportunities to hone skills and reinforce knowledge and understanding through repetition. There were also advantages in being able to experience events which would not otherwise be possible, for example where it would have been too expensive or unforgiving and offer no opportunity for trial and error; involve challenging logistics in order to bring relevant people together at specific points in terms of time and location or to replay, pause and review content. Student motivation and engagement were also often cited in addition to commitment to their studies. This may not necessarily result in increased efficiency should students commit more time to undertaking the tasks, however, there are arguments that suggest that students might engage more and be more likely to retain what they have learnt and that on campus sessions are able to focus upon exploring and extending learning. Greater flexibility existed where continued access to content, peer discussion and tutor support beyond the campus setting was possible. Individually or used in combination, such interventions provided rich, interactive and extended opportunities to support development of team working skills and collaboration during PBL.

Although there were advantages in engaging students beyond the on-campus setting and in providing greater flexibility in terms of access to people and learning resources, this also raised questions regarding the use of staff time. Their involvement in the development of well-designed and appropriate resources and in the support of small groups as part of PBL approaches would need to be considered although in some instances, technology reduced staff time by encouraging greater student autonomy and offering automatic feedback on student activity to the tutors. In addition to staff time there were also some concerns regarding the expense associated with technological resources and the necessary infrastructure which might include staff and student development in addition to technical support. Beyond the use of the technologies, the approach to learning, including the ability to collaborate and work as part of a team would also need to be considered to avoid inefficiency through unresolved conflict.

The development of team working was integral to some of the research projects including technology supported frameworks and scripting which sought to address what might be viewed as ‘soft skills’ such as project planning, negotiation, collaboration, leadership and team management. Rather than allow students to find their own way in terms of teamwork, such studies guided the students’ learning experience and the outcome was, in most instances, positive and encouraged greater awareness when communicating with others. Automated feedback not only allowed for safe experimentation of ideas but also provided prompts which invited students to reflect individually and collectively upon their learning.
In addition to the cognitive, there were gains in the affective domain where enthusiasm, confidence and enjoyment in the learning provided a stronger impetus for team working. Conversely, where unresolved conflict had been reported in some studies, working relationships had fractured and progress in learning had been slowed or had stalled. This largely hinged upon the ability of individuals within the group to employ appropriate skills to communicate effectively, in order to cooperate in the mediation and resolution of disagreement. In some instances, the technology itself was viewed as a potential distraction to learning with students more closely involved with resolving issues or interacting with the resource than committed to the PBL task.

Inclusivity was given less attention than either efficiency or team effectiveness, however, there were instances where students, by virtue of working with peers from other countries, had gained a sense of cross-cultural awareness. There were also reports of increased sensitivity towards others as part of team-working and the use of visualisation to support the process of scaffolding. Most often, the sense that students were able to regulate their own pace of learning was viewed as a positive contribution and a means of providing a structure and framework to support the intricacies of team working as part of a constructivist approach to learning. This appeared to be more effective in the first year of an undergraduate programme where students were gaining awareness of and developing relevant skills for successful team-working alongside the subject knowledge associated with the relevant discipline.

5 CONCLUSION AND RECCOMENDATIONS FOR RESEARCH

This review highlights that although making efficiency gains often inspire the use of technology within constructivist settings, a focus on the effectiveness of technology in motivating and developing attitudes and skills necessary for team working such as self, co and shared regulation skills, is where future research should focus. The development and qualitative research on computer scripts that repeatedly orchestrate individual learners and teammates to interact with each other and also visualise their interactions can lead to effective and efficient ways to support the development of self, co and shared regulation and team working skills as well as trust the between teammates. Use of scripts can also help and or free up staff from orchestrating interactions between teammates and allow different teams to develop in their own pace. A related work, currently in press and also being presented at this conference, highlights the use of computer scripts in developing trust between neuro-typical and neuro-atypical teammates and in developing their regulation and team working skills (Malik and Sime, 2020; Malik and Sime, 2022a; Malik and Sime, 2022b).

In addition to addressing the imbalance in terms of qualitative, mixed methods and quantitative research approaches, recommendations for further research would include exploration of the design and implementation of technologies which support inclusivity and provide reasonable adjustments to allow all students to participate. Current studies are also restricted to some STEM disciplines and tend to focus more upon student performance as the outcome as opposed to attitudes and skills development. Future research might be extended to provide greater representation from across the portfolio of disciplines in, for example, engineering, mathematics and the sciences. STEM and in particular engineering education researchers, could focus on psychological constructs, such as trust and conflict, that are related to teamworking alongside student performance.

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AN INVESTIGATION ON INTEGRATION OF COMPUTATIONAL THINKING INTO ENGINEERING CURRICULUM AT DELFT UNIVERSITY OF TECHNOLOGY

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ABSTRACT

Our life is surrounded by digital devices. Engineering education is one of the cornerstones in higher education for future generations and computational thinking (CT) is deemed as a core component in various engineering curricula. The Delft University of Technology (TU Delft), is the largest technical university in the Netherlands and computing; computational concepts and activities have been integrated into curriculum for years at TU Delft. However, there is not a comprehensive investigation on integration of CT into Engineering Curriculum, this paper presents a case study of Master's level engineering curricula investigating: 1) to what extend CT components are integrated; 2) in what way CT is interpreted and integrated in the curriculum; 3) what educational and assessment methods have been used. The results show that CT has been largely integrated into the investigated curriculum mostly with lectures being the educational method and programming assignments as a method for the assessment. Our analysis shows that understanding the context and patterns in problems and solutions was important in different courses and engineering disciplines, indicating possible directions for integration of CT into curriculum.

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1 INTRODUCTION

The nature and shape of engineering education is an ongoing topic of debate among engineering faculty members, professionals and practising engineers [1]. It appears to be that the enormous changes in societal dynamics and the development of technology also lead to transformation of the engineering curricula. In both the United States and Europe, an emphasis has been placed on digital skills and literacy. In 2016, Barack Obama launched the 'Computer Science for All' initiative. The aims of this initiative were to allow American students from kindergarten through high school to learn computer science and acquire computational thinking (CT) skills. Computer science was referred to as a new basic skill necessary for economic opportunity and social mobility. As for the European Union, the Joint Report of the Council and the Commission on the Implementation of the Strategic Framework for European Cooperation in Education and Training (ET2020) highlights the importance of digital competences. In addition, the study Developing Computational Thinking in Compulsory Education by the Joint Research Centre, which is the European Commission's science and knowledge service, suggests that CT is a subject of importance within the European Union.

Addressing this emphasis on digital competences and computational thinking, in the Netherlands 4TU has been created to foster the collaboration between the four universities of technology (TU Delft, Eindhoven University of Technology, University of Twente and University of Wageningen). In the vision for Higher Engineering Education written by Kamp (2016), the 4TU Centre of Engineering Education in the Netherlands is mentioned as a "Free-Spirits" think tank which aims to develop suitable higher education scenarios by 2030 by examining the appearance of new engineering profiles in the coming 10 to 15 years. Inspired by the Greek Philosopher Heraclitus stating "the only constant in life is change", its vision states that digitalization is one of the driving forces which makes our world become more uncertain, complex and ambiguous. This does not only impact how people live, but also requires the future generations of students to be empowered with lifelong-learning and general problem-solving competencies including the use of digital and computational tools.

CT was first mentioned by Papert (1980) and then advocated by researchers and practitioners since Wing claimed it as "a must-have skill for everyone" living in the 21st Century rather than solely for computer scientists. Ever since, there has been extensive debate and research on the definition of CT and its relevance for education. Several definitions are used in the field, for example, Wing (2011) defined CT as a set of problem solving skills with which the formulation of solution for problems can be carried out by computing agents (either human or mechanics computing machines). Unlike Wing (2011)'s definition which is descriptive and theoretical, some operational definitions attempt to identify more granular constructs that are more practical. Brennan and Resnick (2012)'s three-dimensional framework consists of CT concepts, CT practices and CT perspectives as well as the four compositional frameworks with problem decomposition, pattern recognition, abstraction, algorithm defined by BBC(2018) are frequently used in research and practices. While efforts on concretizing the definition of CT are still ongoing, the importance of helping people adapt and prepare future generations to live in digital society is widely recognized. As a result, researchers, educators, policy makers and practitioners from both Science, Technology, Engineering and Mathematics (STEM) and non-STEM backgrounds are currently investigating the integration of CT into different fields.

Bearing in mind that fostering students' CT skills is a strategic focus of the 4TU, in this work we aim to investigate their integration in engineering curricula. Considering the effort needed for investigation of all relevant faculties, we limit our case study to the MSc programmes of the two [E1] faculties of TU Delft that incline to integrate CT into their curriculum, and we specifically aim to answer the following research questions:

RQ1. To what extent is CT reflected in the curricula of the TU Delft?

RQ2. In what way does the interpretation or reflection of CT differ per faculty?

RQ3. Which educational and assessment methods are used in CT-integrated courses?

2 METHODOLOGY

2.1 Research Scope and Source Data

The scope of this study was limited to the MSc programmes of two TU Delft faculties: Architecture and the Built Environment (ABE), and Electrical Engineering, Mathematics & Computer Science (EEMCS). As our data source we used the TU Delft study guide, in which we initially performed a keyword-based search and then analysed the course data towards answering the research questions. The search criteria were informed after consultations with faculty members. The TU Delft study guide[2] is the formal collection of all courses and study programmes offered by the different faculties of TU Delft. Each course is listed and described in this database with information such as its overview on course design and general course arrangement. A search functionality offers the opportunity to search the course descriptions per faculty for one or multiple keywords. Hence, the study guide was used as the basis for this systematic research into how computational thinking is reflected across the faculties of the TU Delft.

2.2 Identification of Relevant Keywords

To identify courses that discussed CT explicitly, the keywords "computational thinking", "digital skills", and "digital competency" were applied. Besides identifying courses that explicitly discussed CT, we were interested in identifying the courses that implicitly included CT. To identify those courses, we leveraged the operationalization of CT devised by BBC (2018), which comprises problem decomposition, pattern recognition, abstraction and algorithm design. For each of the four components of CT, keywords were defined that signalled the presence of that step of CT (Table 1 in the Appendix). The asterisk (*) in some keywords ensures courses are found where both words occur in the text, although not

[2] https://studiegids.tudelft.nl/bbDefault.do?SIS_SwitchLang=en

sequentially. In addition, it allows for finding both UK and US spelling in e.g. mode*ing. In addition to these general keywords, after consultation with an associate professor for the faculty of Architecture and the Built Environment, the keywords “parametric”, “computational”, “ algorithm”, and “simulation” were added as ABE-specific keywords.

2.3 Filtering of the Relevant Data

After performing the keyword search, several filtering steps were applied (Figure 1 in the Appendix). First, BSc courses were discarded since we were solely interested in MSc courses. Since a considerable number of courses within EEMCS that included one of the CT components, only the courses with at least two CT components were evaluated. Then, while the presence of one or more CT components under each component in the course description signalled the possibility of CT, it was found that merely the appearance of those components were not sufficiently specific to signal the presence of CT. Therefore, the keywords and its corresponding CT components were applied, and an evaluation of the course description in study guide was performed to identify the courses reflecting CT. The courses were scored on the presence or absence for each of the four components of CT. The course descriptions which at least signalled the presence of two out of the four components of CT were included in our validation set while courses with less than two components were discarded. The validation sets were sent to three CT experts (second evaluators) for evaluation together with the operationalization of CT. The courses that were rated by at least three out of four raters as CT were included in the final selection.

2.4 Data Extraction and Synthesis

The selected courses were analysed with the information extracted from CT courses. Types and categories of the assessment method, educational methods, courses and other categorizations were based on observation from the dataset and aggregated by one of the authors with consultation from experts when necessary. Table 2 in Appendix provides an overview of the extracted information per CT course (with the last row presenting the information aggregated based on descriptions of the courses).

3 RESULTS

3.1 Inter-rater Reliability on the Identification of the Relevant Course

A low Fleiss’ kappa inter-rater reliabilities of 0.33 and 0.17 for the courses of the faculties ABE and EEMCS, respectively. These low values indicate that, although the operationalization of CT of this study was provided to the raters, their interpretations of CT were still divergent. Apparently, the provided operationalization left room for interpretation, which led each rater to use its specific background knowledge on CT. Zooming in on the ratings, we observe e.g. that one expert utilised a broad perspective and considered almost all courses of the test sets to be CT, while another expert utilised a narrow perspective and only scored about half of these courses to be CT. Clearly, their interpretations of CT differ greatly.

3.2 CT in the Curricula

A total of 15 ABE MSc courses under two MSc programmes (Geomatics and Architecture, Urbanism and Building Sciences (AU&B)) were designated as CT courses while a total of 27 EEMCS MSc courses were designated as CT courses (an additional filtering step was applied compared to ABE). The keywords that were found in the course descriptions of the CT courses are visualised in Figure 2a and Figure 2b (can be found in Appendix), with the font size correlating to frequency. Compared to the keywords from ABE, we can see "algorithms" and "algorithm design" were much more frequent for EEMCS. Meanwhile, Of the three MSc programmes analysed, unsurprisingly, Computer Science contained the highest number of CT courses. Due to the set-up of the EEMCS MSc programmes, all courses were compulsory choices courses.

Figures 3 and 4 demonstrate the different types of CT courses within ABE and EEMCS respectively. Most courses at ABE were about learning to use a computer program or a modelling task that contributes to analysing the environment or the design of new buildings. For example, in Digital Terrain Modelling students were taught to use datasets to reconstruct a terrain and use these for applications related to the built environment, and in Geomatics as support for energy applications students are taught to build 3D city models. Another type of CT courses at ABE were courses that comprised large projects with a computational component of varying extent. For example, in MEGA[3] students designed a special big building in multi-disciplinary teams. Within this team, just one of the students was responsible for the computational design. On the other hand, in Earthy the design of the building is completely computational. Finally, the course Operations research methods was specifically on teaching research methods and using mathematical modelling to make decisions.

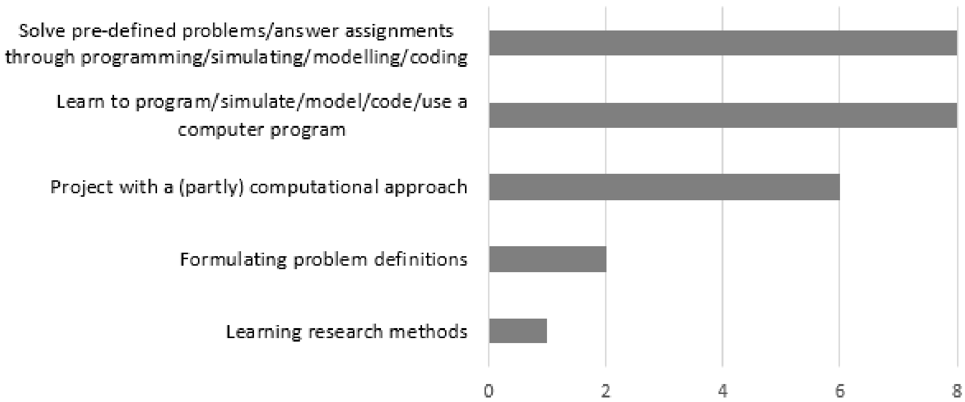

Fig. 3. ABE – Types of reflection of CT in courses

As for EEMCS, the largest part of the courses includes learning about the context and patterns in problems and solutions; frequently in the form of students being taught to recognise which algorithms to use for which problems. For example, in Object Classification

[3] MEGA is a collaborative integral multi-disciplinary design of a special big and/or tall building.

with Radar two of the four learning goals specifically refer to recognizing patterns in the data and the type of problem and deciding on the approach dependent on these patterns: 'Analyse and compare the different domains of radar data that can be exploited for objects classification, and the convenience of use of one rather than the other in different situations' and 'Propose and evaluate possible approaches for given classification problems based on radar sensors data'. Furthermore, more than half of the courses involved a larger project with a (partly) computational approach. Interestingly, whereas the ABE faculty always started out with a problem (e.g., I want to design a building and I need to know the terrain) and then took a computational approach to solve the problem, the EEMS faculty also frequently took the algorithm as a starting point and then went looking for a problem to be solved, sometimes looking at other faculties of the TU Delft to provide problems to be computationally solved.

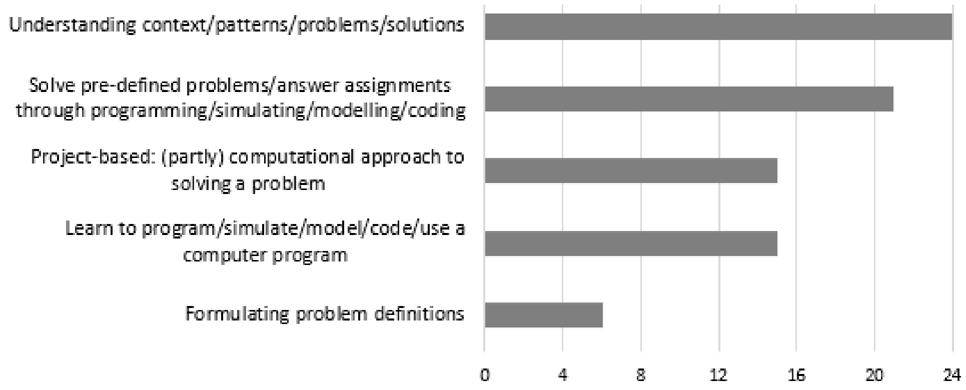

Fig. 4. EEMCS - Types of reflection of CT in courses

To conclude, these courses illustrate how CT is important also at a design faculty and the EEMCS faculty provided many CT courses. In a design faculty, there are many problems to be solved (e.g., how to best design the building) and in some of the courses a (partly) computational approach is taken to solve these problems. Meanwhile, understanding the context and patterns in problems and solutions was important in almost all courses; demonstrating the importance of this step of CT.

3.3 Educational Methods

Zooming in on the different educational methods, we see that a wide variety of methods was used in CT courses at ABE (See Figure 5). Contrary to what one might expect given the practical nature of CT, lectures were the most common instructional method. However, within one course on approximately 4 educational methods were used, signalling that lectures were often used in conjunction with different educational methods. For example, in the course Geomatics as support for energy applications three education methods are used: lectures to provide the theoretical background, practicals to allow the student to practice building models while supervision is present, and self-study to further dive into the theoretical background and do more modelling. Besides lectures, practicals and self-study, computational assignments were a common educational method, which is in line with expectations: computational assignments allow the student to apply their CT skills in practice. In addition, notable is that a fair number of courses included tutoring sessions. These sessions are a common way of teaching in the ABE faculty, during which a tutor provides feedback on the work or design of the student or students.

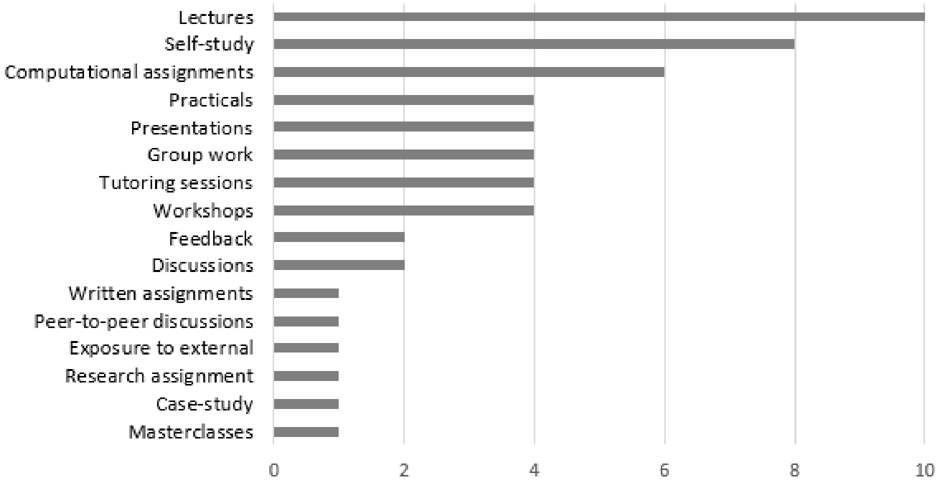

Fig. 5. ABE - Occurrences of different educational methods in CT courses

Figure 6 demonstrates the utilised educational methods at EEMCS, with on average 3 educational methods per course with lectures being the most used educational method. In 37% of the courses, practicals and/or computational assignments were used as educational methods. Larger computational groups or individual projects were more common in the EEMCS faculty. For example, in the course Crowd Computing students are working throughout the entire course for six hours per week in a group on an extensive computational project. Besides this group project, the other utilised education methods are lectures and computational assignments. Notable is the occurrence of some more innovative instructional methods like recorded lectures for the course Applied Machine learning and lectures by students for the course Machine Learning in Bioinformatics.

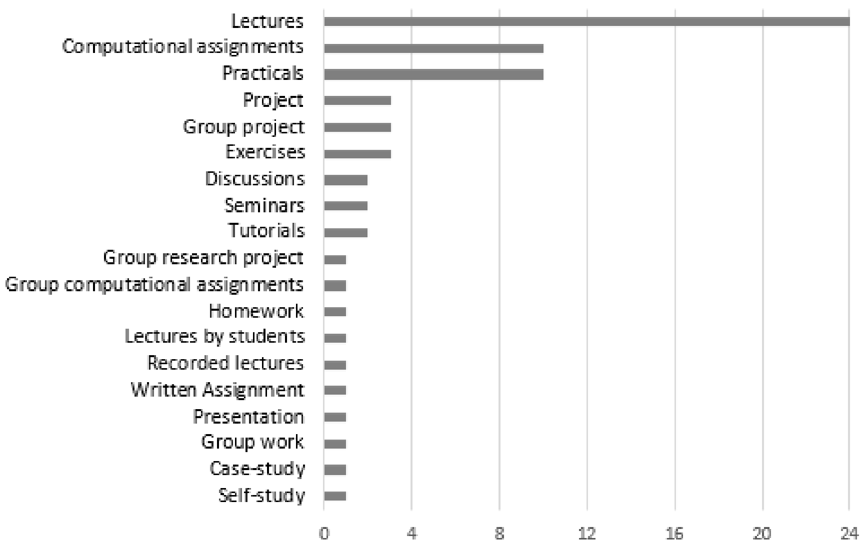

Fig. 6. EEMCS - Occurrences of different educational methods in CT courses

3.4 Assessment Methods

For the assessment at ABE and EEMCS, most courses used more than one assessment method and overview of assessment methods being used for both faculties are presented in Figure 7 and Figure 8 respectively, with computational assignment (s) being the most common assessment method. The more traditional written exam was also frequently used, often in combination with computational assignments as in e.g. Geoweb Technology, Geographical Information Systems (GIS) and Cartography and Python Programming for Geomatics. Group presentations, group reports and individual reports were also common; it should be noted that often these reports were about the developed computational model. For example, in Operations Research Methods the assessment was based on a written assignment and on a report on two mathematical models. In addition, they were often used in parallel (e.g., Algorithms for Intelligent Decision Making, Artificial Intelligence Techniques and Evolutionary Algorithms). Oral exam is also used as an assessment type; though it might be labour intensive.

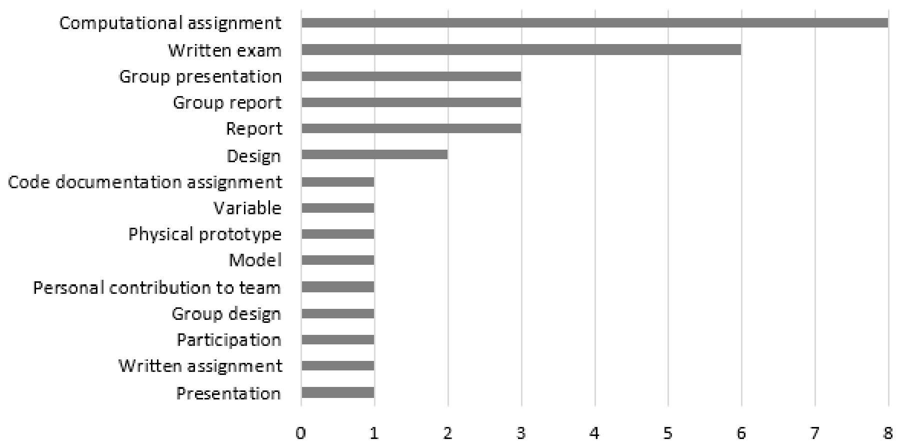

Fig. 7. ABE - Occurrences of different assessment methods.

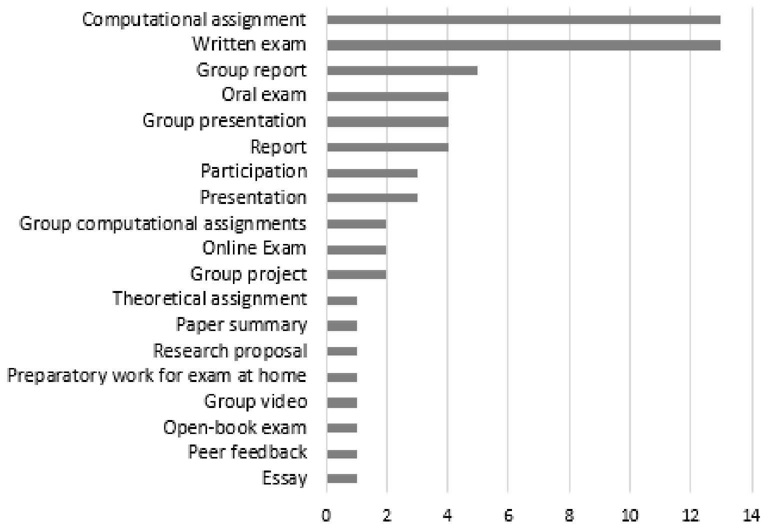

Fig. 8. EEMCS - Occurrences of different assessment methods.

4 CONCLUSIONS, LIMITATIONS AND FUTURE WORK

With the preliminary results of this work so far, several conclusions can be made: First of all, aligned with the findings of the group concept mapping study from Specht et al. (2019), this work finds that agreement on definitions and the relations between different competences and skills under computational thinking is still vague even for experts. For developing an embedding of CT skills in an engineering curriculum necessary definitions and focus should be aligned. Secondly, the examples from the two different faculties of TU Delft show different approaches and embedding CT concepts into the curriculum. On the one hand fundamental developments or algorithms and computational abstractions need to be developed extending CS curricula and there focus, on the other hand more design oriented engineering disciplines embed computational tools and skills often in concrete design and project work. Last but not the least, we observed course designs in which computational tools and digital skills can be linked to specific subtasks of design challenges but also more generic courses which integrate computational tools as a base element of engineering design.

However, the authors spotted major limitations of this work regarding its methodology and its scope, mainly being: this is a case study on specific faculties of one university and, even though both are large and well established faculties, they might not be representative of engineering faculties in other countries. Also, that the study was based on the information on the study guide which, even if it is a requirement that it is updated yearly, might not fully reflect instruction methods that the instructors apply. Furthermore, the course descriptions used for this work was limited to academic year 2020-2021, which indicates that effectiveness of the findings in this study is time delimited and engineering education is changing with the technological and societal dynamics, which indicate that longitudinal observations and investigations are needed. Regarding the methodology, though this work follows certain level of systemacy and considers the potential bias caused by individual work, several aspects should be noted: Information coding and data synthesis was weak regarding the verification of the validity; the conclusions were made merely with observation and analysis from course descriptions, making it weak as actual situations may differ from the course descriptions.

To further advance this work, the authors plan to conduct focus group study or interviews to gain more insights about the integration of CT into Engineering curriculum and establish more solidate coding schemes and verification standards to improve the validity of the extracted information in future work.

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APPENDIX

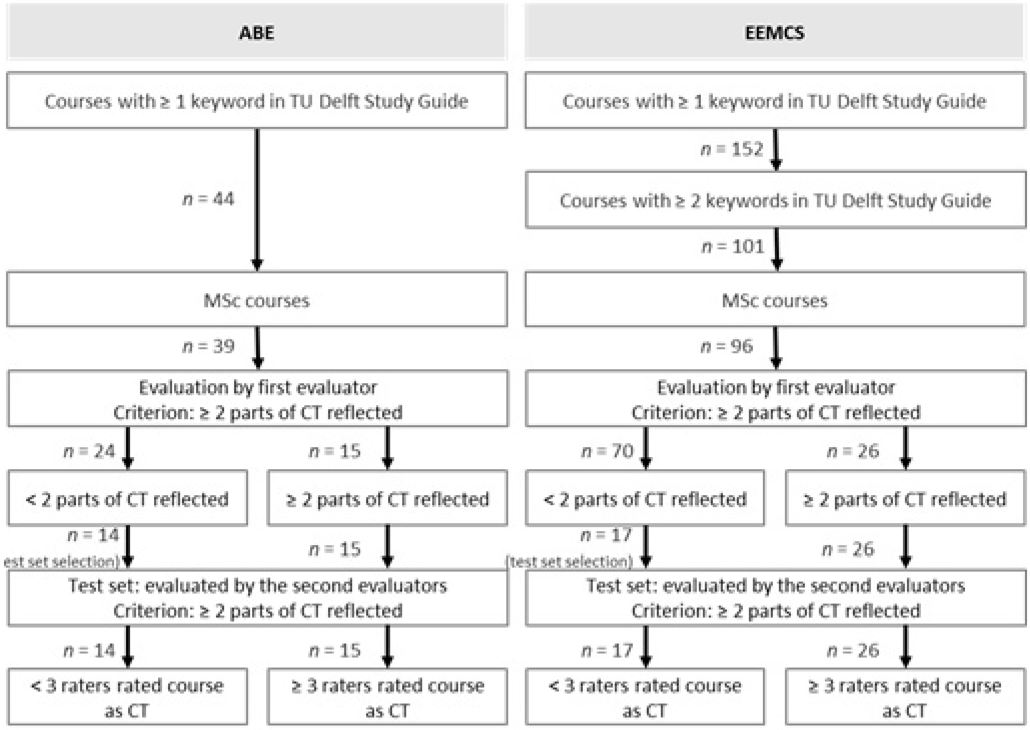

Fig. 1. Selection process of the CT courses. ABE: (Architecture and the Built Environment), EEMCS: (Electrical Engineering, Mathematics & Computer Science)

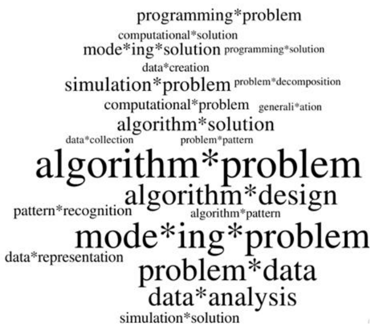

Fig. 2a. ABE – Word cloud of the keywords in the CT courses. A larger font size correlates with a higher occurrence

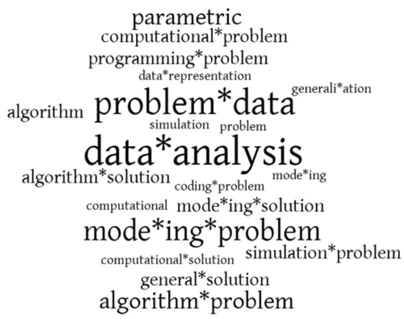

Fig. 2b. EEMCS – Word cloud of the keywords in the CT courses. A larger font size correlates with a higher occurrence

Table 1. Overview of the keywords used to identify courses that implicitly include CT

Four Components	Keywords
Problem decomposition	Problem*decomposition; Problem*data; Problem*pattern; Problem* abstraction
Pattern Recognition	Pattern* recognition; Data*analysis; Data*creation; Data*collection; Data*representation; Identif* patterns

Abstraction	Abstraction; Generali*ation; General*solution; Formulating* solution
Algorithm Design	Algorithm* design; Algorithmic* thinking; Algorithm* problem; Algorithm* pattern; Algorithm* solution; Computational* problem; Computational* pattern

Table 2. Extracted information per CT course

Categories	Sub-categories
General information	Date of consultation; Keyword hits; number of keywords; Course Title; Course code
Place in Curriculum	ECTS; Semester (Q1[4] Q2 Q3 Q4); Programme; Track; MSc year; Elective vs obligatory vs obligatory with choice
Study Description information	Link; Offered by; E-mail; Course content – TOPIC; Study goals – ALL; Study goals – TOPIC; Education methods; Ass. Type; Ass. Process; Ass.[5] Criteria
Evaluation	Presence of: Problem decomposition, Pattern recognition, Abstraction, Algorithm design; Type of course; Sure (yes / no); Notes

[4] Q1 – Q4 refer to Quarter 1 to Quarter 4 in an academic year.

[5] Ass.: Abbreviation of assessment.

CONCEPT PAPERS

Remote Learning and Examination based on Augmented Reality

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Virtual and Augmented Reality in Education
Keywords: *Augmented Reality, Assisted reality, Remote learning, Remote coaching, Digital active learning*

doi:10.5821/conference-9788412322262.1301

ABSTRACT

Remote Learning and Examination based on Augmented Reality (RELAR) is a European Erasmus+ project (2020-1-NL01-KA226-VET-083043) that aims to create a crisis-proof resilient education environment, enabling remote coaching and digital skills training based on AR. RELAR integrates seven European partners –Vocational Training Institutions and Higher Education Institutions– all linked to the maritime industry. The industry itself is also represented.

With the help of a reference group, a set of learning outcomes has been defined to develop three demo scenarios to test and demonstrate the RELAR system, which is based on the RealWear HMT-1 assisted reality hands-free computer. All scenarios are scaffolded on the same framework that integrates active learning pedagogy, curriculum requirements and technological integration.

This digital active learning process pedagogy incorporates two processes for instruction: a remote instruction process called ‘Expert Coaching’ that gives the students the possibility of receiving instant feedback while taking actions and decisions; and a remote assessment process named ‘Digital Workflow’ that incorporates formative assessment to consolidate learning. The curricular aspect focuses on the professional competencies students will acquire, the expected learning outcomes, the required knowledge, and the transferable skills required by students to perform professionally. Finally, technological integration describes how and when the assisted reality system should be incorporated to add value to the learning process.

This paper describes the work in the learning spaces currently under development by the partnership based on the same methodological and pedagogical foundations.

1 INTRODUCTION

RELAR project aims to create a crisis-proof resilient maritime educational ecosystem by enabling remote learning and examination using Augmented Reality (AR). The project addresses the difficulties of the maritime and port education ecosystem caused by the situation unearthed by COVID-19 and any other crisis that may affect face-to-face education and training. In this context, new digital technologies such as AR can make it possible to transfer the expertise and knowledge of industrial organisations while improving security, safety, and efficiency by empowering frontline connected trainees and workers with remote technology. The RELAR consortium partners will identify and adopt a joint architecture and framework for future interoperability, scalability and sustainability of remote learning. The core concepts of the architecture will be inspired by the background and experience of functional design approaches for remote learning and assessment developed by STC Group for maritime education [1].

RELAR is formed by a consortium of seven European Vocational Education & Training (VET) Institutions and Higher Education Institutions (HEI), and industry organisations, all linked to the maritime industry.

The consortium –listed below– is coordinated by a lead partner, which is currently the STC Group.

- Shipping and Transport College Group, STC Group.
- Malta College of Arts, Science & Technology, MCAST.
- Šolski center Nova Gorica.
- Romanian maritime training centre, CERONAV.
- Satakunta University of Applied Sciences, SAMK.
- Universidad de La Laguna, ULL.
- University of the Aegean, Aegean.

This work is possible thanks to the consortium members and the following Industry associated partners:

- Knowledge Insight.
- KOTUG International.
- WeAR.
- WinNova.
- ONEX Syros Shipyards.
- MarineTraffic.
- Creative Solutions.
- Palumbo Shipyard Malta.
- Cassar Shipyard.
- Romanian Naval Authority.
- Tenerife Shipyards.
- Hidramar Shipyards.

RELAR project will deliver two Intellectual Outputs (IOs):

- *Architecture and framework* (IO1) contemplate technical development aspects.
- *Commons* (IO2) incorporates the pedagogical aspects of the project.

Given the focus of this conference on Engineering Education, this paper describes the development of IO2, which consists in the development of shared resources that will be integrated into three different demo scenarios that will incorporate pedagogical content. The idea behind these demos is to show how common resources developed by the consortium can be integrated with the RELAR ecosystem and how researchers, the educational community and even businesses and industry can use them and develop them further.

Three partners with experience in maritime education are building the above-mentioned demo scenarios for learning and examination purposes for the following use cases: *Marine Engineering* (developed by ULL), *Shipyard Technician* (developed by MCAST), and *Logistics/Fleet Technician* (developed by Šolski center Nova Gorica). All three demo scenarios will share the same pedagogical framework named in RELAR as Digital Active Learning process, which is described in detail in next section.

2 METHODOLOGY

The development of each demo scenario needed a shared structure to make them comparable, so it was necessary to define the common requirements, showed in Table 1:

Table 1. Common requirements for demo scenarios

Definition	Requirement
Level for qualification and learning outcomes, based on the European Qualification Framework (EQF)	4
Total learning hours, based on the European Credit Transfer and Accumulation System (ECTS)	1 ECTS (25 hours)
Assessment of the learning outcomes	Up to partner's decision
Providing of formal certification	Up to partner's decision
Cost of the contents	Free of charge
Delivering language	English

2.1 Designing Demo Scenarios

As much as possible, the development of the scenarios would follow a Scenario-Based Learning (SBL) methodology. This strategy uses an active learning approach, using real-life situations for exposing the learners to a relevant learning experience. This methodology will help learners in critical thinking skills training and communication skills training. Learners would also be able to understand the cause-effect in relation at the workplace [2].

Each scenario's methodology is based on three components that facilitate the adoption of active learning in Engineering Education: Curriculum, Pedagogy, and Technology (see Fig. 1) [3].

Curriculum. The curricular aspect is built-in base on the descriptors proposed by EQF level 4, *Knowledge, Skills,* and *Responsibility and autonomy* [4]. From these descriptors are extracted four aspects that feed each other and are used to determine the final outputs for the RELAR scenarios: *Professional competencies*, *Learning* *outcomes*, *Subject knowledge*, and *Transferable skills*. Those are interrelated in such a way that the learning outcomes are dependent on the professional competencies, the required knowledge is set by the learning outcomes and transferable skills are determined by the professional work environment (see Fig. 2).

This loop in the curricular aspect guarantees to select all aspects related to the subject and how it connects to future application in learners occupation.

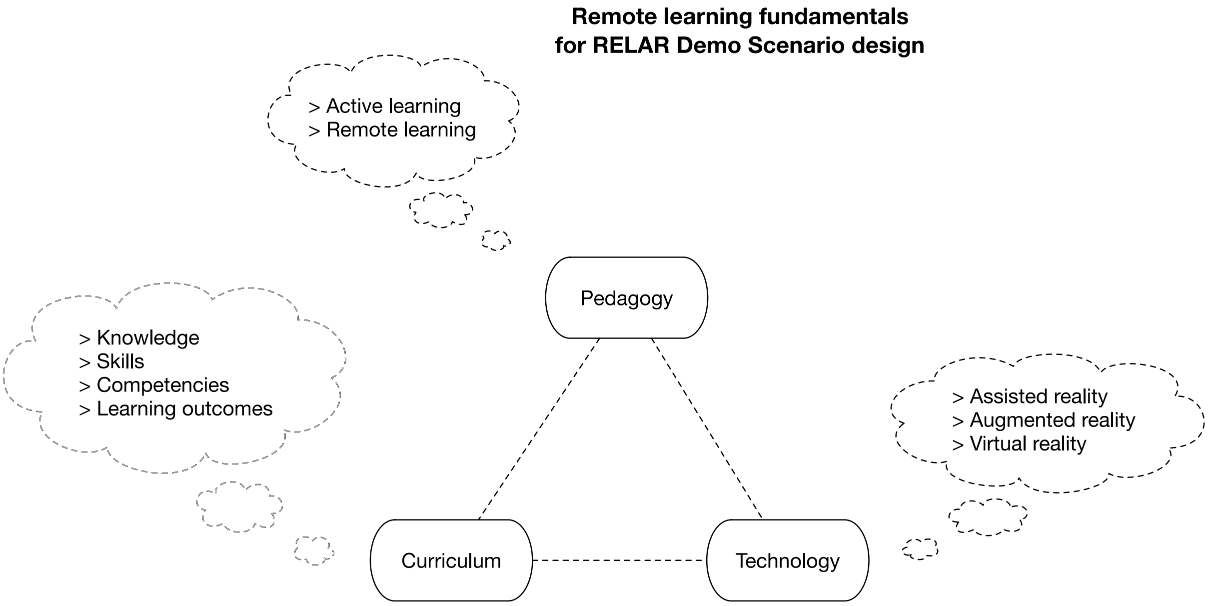

Fig. 1. Learning fundamentals for RELAR Demo Scenario design

Pedagogy. Pedagogical framework for Demo Scenario design is based on active learning and remote learning. The instructor's role during the process is to guide and facilitate the learners through their actions and to give feedback when it's needed. Considering it necessary for proper active learning, the activation of previous knowledge is fundamental, where wrong concepts and misconceptions are corrected and helps to relate previous experiences to a new situation. Creating new knowledge and competencies, and consolidating them are the next steps, always considering the learner's motivation for its optimal autonomous learning process (see Fig. 3).

The *Digital Active Learning process* incorporates two different actions for remote instruction called *Expert Coaching* and *Digital Workflow*.

During Expert Coaching, learners receive instant feedback through selected technology while they are taking their own actions and decisions. Digital Workflow contemplates asynchronous formative assessment to consolidate learning.

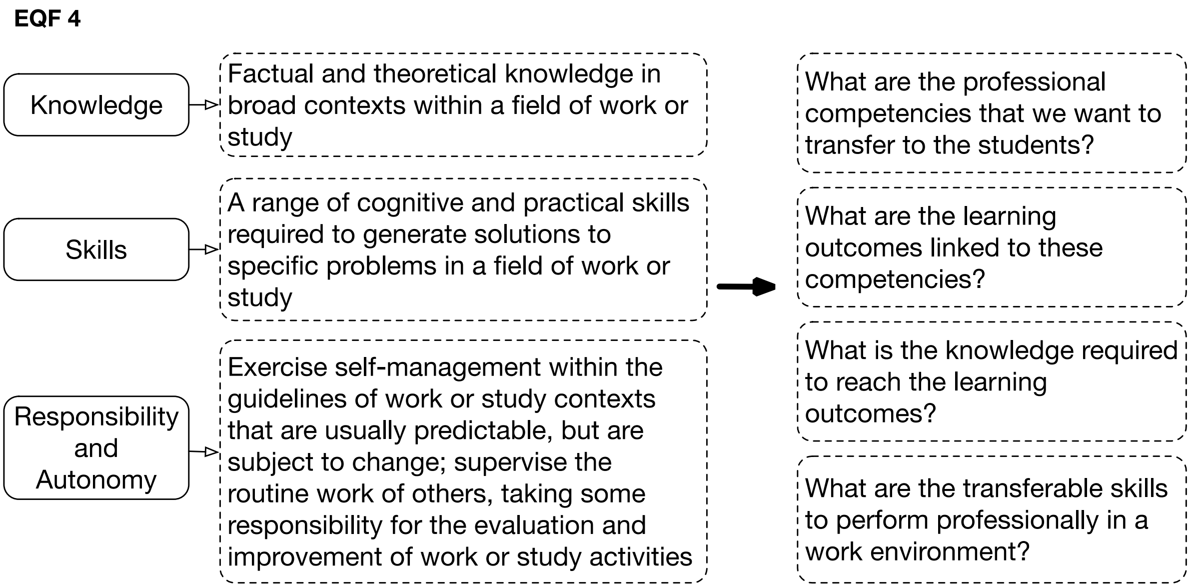

Fig. 2. RELAR curriculum aspects

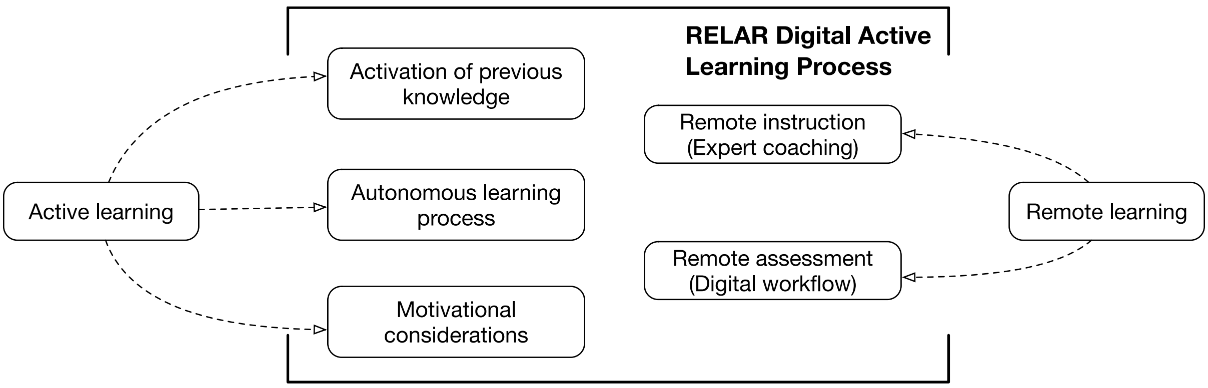

Fig. 3. RELAR pedagogical aspects

Technology. Technological integration describes how and when assisted reality system should be incorporated into the learning process. For this purpose, HMT-1 device is the chosen tool by the consortium, leaving other devices based on AR and VR as feasible options for similar scenarios (see Fig. 4).

HMT-1 device is a wearable computer that is designed to be used in industrial and commercial environments. It is a rugged device that can be worn on the head, and it includes a display, camera, microphone, and speakers. The device runs on the Android operating system, and it has been designed to be used with a variety of applications [5].

Its features allow the instructor to follow the user's view using a video call, capable to maintain a synchronous connection for immediate feedback or recording the action for asynchronous review, helping in Expert Coaching and Digital Workflow, respectively.

From the learner's point of view, the device can be used as a tool for viewing documentation related to their actions or as a guide to follow previously generated workflows.

Learning Management Systems (LMS) and videoconferences are useful tools to use in the digital active learning progress, to follow and share between learners and instructor in asynchronous or synchronous ways, respectively.

Technological integration into the digital active learning process is possible by the collaboration between lead and support partners, iterating with the possibilities and limits on software or hardware.

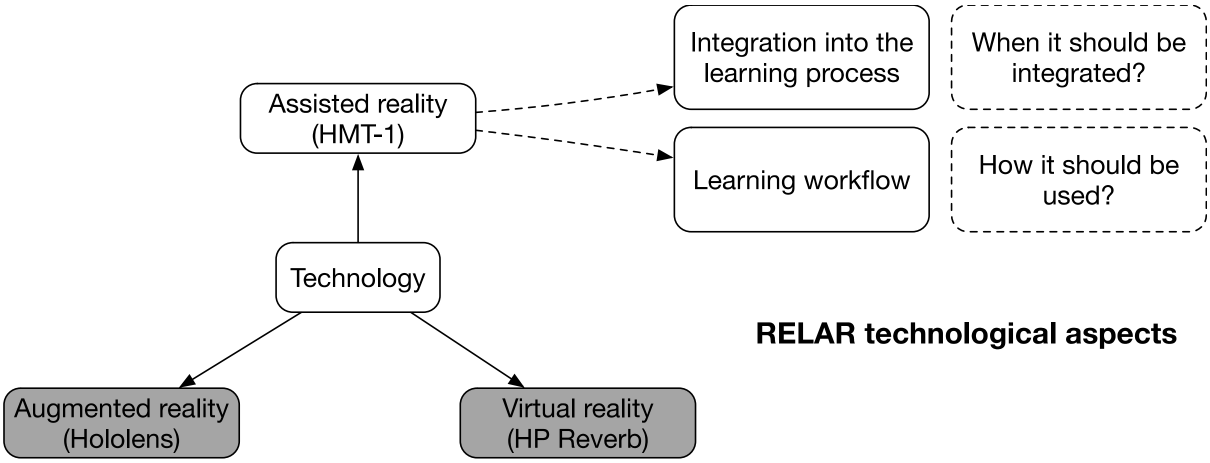

Fig. 4. RELAR technological aspects

2.2 Demo scenario workflow

In general words, RELAR demo scenarios are divided into 3 phases (see Fig. 5). 1st phase focuses on the activation of previous knowledge, where students can be exposed to the topic knowledge that they already should know. Using self-evaluation tests and having an open discussion between classmates and instructor is a proper way to know and understand lack of knowledge or misconceptions from the learners, facilitating flexible variations during the learning experience.

2nd stage's aim is to create new knowledge and competencies. Learners themselves must work as teams to investigate digital content about the topic and elaborate their own content to take action in training. During this stage can receive instant feedback from the instructor via HMT-1 (expert coaching).

On 3rd stage, the knowledge has to be consolidated, expecting that it can be transferred to new situations in learners' future professional environment. For this stage, learners may build their own workflow to follow in the expected problem. The learner action can be recorded by the HMT-1 device to receive asynchronous feedback from the instructor (digital workflow). This final stage could be used as an assessment of the topic.

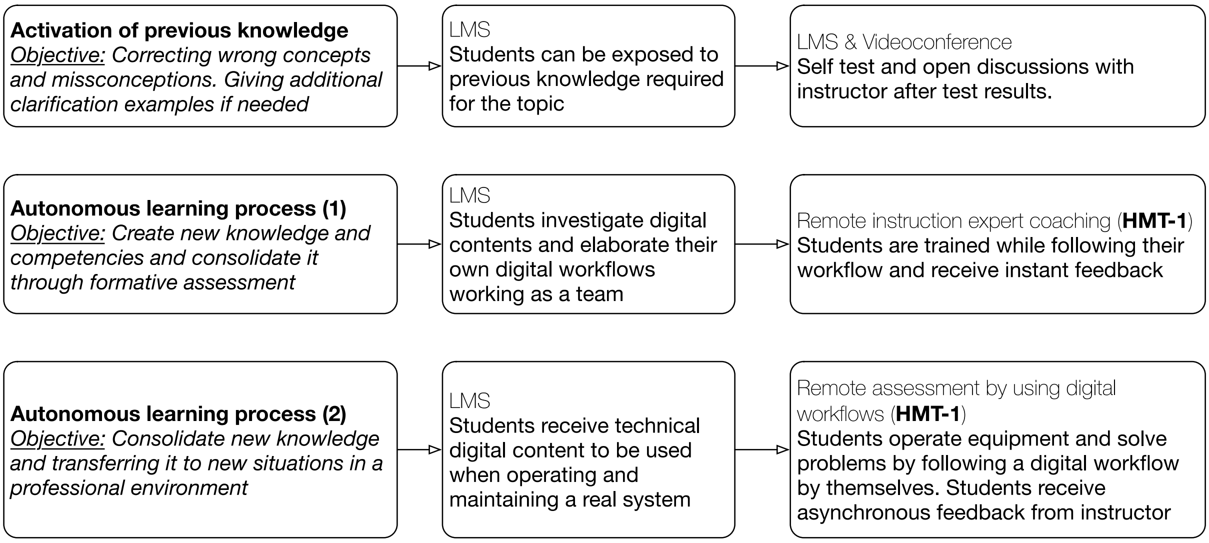

Fig. 5. RELAR digital active learning process

3 EXPECTED RESULTS

In future Intellectual Outputs scheduled in RELAR actions, the scenarios created by the consortium will be tested, ensuring that demo scenarios are correctly build in its three aspects, optimizing them if needed. The experience must be validated by the reference panel, through a series of meetings where product will be showcased.

As part of the dissemination activities, the partners will organise nine Transnational Meetings in total, of which four will be Training Events. During the Transnational Meetings teachers, students and experts from maritime industry and other sectors get familiar with RELAR and receive the necessary information on how to use it to educate and examine students and professionals on-the-job remotely.

During ‘train the expert’ sessions the partners ensure that the level of technical knowledge, the digital skills and understanding of concepts among teachers and trainers is sufficient for using RELAR in their daily work.

During ‘train the trainer’ sessions teachers and trainers get familiar with using RELAR scenarios for learning and examination using RELAR scenarios.

By the end of the project’s schedule, a RELAR Trainers’ pack must be developed by various partners. This trainer’s pack will include standard procedures with hardware and software and scenario specific info.

RELAR is a project under development with expectations of improving learning outcomes in engineering by using devices that are becoming common in the industry 4.0. With the backup of institutions and industry, future RELAR editions could have a vague expansion on the use of other devices and technologies and incorporating and testing over other environments.

4 ACKNOWLEDGMENTS

Remote learning and examination by using AR in maritime VET education, RELAR, is a European Erasmus+ project with agreement number 2020-1-NL01-KA226-VET-083043. This project is scheduled between May 2021 until April 2023.

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THE BERLIN ETHICS CERTIFICATE: CONCEPTUALIZING INTERDISCIPLINARITY AS A CORE BUILDING BLOCK OF ETHICS IN ENGINEERING EDUCATION

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Keywords: *Interdisciplinary Education, Engineering Ethics, Integrated Ethics, Situated Knowledge, Curriculum Development*

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ABSTRACT

To address the need for more responsible research and innovation, there is a growing call to integrate ethics education across the science and engineering curriculum. Accordingly, ethics education must not be limited to the avoidance of scientific misconduct but rather be oriented toward addressing the complexity of planetary challenges and realizing social good. Designing curricula to accommodate the ambition of integrated ethics, however, remains a great institutional and epistemic challenge. In this paper, we introduce the *Berlin Ethics Certificate* (BEC) at the Technical University of Berlin, to demonstrate how this challenge can be addressed by using interdisciplinarity as a core building block of integrated ethics education. The BEC's unique approach to ethics education enables the positioning of ethical issues in all study programs within the university by designing future-oriented interdisciplinary courses open to all students, be they from the humanities, natural or engineering sciences. The paper outlines the BEC's conceptualization of interdisciplinarity, ultimately arguing that interdisciplinary ethics education must be built upon the epistemic practice of situating knowledge. Methodologically, we show how the BEC approaches integrated ethics education through three iterative steps: 1) situating disciplinary knowledge in relation to other forms of knowledge, values and experiences (by focusing on multidisciplinary learning experiences), 2) establishing a common epistemic practice of collaboration (by focusing on interdisciplinary learning experiences), and 3) actively engaging with non-academic stakeholders to create responsible technology and take ethical action beyond the university (by focusing on transdisciplinary learning experiences). Examples of how the BEC implements this methodology are shown, which may serve as suggestions of best practices in integrated ethics education.

1 INTRODUCTION

In face of the many planetary-scale crises faced by societies today, dealing with ethics and figuring out how to shape responsible futures is becoming an urgent matter. We are arguably more dependent on science and technology than ever before, and thus also more vulnerable to associated risks. To meet the demand of these challenges, teaching ethics to engineers has become common practice, as ethical, social and environmental considerations have been widely recognized as critical for engineering, computer and data science education. In the European context, the call for responsible research and innovation has placed further emphasis on ethics education in the technical sciences to steer processes of technological development toward socially desirable effects and mitigate downstream harms.

However, in the growing body of research on ethics in engineering education, there is considerable debate regarding proper course content and learning objectives, best teaching methods, and effectiveness of outcomes [1][2]. Most discussed is the question of how to best incorporate ethics into engineering education. The dominant paradigm, stemming from a lineage of professional and business ethics, has focused on the avoidance of individual scientific and moral misconduct (e.g., Responsible Conduct in Research in the US), and siloed modes of ethical reasoning taught in appendix "applied ethics" modules [3]. There is increasing recognition of the limitations of this paradigm, namely its failure to teach ethical reasoning skills beyond individual compliance and its subordination of ethics to dominant motives of technological progress and economic growth [1][3]. To address these limitations, there is a growing call to integrate ethics education across the science and engineering curriculum [2]. Accordingly, ethics education must not be limited to codes of conduct but rather be oriented towards addressing the complexity of current and future local to planetary-scale challenges and bringing about positive societal change. A key element of such an approach involves integrating ethical reflection across the curriculum so that ethical questions can be addressed from the perspective of many disciplines. Designing curricula to accommodate the ambition of integrated ethics, however, remains a great institutional and epistemic challenge, primarily due to the difficulty of cross-disciplinary activity.

In this paper, we present a response to this challenge in ethics education: the Technical University of Berlin's newly established certificate program *Reflection and Responsibility—Berlin Ethics Certificate*. The certificate program integrates ethical reflection across all study programs by using interdisciplinarity as a core building block of ethics education. In section 2, we first outline the basic structure of the certificate and its setting at the Technical University of Berlin (TUB), where ethics and the humanities are granted a special status due to the history of the university. In section 3, we propose interdisciplinarity as a building block of integrated ethics education with the Berlin Ethics Certificate (BEC). In section 3.1, we conceptualize interdisciplinarity as an epistemic practice, focusing on the dynamics of knowledge production in interdisciplinary collaboration and the epistemic requirements for actors involved. In section 3.2., we argue that interdisciplinary collaboration must be founded on the practice of situating knowledge, which allows for students to perceive their disciplinary and non-disciplinary knowledge as partial and gain an awareness of their values and moral intuitions, thereby enabling them to successfully enter a process of joint reflection. In section 3.3, we then show how this practice of situating knowledge is used by the BEC to ultimately generate socially responsible and epistemically robust knowledge. Finally, in section 4, we provide concrete examples from the BEC to demonstrate how integrated ethics education is implemented by focusing on multi-, inter- and transdisciplinary learning experiences.

2 THE BERLIN ETHICS CERTIFICATE AT TU BERLIN

Today, numerous German and international technical universities have humanities departments and offer affiliated study programs. However, the presence of different disciplinary cultures at the TUB is special in this respect, as it has had a humanities faculty since 1950. The reference to humanistic-oriented values through the humanities as well as a civil clause are special characteristics rooted in the TUB's historical responsibility accepted for the atrocities committed during the era of National Socialism in Germany.[4] In line with this, the present mission statement states that "research and teaching in the natural, planning and engineering sciences are inextricably linked with the humanities and social sciences" [4]. According to its mission statement for teaching, academic education should "enable students to develop as individuals". Furthermore, they should "learn to place their knowledge and actions within a broader historical, social, and cultural context and to reflect on the ethical consequences of their actions" [5]. With its focus on social and ethical responsibility on one hand, and interdisciplinary community building on the other, the BEC realizes these principles. Within the program, students are educated to take responsibility for the future by orienting their scientific and technological practices toward desirable visions for society and to practice interdisciplinary collaboration.

Reflection and Responsibility—Berlin Ethics Certificate offers students the opportunity to develop a specialization in ethics, science theory and technology reflection as a complement to their disciplinary studies. Students from all study programs, including the humanities, social, natural and engineering sciences, may volunteer to register for the certificate program, which is completed by attending courses of their choice offered by the BEC. The BEC was launched in 2021 and is coordinated by a working group of the *Berlin Ethics Lab* at TU Berlin and an interdisciplinary advisory board of the *Berlin University Alliance*.

[4] Between 1933 and 1945, numerous Jewish scientists were expelled from the formerly *Technische Hochschule Berlin*, while its remaining researchers played an essential role in maintaining a network among science and military actors and participated in National Socialist armament research. Following the war, the partially destroyed university was reinaugurated in 1946 as *Technische Universität Berlin* by the British allies with a new humanistic orientation and educational mission, instantiated by the founding of the Faculty of Humanities in 1950.

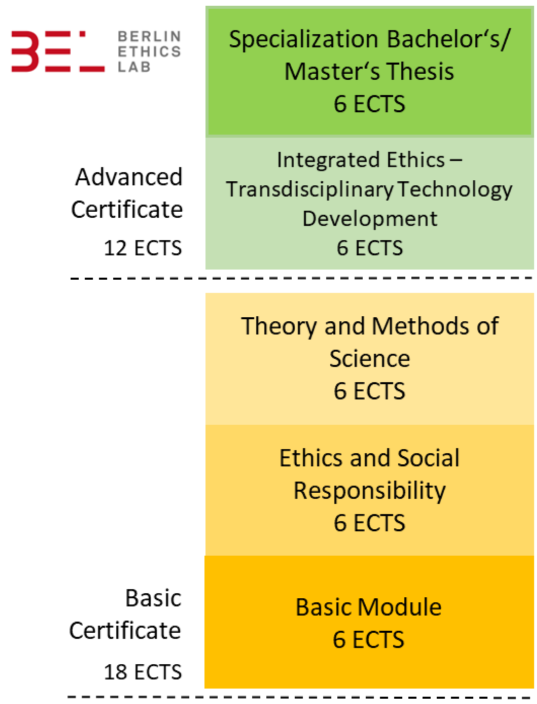

Fig.1 *Two-stage structure of the Berlin Ethics Certificate*

The BEC's two-stage structure enables the acquisition of a foundational *Basic Certificate* and optional supplementary *Advanced Certificate*, whereby required credit points can be distributed over bachelor and master's degree programs and completed within the standard period of study [Fig. 1]. The qualification can be acquired via compulsory or elective courses, which upon completion are accredited within BEC "container modules". Corresponding courses are accredited based on their thematic and credit point conformity to BEC container modules and are primarily drawn from the existing rich curriculum of TU Berlin. In addition, supplementary interdisciplinary courses have been created, including a compulsory *Basic Module* for all participants of the BEC, which lays the groundwork for ethical reflection on a personal level as well as for interdisciplinary cooperation.

3 INTERDISCIPLINARITY AS A BUILDING BLOCK FOR ETHICS EDUCATION

Although the question of how interdisciplinarity can contribute to ethics education is not new [6][7] and there is wide agreement that interdisciplinary collaboration is necessary for addressing real-world problems [8], there exist few examples of best practices. Before we explain in more detail how the BEC employs interdisciplinarity as a core building block, we want to outline the BEC's conceptualization of interdisciplinarity. This is important as concepts of interdisciplinarity in academic teaching and research vary due to a multitude of approaches, and reaching a uniform general definition seems difficult [9]. A common delineation, however, distinguishes interdisciplinarity as a form of synergistic interaction between disciplines rather than a mere combination of disciplines as in the case of multidisciplinarity [7]. In the field of possible interaction between different disciplines, a rough distinction can be made between multi-, inter-, and transdisciplinarity. While these three kinds of interaction share the aspect of bringing together different forms of (disciplinary) knowledge, they differ in terms of how actors are involved in interactive processes and in which ways various forms of knowledge interact to respond to different problems.

3.1 The Berlin Ethics Certificate's conceptualization of interdisciplinarity

The BEC understands interdisciplinarity as a temporary, collaborative process of knowledge production, where diverse epistemic actors with different disciplinary backgrounds come together in a common working environment by collaborating on project-based work. By bringing in their different expertise, namely their prior knowledge and disciplinary methods, actors enter a joint epistemic process, which unfolds in a milieu of reflection—a joint arena of thinking and reasoning [10]. A successful interdisciplinary process leads to an epistemic ascent (in the form of new knowledge or insights) through knowledge generation by knowledge integration. This contrasts with multidisciplinarity, where no integration of knowledge takes place, and transdisciplinarity, where non-academic actors enter the joint process of knowledge production.

From an epistemological point of view, interdisciplinary knowledge production can be characterized by how the various actors are involved in the joint epistemic process of project work. Firstly, actors have only partial (disciplinary and non-disciplinary) knowledge and are ignorant in other domains relevant to the joint project and must therefore develop strategies to deal with limited knowledge as well as known and unknown unknowns (given their epistemic perspective). Secondly, epistemic actors must integrate bodies of knowledge from other disciplines into their own knowledge horizon and must therefore develop strategies to deal competently with knowledge without understanding it in depth. Thirdly, none of the epistemic actors involved in the process have total knowledge in the sense of being able to fully understand the initial knowledge basis of the project (such as initial assumptions or methods) as well as the emerging knowledge. Therefore, new strategies for collaborative testing and validation of emerging knowledge are needed.

Interdisciplinary collaboration places high demands on the design of the resulting milieu of reflection (based on the framework design and process design of the project) as well as on the persons participating in the joint process. As epistemic actors they must bring specific competencies and epistemic values including humility in recognition of the knowledge of others. This recognition of other modes of knowledge production presupposes a recognition of one's own epistemic boundaries, which is based on honest and clear communication of the limits of one's disciplinary knowledge, methods, and worldview (e.g. "here I am stuck", "here I am uncertain", "here I need help", "here I made a mistake"). Curiosity and openness towards other points of view and towards unknowns as well as an eagerness to learning from others are crucial for interdisciplinary collaboration. This, in turn, presupposes an agility to taking another perspective and a readiness for change. Furthermore, trust is necessary to rely epistemically on the expertise of others in areas where one might have none. Lastly, the willingness to share (knowledge, methods, failures) and ability to actively listen are also vital to the epistemic success of the joint process.

3.2 These demands clearly show that interdisciplinary collaboration does not come without the effort of those involved. To make this kind of project-based collaboration work successful and satisfying, specific education of the persons involved is needed. In addition, the process design should aim at targeted interventions to raise awareness and sensitivity towards

the above-mentioned prerequisites. Finally, of equal importance is the framework design, which implements a culture of interaction. Essential here is the fostering of values which trigger a positive and stimulating mutual learning environment, such as social and moral (non-epistemic) ones. Specifically, an interdisciplinary learning environment should foster treatment with dignity over disrespect; empowerment rather than intimidation; encouragement rather than discouragement; independence and personal responsibility instead of overdependence; recognition of differences instead of discrimination; and allowing for learning from mistakes instead of (public) shaming. Practices of situating knowledge

As the BEC's conceptualization of interdisciplinarity shows, a high degree of reflexivity on the part of all actors involved is required. Thus, to provide the foundation for interdisciplinary collaboration, BEC draws on epistemic practices of situating knowledge in multidisciplinary learning environments. Our approach is inspired by Donna Haraway's concept of *situated knowledge* [11], which expresses the fundamental conditionality of all scientific knowledge, by highlighting the social location of the researcher and the historical, political, and disciplinary constraints that condition the production of knowledge. Situated knowledges serve to create "a more adequate, richer, better account of a world, in order to live in it well and in critical, reflexive relation to our own as well as others' practices of domination and the unequal parts of privilege and oppression that make up all positions" (p. 579). Through learning that knowledge is always situated, students are prepared to engage in inter- and transdisciplinary collaboration to address ethical issues. Educational approaches of the BEC allow students to situate their knowledge in four respects, which exist in an iterative process and do not correspond to an explicit order.

Firstly, one's own disciplinary knowledge is situated within a broader academic knowledge framework. Students get an understanding of the scope and limitations of their respective disciplinary methods by being exposed to differing approaches. Examining the similarities and differences of their own disciplinary approach relative to others allows them to become aware of their epistemic blind spots and "disciplinary goggles", which frame how they address the world.

Secondly, one's own disciplinary knowledge is situated within one's broader non-academic knowledge stemming from their life experiences. Rather than leaving their life experiences "at the door" and engaging with topics on a purely intellectual or abstract basis, students are encouraged to understand their academic practice through the lens of their own personal and non-academic experiences.

Thirdly, one's own disciplinary knowledge is situated within one's personal values and moral intuitions. Students are encouraged to see their emotions, values, customs and background as a resource for collaborative practices. The emphasis on a holistic perspective on the self enables students to carry ethical reflection taught inside the classroom beyond their academic experience.

Lastly, one's own disciplinary knowledge is situated with respect to one's social positioning as means of gaining a reflexive awareness of power relations and their ethical consequences in process of knowledge production. In this sense ethics is approached from perspectives that account for the actual non-ideal conditions that inform our realities, including those of oppression and difference. Such a critical theory-informed approach to ethics is not only concerned with analyzing the impact of emerging technologies on society, but also affecting change.

Through these practices of situating knowledge, students explore resonance and reciprocity at the intersections of their knowledge opening up new lines of affinity and common ground while allowing for epistemic pluralism. In addition, community building, as a key aspect of the BEC program, is achieved by students gaining an awareness of the interdependencies amongst each other and their environment and developing a sense of collective responsibility for improving societal conditions. Situating knowledge in such a way prepares the ground for an interdisciplinary reflection of ethical issues in order to generate socially responsible and epistemically robust knowledge.

3.3 Interdisciplinarity for socially responsible and epistemically robust knowledge

Based on the practice of situating knowledge, the BEC employs interdisciplinarity as a core building block for integrated ethics education. Social and ethical responsibility and technology reflection are taught in interdisciplinary learning environments whereby students from engineering, science, the humanities and social science work together on common projects. Thereby, the BEC's ethics education goes beyond merely "ethics for engineers" so that ethical questions and problem framings can be sought simultaneously from many disciplinary perspectives. We concur that practicing ethics can be seen as "an inherently interdisciplinary endeavor" [6] (p. 259), ethical problems in society are multifaceted and arise from the intersection of different knowledge domains. Students of the BEC experience how knowledge is generated mutually through a guided collaboration of their respective disciplines, practices of disagreement and compromise, and exploring alternative perspectives. By this, interdisciplinary collaboration contributes to the generation of socially responsible and epistemically robust knowledge, with the aim of directing scientific and technological processes towards beneficial outcomes for society and the environment, as emphasised in approaches of technology assessment (TA) and responsible research and innovation (RRI) [12][13]. Accordingly, robust knowledge is crucial for effectively addressing the complex problems of the 21st century, including in the context of emerging technologies, which can no longer be adequately addressed by isolated disciplines. Robust knowledge stems from epistemic processes which bring together a multiplicity of disciplinary and societal perspectives, across many time scales and spatial contexts. Crucially, robust knowledge is not only about integrating diverse disciplinary knowledge, but also considering the social positions and power relations of the actors involved or affected, along with their diverse values and experiences, with the goal of protecting and promoting human emancipation in the scientific process. In the following, we show how the BEC enables students from different disciplines to come together in an interdisciplinary learning environment, thereby demonstrating the BEC's approach to integrated ethics.

4 HOW INTERDISCIPLINARITY IS TURNED INTO A TEACHING CONCEPT: EXAMPLES FROM THE BERLIN ETHICS CERTIFICATE

The BEC implements integrated ethics education through three iterative steps: 1) situating disciplinary knowledge in relation to other forms of knowledge, values and experiences (by focusing on multidisciplinary learning experiences), 2) establishing a common epistemic practice of collaboration (by focusing on interdisciplinary learning experiences), and 3) actively engaging with non-academic stakeholders to create responsible technology and take ethical action beyond the university (by focusing on transdisciplinary learning experiences).

As mentioned in section 2, the BEC qualifications can be acquired via compulsory or elective courses that are open to all students of TU Berlin and can be accredited upon completion within the BEC modules. Corresponding courses are accredited based on their thematic and credit point conformity to the BEC modules. Due to the character of the interdisciplinary "container modules", the BEC allows students a high degree of freedom in the choice of course content. At the same time, the structure of the certificate (basic and advanced) reflects the close connection between ethics, epistemology and inter- and transdisciplinarity, as conceptualized by the BEC.

The BEC's mandatory module, "Reflection and Responsibility — Basic Module," lays the foundation for ethical reflection at the personal level through multidisciplinary learning experiences which focus on situating knowledge. The overall structure of this module includes a total of five workshops (corresponding to themes of responsibility, ethics, philosophy of science, inter- and transdisciplinarity), which provide the thematic and methodological foundation for all other modules (i.e. "Ethics and Social Responsibility", "Theory and Methods of Science", "Integrated Ethics — Transdisciplinary Technology Development") of the BEC [Fig. 1]. Drawing on their own disciplinary as well as everyday experiences, students learn to situate their knowledge within a multidisciplinary learning environment. For example, in the philosophy of science workshop, students are grouped by discipline and explore the epistemic possibilities and boundaries of their own disciplinary methods in relation to those of other disciplines. Over the course of the module, students are tasked with developing an ethical question on a self-elected topic, where the idea is that they reflect their own knowledge, values and experiences to critically engage with a relevant societal issue. Through the method of situating knowledge, the module ultimately teaches the relevance of individual and collective responsibility to epistemology, and interdisciplinarity to ethical reflection on real-world problems.

The course "Ethical and Social Challenges of Emerging Technologies: Automation, Robotics, AI" — which can be accredited under the container module "Ethics and

Social Responsibility" — serves as an example of an interdisciplinary learning experience. In interdisciplinary teams, students develop in-depth proposals for responsible technology design by establishing a common epistemic practice which progresses in a milieu of reflection. The selection of their own case study gives students the opportunity to seek personally and ethically relevant connections between technology, science, environment, society and each other. This bottom-up approach also allows students to think beyond mere technological problem solving and tech-solutionism by assessing technology in a wider socio-technical framework. Interdisciplinary methods are developed in joint workshops on systems thinking and framework analysis, value assessment, and critical design thinking. Ethics thereby is not taught as mere theory ready to be applied, but is actively experienced as an interdisciplinary epistemic practice, one that is tangible and practicable through project-based learning.

Finally, the BEC specialization module "Integrated Ethics — Transdisciplinary Technology Development", which is still under planning, aims at transdisciplinary learning by addressing real-world problems through action-oriented engagement with stakeholders. By exploring ethical questions in a practical project, students learn methods of participatory technology design and integrated technology assessment. They experience directly that technological futures can be shaped in cooperation with societal actors towards mutually desirable outcomes.

Based on the epistemic practice of situating knowledge, participating in the BEC enables students to trace a process from reflection to action, that is, to engage in processes of ethical reflection within multi-, inter- and transdisciplinary learning experiences, thereby making knowledge production more reflexive, responsible and robust.

4 SUMMARY AND ACKNOWLEDGMENTS

While there is a growing call to integrate ethics across engineering curricula and broaden ethical reflection beyond individual compliance, there is no standard curriculum or agreed upon methodology of how to do so. The Berlin Ethics Certificate presents a novel curriculum structure and epistemological approach for integrated ethics, which employs interdisciplinarity as a core driver of ethical reflection.

In this paper, we have argued that crucial to the integration of ethical reflection into science and technology education is the conceptualization of interdisciplinarity as an epistemic practice, which draws on situating knowledge. The epistemic practices of situating knowledge address the call for ethics education to be more emotionally engaging, critically reflective, grounded in real-life experience, and responsive to the complexity and inherent interdisciplinary nature of real-world problems. Situating one's disciplinary knowledge in relation to other disciplines, as well as one's personal experiences, values, and social positioning, allows one to engage in interdisciplinary joint reflection. In this joint process of interdisciplinary collaboration, new knowledge is generated by the integration of partial perspectives and the common search for novel methodologies to test and validate emerging knowledge. Through the BEC's approach to ethics, which upholds the necessity of robust knowledge stemming from a diversity of standpoints, interdisciplinary collaboration is oriented toward taking ethical action. In this sense, students learn to associate ethics with broader societal engagement rather than the simple prevention of scientific misconduct. Through the BEC's emphasis on community building, the shared practice of ethics not only fosters mutual understanding in the disciplinary sense but also allows for students to experience collective responsibility for the future.

Beyond its theoretical contribution of understanding interdisciplinarity as an epistemic practice based on situating knowledge, this paper has outlined a new structural approach for integrating ethics across the curriculum. Rather than teaching "ethics for engineers", the BEC's structure allows for ethical problem framings to be investigated simultaneously by students from a range of disciplinary backgrounds. We have outlined several concrete examples and courses, which may serve as examples of best practice for interdisciplinary and integrated ethics education. Only when ethical reflection becomes integrated into the education of students dealing with science and technology, can we begin to address the complexity of the societal challenges we face.

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IMPLEMENTING AGILE CONTINUOUS EDUCATION (ACE) AT MIT AND BEYOND: THE MIT REFUGEE ACTION HUB (REACT) CASE

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ABSTRACT

The rapid pace of change in technology, business models, and work practices is causing ever-increasing strain on the global workforce. Companies in every industry need to train professionals with updated skill-sets in a rapid and continuous manner. However, traditional educational models — university classes and in-person degrees— are increasingly incompatible with the needs of professionals, the market, and society as a whole. New models of education require more flexible, granular and affordable alternatives. MIT is currently developing a new educational framework called Agile Continuous Education (ACE). ACE describes workforce level education offered in a flexible, cost-effective and time-efficient manner by combining individual, group, and real-life mentored learning through multiple traditional and emerging learning modalities.

This paper introduces the ACE framework along with its different learning approaches and modalities (e.g. asynchronous and synchronous online courses, virtual synchronous bootcamps, and real-life mentored apprenticeships and internships) and presents the MIT Refugee Action Hub (ReACT) as an illustrative example. MIT ReACT is an institute-wide effort to develop global education programs for underserved communities, including refugees, displaced persons, migrants and economically disadvantaged populations, with the goal of promoting the learner's social integration and formal inclusion into the job market. MIT ReACT's core programs are the Certificate in Computer and Data Science (CDS) and the MicroMasters in Data, Economics and Development Policy, which consist of a combination of online courses, bootcamps, and global apprenticeships. Currently, MIT ReACT has regional presence in the Middle East and North Africa, East Africa, South America, Asia, Europe and North America.

1 INTRODUCTION

Emerging global challenges are adding to already intensifying demands for national and international competitiveness, and across the world many point to the urgent need to speed up innovation and modernize organizations [1]. STEM is a key pillar in the modern innovation-based economy, though by no means the only [2]. Rapid innovation requires an innovative workforce, and yet there is a global shortage of skilled workers [3] in the STEM field and beyond. All this while thousands of already highly skilled professionals get forcibly displaced every year, without knowing a formal carefully designed mechanism to support them in being able to demonstrate their skills, continuing their education, and actively getting back to work.

Traditionally the main avenue towards expertise building has been graduate-level programs. These are usually based on traditional practices – classes and in-person degrees, for example – which are increasingly incompatible with the learner, societal, and market needs. They are monolithic and often inconvenient for full-time employees balancing personal, professional, and financial obligations.

As companies in every industry feel the need to train professionals with updated skill-sets in a rapid and continuous manner, the industry is working on adjusting their corporate training programs to meet current market needs, including university-industry collaborations [4,5]. However, the vast majority of these programs are developed with the company's needs, rather than employees' professional goals, in mind. Furthermore, corporate training is an extremely heterogeneous field without clear quality standards, skills accreditation or standardized assessment.

Workforce education today needs a new model to complement traditional graduate education: one that is more agile, continuous, granular, incremental, convenient and affordable while still ensuring and assuring high quality. Additionally, this new agile model needs to be attuned to the needs of employers and learners, apply the latest developments from the science of learning, use modern educational technology and pedagogy, and present content in a fluid, flexible and digestible way to ensure student success. We introduce a model that we refer to as Agile Continuous Education (ACE), a philosophy and framework to standardize this new and emerging –though fluid– paradigm of upskilling.

1 THE ACE FRAMEWORK

The ACE framework that the Massachusetts Institute of Technology (MIT) is proposing focuses on providing education in a flexible, cost- and time-efficient manner by combining a broader range of modalities: online, on-site on campus, and at-work. As presented in Figure 1, the ACE framework is built on 3 pillars: *individual* learning, *group* learning, and *real-life mentored* learning. A complete learning path should include experiences combining all 3 modalities. As an example, based on current MIT offerings and opportunities, a learner can start with individual coursework online or in-person and build a digital academic portfolio of credentials at their own pace. However social aspects of learning are equally important, particularly considering that most workers will need to work in teams. For this reason, the second pillar of the framework is a group learning component. We cite the example of MIT Bootcamps, which are "guided hackathons" – intense, facilitated, hands-on, project-based, online or on-site activities – as an example of a group activity in which learners can firm up their skills in a team setting. Working with others has the additional benefit of identifying and rectifying possible blind spots from individual activities; coaching in MIT Bootcamps further brings about the exercise of deliberate practice [6]. The third pillar in the ACE framework, we argue, must be a mentored, real-life learning experience (e.g. through apprenticeships, or a collaborative university/industry project), where learners set specific skills development goals at the beginning of at-work engagements. This third phase, we argue, gives the learner the opportunity to apply their new skills and to firm them up in the context of the real world by participating in carefully structured and mentored experiences.

ACE provides new degrees of freedom to workforce learners by:

- Encouraging them to try new courses and content, and earn credentials along the way;
- Offering them the possibility to use credentials and to be subsequently accredited in a full-time academic program (e.g. the MIT Micromasters programs);
- Making content and certification available in smaller bite-sized chunks when and where it fits best to work and personal-life;
- Allowing them to customize their path based on personal preferences, rapidly-evolving industry needs, or personal future career goals;
- Allowing them to apply learned skills and knowledge in more rapid cycles (in a more agile way) in real-world projects;
- Enabling these benefits to be delivered in a more cost-efficient manner;
- Facilitating exposure to the real work environment so they better understand work and culture in potentially unfamiliar fields and roles; and
- Exposing them to career choices via smaller engagements designed for both learning and experience, allowing their career decisions to follow a discovery driven path. Learners are consequently equipped to make informed decisions about the role and industry that will best fit.

Fig. 1. The 3 pillars of ACE

The ACE framework combines known educational approaches that have been developed and tested at MIT and elsewhere; it does so in a way that systematizes what is otherwise unstructured, in keeping with the discipline of the three pillars we have described: *individual* learning, *group* learning, and *real-life mentored* learning.

To ensure speed and relevance in ACE delivery, we sought a use case that would put the ideas to the test amid an urgent need: the MIT Refugee Action Hub (ReACT). We present ReACT below as a "case study" to illustrate the potential for ACE to revolutionize lifelong learning.

2 MIT REFUGEE ACTION HUB (REACT)

The MIT Refugee Action Hub (ReACT) is an institute-wide effort to develop global education programs that target the needs of underserved communities, including refugees, displaced people, migrants and economically disadvantaged populations. MIT believes that education is a critical tool to help underserved learners achieve their personal and professional goals, by giving them a platform to recognize and leverage their talents, access a professional career, and create positive change in their lives and communities.

ReACT launched in May 2017 as a response to the MIT SOLVE call to find creative solutions to the problem of refugee education. It focused on the creation of a center at MIT to design and deploy new learning opportunities for displaced populations around the world. Driven by his own experience as a refugee, Prof Admir Masic has since led a collaborative effort with internal partners including MIT Bootcamps, MITx, MISTI, the MIT Enterprise Forum Pan-Arab Region, and external partners around the world to address the complex problems of this growing crisis and offer programs with the potential to change the narrative of the refugee experience.

With 79.5 million forcibly displaced people around the world, and only 3% of them able to access higher education, there has never been a greater need for the kind of globally focused educational innovation offered by MIT [7,8].

2.1 ReACT cohorts, learners and hubs

ReACT's global cohorts connect to a worldwide network of universities, nonprofits, organizations and companies committed to serving underserved communities and connecting them with relevant learning resources, professional development opportunities, and meaningful employment.

The first ReACT cohort was established in 2018 to support mostly Syrian refugees resettled in Jordan (the first ReACT hub) and refugees from Palestine and other nearby regions. Their learning path focused on skills development in computer programming, entrepreneurship and innovation, using curriculum drawn from MIT courses, MIT Bootcamp workshops and maker activities. After the two week in-person Immersion and Acceleration workshop, learners completed two MITx MOOCs on basic Python programming and computational thinking as well as a third elective course of their choosing. Since then two more cohorts have completed the Certificate in Computer and Data Science program, and a fourth one is currently undergoing activities. In all, 90 individuals have completed ReACT training, and 65% found employment in the field within 6 months.

Throughout these four cohorts, the ReACT learning path has evolved to better respond to the learners' professional, socio-academic and personal needs as well as external factors, including the COVID pandemic. COVID forced the ReACT programs to be completely virtual but created opportunities for the program to extend and accept more learners globally. From one hub in Jordan in 2018, ReACT programs currently take place in 6 different Hub locations, supporting learners from more than 29 countries. Table I presents a summary of the ReACT cohorts, its number of learners per cohort, their location and overall completion rates. The location of the currently active ReACT hubs all over the world is summarized in Fig. 2.

Table 1. Summary of ReACT cohort data (dates, learners, locations and completion rates)

Cohort number	Learning journey dates	Number of locations	Total # learners enrolled
1	May 2017- Oct 2017	1 (Jordan)	17
2	January 2018 - January 2019	1 (Jordan)	22
3	September 2020 - Sept 2021	3 (Jordan, Colombia, Uganda)	50
4	Jan 2022 - present (currently ongoing)	6 (Jordan, Colombia, Uganda, Uruguay, Afghanistan, Greece, USA)	136

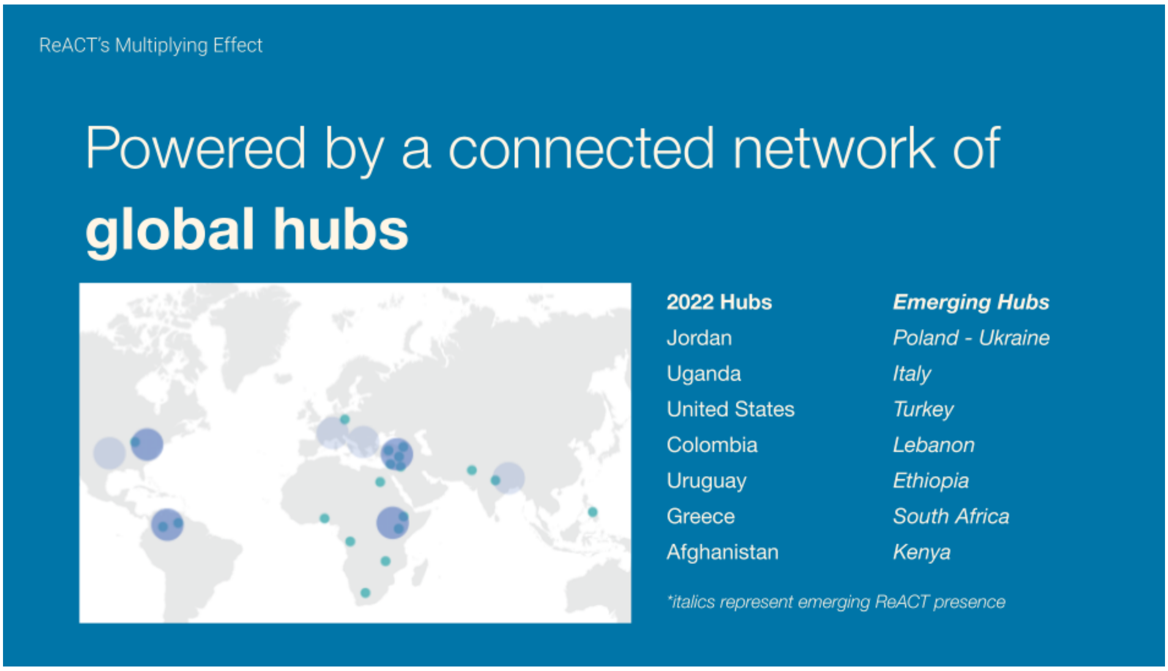

Fig. 2. Location of MIT ReACT hubs around the globe (updated April 2022)

2.2 Implementing ACE through the MIT ReACT Computer and Data Science (CDS) Certificate Program

ReACT's cornerstone program is its Certificate in Computer and Data Science (CDS), a yearlong online program in which participants hone the skills needed for success in the 21st-century economy. The CDS is a high-touch ACE program, consisting of online courses, bootcamps, and learning through internships. In CDS learners study computer programming and data analysis, while also focusing on cross-cultural collaborations and work readiness, innovation thinking and entrepreneurship.

The CDS learning journey is structured around the 3 main ACE pillars. As learners progress through the program, they advance capacities in academic and technical skills using *individual*, *group* and *real-life mentored* learning:

- *Individual* learning through online MIT courses in computer and data science,
- *Group* learning through participation in the MIT Innovation Leadership Bootcamp, synchronous online workshops focused on human skills development, peer communities through study groups supported by community Teaching Assistants and online social gatherings, and
- *Real-life mentored* learning supported by mentored activities that cover paid internships or mentored learning projects. Learners are also matched 1:1 with a mentor with professional experience in the tech sector.

Individual learning: Learners complete three online instructor-led asynchronous MITx courses in computational thinking, coding, programming using Python, and data science, as well as their choice of electives on the edX catalog to allow specialization in data science for healthcare or economic development policy.

Group learning: The cohort starts with an orientation workshop, where learners participate in visioning and goal-setting activities, strengthen their skills in virtual networking and interactive information and communication technologies, are exposed to opportunities to improve their English, and begin developing an online community.

ReACT partners with Na'amal, which aims "to pave a way for accessible remote employment for refugees and other vulnerable populations" [9] and leads several interactive workshops on planning, success in remote work, communication, data compliance and digital security, and self-management.
Current cohorts also participate in the intensive 10-week online MIT Innovation Leadership Bootcamp, where learners collaborate across cultures and time zones to build new entrepreneurial ventures. The ReACT cohort is integrated within the MIT Bootcamp's larger class of several hundreds of aspiring global entrepreneurs, creating opportunities for ReACT learners to be meaningfully immersed in wider networks while developing their leadership capacities.

Real-life mentored learning: ReACT develops computational thinkers ready to enter high-skill careers as full-stack engineers, software developers, business planning analysts, and data and information management at various companies. MIT ReACT staff connect learners to local and remote paid internships. Priority is given to high-skill, meaningful internships within the tech sector and with companies that indicate interest in hiring full-time after a successful internship. MIT uses its institutional networks through the MIT Alumni Association, the J-WEL, and MISTI program to connect ReACT learners with internship opportunities in locations where these refugees live. Alternatively, some learners are given the option to pursue real-life mentored learning completing specific projects either within their current place of employment or independently as individuals or small teams. These experiences are especially important for learners who do not have prior work experience but can use what they learn from ReACT to build Github or Linkedin portfolios or personal websites that showcase their job-ready skills.

Preliminary evaluation research on the implementation and efficiency of the React program is scheduled to begin in August 2022.

3 THE FUTURE OF ACE

Although MIT ACE developed this framework with existing MIT courses, programs, and learning experiences in mind, it is our aspiration that it will be adapted and used by other institutions as well, and possibly at different educational levels. To further shape and promote ACE authors would like to connect with professionals seeking to advance their knowledge and skills in the field of education; learning & development leaders at companies; education policy makers; MIT and other university scholars conducting research in ACE and ACE-like models; and those interested in the current development of education and its future. Together we are aiming to further explore:

- Efficient and scalable coaching and mentorship for learners as they are building their own learning pathways and progress toward career goals.
- Better practices to inform how “human skills” [10] such as critical, creative, and ethical thinking, could be best integrated in the content.
- How the global education community can guide the ACE framework standardization, including discussions about accreditation, digital credentials, unified transcripts, and record achievements.

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A UPC innovation teaching project for the incorporation of the gender perspective in nautical, marine and naval engineering

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ABSTRACT

There has been a rising awareness in recent years of the gender inequalities within STEM-related programmes and the need to overcome them and so bridge the gender gap in these academic disciplines. Different initiatives have arisen, among which there are gender equality policies, regulations and programmes. In line with this, the Catalan University Quality Assurance Agency (AQU) promoted a regulation for the incorporation of the gender perspective in all the bachelor's and master's degrees in tertiary education in Catalonia by 2021. To comply with this regulation and also to promote a culture of equity and equality of opportunities for women, the Universitat Politècnica de Catalunya (UPC) fostered different projects within its community. One of these projects has been developed by the Gender Equality Commission at Barcelona School of Nautical Studies and consists in the development of a web platform with resources for lecturers to incorporate this new transversal competence of gender perspective in the nautical, marine and naval engineering study plans. The main objective of this teaching innovation project is to aid teachers with the incorporation of this competence not only by providing online tools and resources but also gender-focused teacher training to allow them to design tailor-made activities and strategies. Some tests were also administered to assess the effectiveness of the implementation of these newly-designed gender equality teaching practices and some sample study plans and activities were developed to serve as a model and example of good practices for the incorporation of gender mainstreaming in the disciplines of nautical, marine and naval engineering.

1 INTRODUCTION

1.1 Framework

In order to promote gender mainstreaming in all Catalan Universities, the Catalan University Quality Assurance Agency (AQU) published in 2018 the General Framework for the incorporation of the gender perspective in university teaching [1], following the Resolution 693 / XII of the Official Gazette of the Parliament of Catalonia (BOPC number 505, of 9 January 2020) [2] on the recognition and guarantee of women's rights. To foster a culture of equity and equality of opportunities for women at the Universitat Politècnica de Catalunya (UPC), and also to comply with these recommendations, the Governing Council of the UPC, which establishes the University's strategic and programmatic lines, approved on 1 April 2020 the incorporation of the new transversal competence on gender perspective (Agreement CG / 2020/02/13) [3]. According to point 2 of this UPC Governing Council Agreement, "All bachelor's and master's degrees taught at the UPC must gradually incorporate the new competence on gender perspective."

The Commission for Gender Equality of the Barcelona School of Nautical Studies was created to promote actions and address issues aimed at ensuring and achieving gender equality within the school community. In accordance with this, and in order to assume the mandate of the Governing Council of the UPC for the incorporation of the new competence of gender perspective in teaching, the commission, constituted as a work group, presented the proposal for an innovation teaching project for the development of a web platform with resources for the incorporation of the gender perspective in the Nautical, Marine and Naval engineering bachelor and master's degrees. This proposal was approved in July 2021 and developed during the academic year 2021-2022.

1.2 Objectives

The incorporation of gender mainstreaming in education improves the quality of instruction and the social relevance of the contents taught while avoiding partial and androcentric interpretations of society and knowledge. Gender-sensitive teaching also encourages students' critical thinking capacity and provides them with tools to identify gender bias, stereotypes and roles. All this gender awareness is essential to cater for diverse roles and needs and to avoid gender blindness not only in university teaching but also in students' future careers, which may aid with the transformation of present unequal gender relations [4]. This is one of the reasons why gender mainstreaming in education is promoted by national and international institutions and organisations, as a strategy towards combating discrimination and realising gender equality.

In keeping with this, the main goal of the innovation project presented here was to provide resources to teachers for the progressive incorporation of the gender perspective in the curricula of all the studies of the Barcelona School of Nautical Studies. This main goal fostered different types of actions to encourage teaching staff participation in addressing gender equality issues in teaching, such as specific teacher training to empower them with respect to the implementation of this new gender perspective. The final aim was to provide training and resources on gender-sensitive pedagogies and innovative teaching methodologies that reduce inequalities, biases and stereotypes. This way we may also address the current gender gap in nautical, marine and naval engineering studies, which the 2021-2022 academic year only recorded 16.9% of female students enrolled according to the Planification, Evaluation and Quality Office (GPAC[1]) data.

2 METHODOLOGY

According to AQU [1], "when applied to teaching, the gender perspective implies a process of reflection which affects the design of the competences and skills in the programme's curriculum, the design of courses, including learning outcomes, the content taught, examples provided, the language used, the sources selected, the method of assessment and the way in which the learning environment is managed. To ensure the successful mainstreaming of the gender perspective, teaching staff need to acquire this skill through the training provided by universities' teaching innovation

[1] GPAC: Gabinet de Planificació, Avaluació i Qualitat

units and the specific courses organised by gender equality units and observatories." In consonance with this, the innovation project attempted to aid teachers to assess gender inequality, transform their curricula, develop sex- and gender-sensitive content, include more gender-balanced references, foster a more inclusive learning environment and apply gender-sensitive teaching methods and assessment.

2.1 Project areas

In order to design solutions that could help teachers assess inequality and develop the necessary abilities to transform their curricula, course contents and teaching methods, along the lines of the definition above, the innovation project provided different types of resources and training, which were organised around the five main areas described below:

AREA 1. Development of gender-sensitive curricula

This area contemplates the development of gender-sensitive curricula incorporating the gender perspective at different levels, namely, in terms of inclusive vocabulary, gender-sensitive goals and content, gender-balanced references and inclusive evaluation activities. Teaching content should be inclusive, avoid gender bias and stereotypes, and incorporate female references as role models for students. On the other hand, including women in the bibliographic references with their full name would also help to give female researchers more visibility. Finally, it has been demonstrated that the different types of exam questions and teacher's performance may also affect students' answers according to gender, which should also be taken into consideration.

AREA 2. Guide of resources and good teaching practices to promote gender equality

The guide of resources and good teaching practices should be used as a tool to promote the incorporation of the gender perspective in teaching not only in terms of content and assessment but also in terms of teaching methodology and classroom management. The teaching methodology should take into account the different learning styles and allow students to reflect on social issues relative to gender equality. Classroom management should consider assigning roles in classroom interaction so as not to fall into gender biases, offer a balanced participation, and a variety of experiences that address diverse gender needs.

AREA 3. Teacher training on gender and feminist pedagogies

The two areas above in isolation would not prove effective if they do not go hand in hand with some gender-specific teacher training. Therefore, to help and empower teachers with tools to effectively incorporate the gender perspective in their teaching, training courses and seminars were held to cover and address all the issues described in areas 1 and 2.

AREA 4. Development of diagnostic tools

In order to assess teacher performance and the general sensitivity of the different community groups towards gender equality, different diagnostic tools were developed and incorporated in the platform to diagnose the degree of gender-sensitivity of the school and management, teaching materials, teaching and administrative staff and students. These tools, generally with a survey or checklist format, were designed to assess the extent to which gender mainstreaming is supported and promoted by the school, the community and the curricula with the aim to provide suggestions and encourage community members to progress in this journey.

AREA 5. Dissemination of the project

The work carried out during the project has been disseminated both internally, within the university, and externally, in conferences and journals, with other practitioners within and outside the discipline so as to share some insights on issues relative to the incorporation of the gender perspective in university teaching.

2.2 Teacher training

As it is essential to train students to work on projects, assignments, bachelor's or master's degree projects with a gender perspective, it becomes equally essential to train teaching staff to help them in this endeavour. Departing from the premise that all courses can mainstream gender, teachers need to be provided with the necessary tools and knowledge to incorporate the gender perspective effectively in their teaching. In order to acquire this required knowledge, practitioners should be encouraged to participate in training courses so that they can identify aspects that can be improved or reinforced and so transform their curricula and develop gender-sensitive teaching methodologies and materials accordingly.

The teacher training course on gender mainstreaming was based on the framework of feminist theory and, more specifically, feminist pedagogy, which according to Crabtree, Sapp and Licona (2009 p.4), can be defined as follows: "Feminist pedagogy is a set of assumptions about knowledge and knowing, approaches to content across the disciplines, teaching objectives and strategies, classroom practices, and instructional relationships that are grounded in critical pedagogical and feminist theory. It is an ideology of teaching inasmuch as it is a framework for developing particular strategies and methods of teaching in the service of particular objectives for learning outcomes and social change."[5] Thus, the incorporation of feminist pedagogy in teaching is more a way or rethinking teaching and learning than a methodological perspective [6]. In an attempt to simplify and choose some fundamentals of feminist pedagogy applicable to our teaching context, which undoubtedly falls into an oversimplification, the following were selected to be implemented in the development of the course activities:

- reorganising the relationship between students and teachers to break with the traditional hierarchy in the classroom and question the traditional structural assignment of the principle of authority from a critical perspective.
- creating a shared and collaborative learning environment where students' experiences and knowledge are valued, thus empowering students based on the recognition of their knowledge.

- respecting different identities, rhythms and learning processes.
- developing pedagogical proposals that gather this diversity of knowledge and break with the idea of single, absolute and reductionist thinking.
- transforming learning to allow students *and* teachers not only acquire new knowledge but to shift their thinking in new directions so that their personal interpretations of experience and knowledge can be re-read in new, critical ways.
- creating a safe space in the classroom that tries to overcome prejudices, stereotypes and discrimination, thus enhancing the sense of community.

In keeping with this philosophy, the innovation project described here incorporated some gender-specific training for the teachers of Barcelona School of Nautical Studies. Fifteen teachers participated in a specially-designed course to learn about gender-sensitive pedagogies and innovative teaching methodologies to transform their curricula. The course consisted of three theoretical sessions followed by some individual guided work and two final sessions to discuss with the whole group the activities developed. The feedback received in these final sessions served to refine the activities and a final version of the valuable materials produced was included in a repository on the project platform to be used as a guide and example for other teachers.

3 PROJECT OUTCOMES

3.1 Web Platform

The main outcome of the project was the development of a web platform with resources for the incorporation of gender mainstreaming in the discipline of nautical, marine and naval engineering, encompassing the five project areas described in section 2.1. This platform constitutes a flexible tool to generate a comprehensive and dynamic virtual learning environment, which allows interaction between users to share experiences and knowledge. This platform, which is linked to the Barcelona School of Nautical Studies website, has three major sections, as illustrated in Figure 1:

- Section 1. Gender equality observatory
- Section 2. General resources on gender equality
- Section 3. Resources for the incorporation of gender mainstreaming in teaching and research

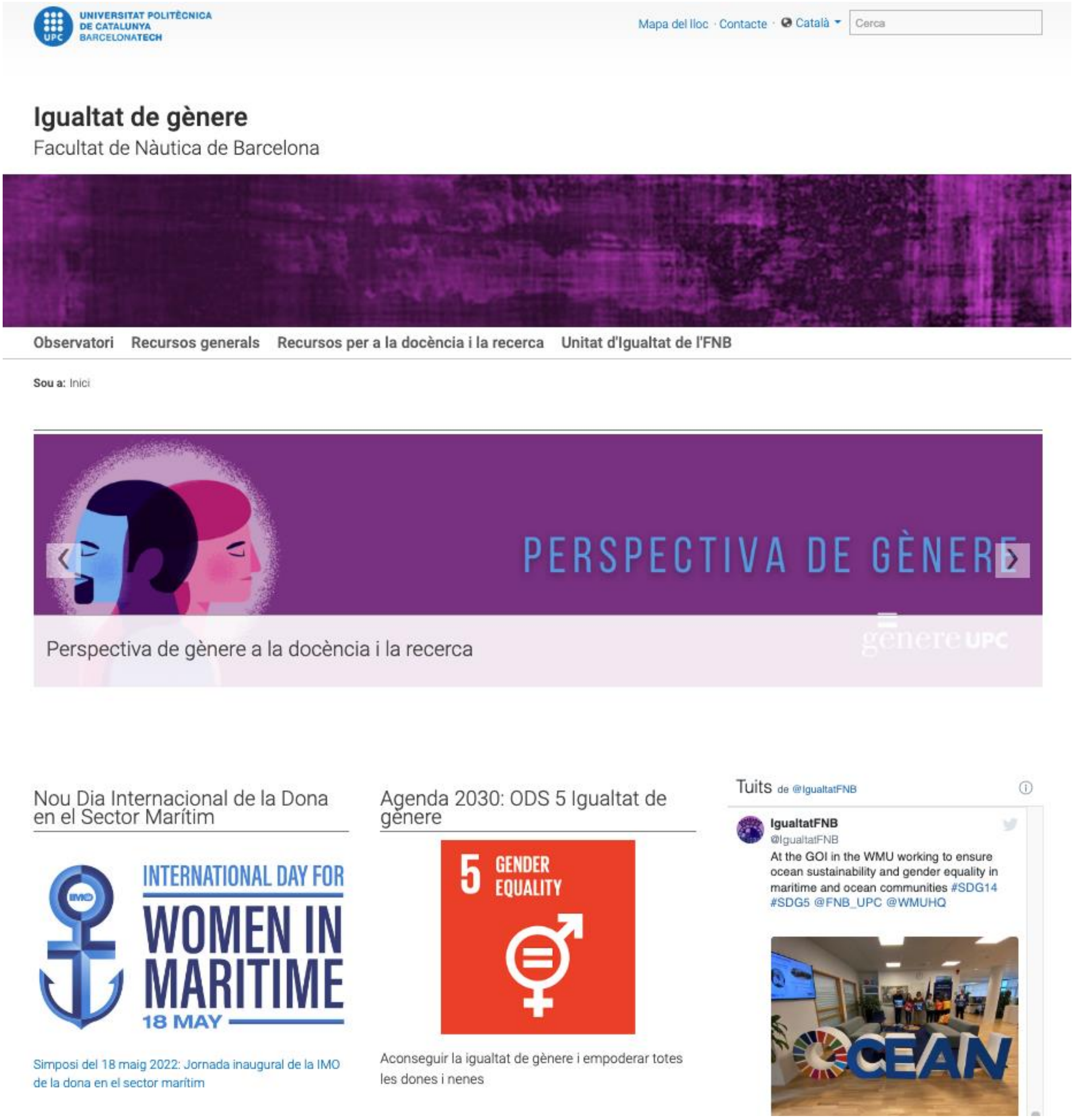

Fig. 1. Web platform homepage

All the resources provided in the different sections are specifically addressed to students, teaching and administrative staff of the discipline of nautical, marine and naval engineering. Below is a description of the resources available in each section:

Section 1. Gender equality observatory

This section includes gender-disaggregated data and statistics to allow the community learn about the reality of the maritime sector and studies. In addition, different diagnostic tools have been incorporated to determine the extent to which gender mainstreaming is supported and promoted by the school and its programmes, and the teaching staff. Also, the degree of gender-sensitivity of the different groups of the community is gathered and analysed with the aim to detect gaps, deviations and difficulties and so identify the aspects that can be improved or reinforced.

Section 2. General resources on gender equality

The resources in this section are divided into two main groups. The first group includes some basic gender literacy to learn about the different key concepts associated with gender and guides on the use of a gender inclusive language. The second group contains resources on gender equality for the maritime community such as programs, organisations and associations involved in promoting equality in the sector.

Section 3. Resources for the incorporation of gender mainstreaming in teaching and research

This third section includes resources for the incorporation of gender mainstreaming in university education and research with a special emphasis on the maritime field. The resources in this section are mainly addressed to teachers and researchers and consist of relevant bibliography, guides and specific practical resources for classroom use. A valuable collection of resources in this section is the repository of gender-sensitive syllabus proposals generated in the teacher training course as explained in section 3.2. below.

3.2 Repository of gender-sensitive curricula

The gender-specific teacher training course offered to the teachers of Barcelona School of Nautical Studies served not only to empower teachers with the necessary tools to effectively incorporate the gender perspective in their teaching, but also to generate a repository of gender-sensitive curricula to be used as guide of good teaching practices by other teachers. The activities developed involved transforming the existing course syllabuses with respect to objectives, content, assessment, methodology and references. To develop the activity teachers could focus on one or several of these aspects depending on their needs and interests. The result was a collection of syllabus proposals with an enhanced gender mainstreaming approach. This was an important output of the project in itself as it allowed teachers to reflect on different questions relative to gender pedagogies, confront the challenge of resisting a single, dominant, institutionalised narrative and look for and find ways to transform their teaching and study plans. The proposals stemming from the course were incorporated in section 3 of the platform.

4 SUMMARY

This innovation teaching project constitutes a step forward towards the incorporation of gender mainstreaming in the disciplines of nautical, marine and naval engineering. The resources and tools incorporated in the web platform developed may serve to enhance curricular design and content, learning outcomes, teaching and assessment methods and consider student diversity. At the same time, these resources may prove useful to detect and avoid gender blindness, bias and stereotypes in teaching and so avoid the production of future professional outputs and projects based on androcentric patterns. Finally, the participation of teaching staff in the project has been key to empower them with the tools and knowledge to incorporate the gender perspective effectively in their teaching while becoming a valuable asset to develop gender-sensitive materials.

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AN ONGOING SPATIAL INTERVENTION PROJECT IN IRISH SECONDARY SCHOOLS FOR IMPROVED ENGINEERING EDUCATION

RESEARCH PAPER

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ABSTRACT

Spatial skills have been shown to strongly predict STEM attainment and can therefore be a determining factor in choosing to pursue high-paying engineering careers. This strong reliance on them particularly limits students with low spatial skills – a group over-represented by girls and students of low socioeconomic status. It has also been demonstrated that spatial training leads to meaningful improvements in skill development. In Ireland, as in most countries, spatial thinking is not explicitly taught at the pre-college level, even though it could influence students' eventual career paths. Currently, only a person's previous experiences outside the classroom influence skill development. In order to increase the number of students who select engineering and other STEM occupations as a career path, an explicit emphasis on training spatial thinking is likely to be very beneficial in pre-college education. An established spatial intervention course was selected for delivery to secondary schools in Ireland. Through training and ongoing support, teachers' spatial skills, and pedagogical content knowledge for spatial thinking are being developed to be shared with their students, leading to an increase in students' spatial skill level and future employment opportunities.

1 SPATIAL SKILLS

Spatial skills can be defined as spatial visualization, which includes the ability to imagine and mentally transform spatial information [3]. Wai, Lubinski, and Benbow [9] examined the importance of mathematical, verbal, and spatial skills in high school students using measures of spatial visualization and how they affected their later career choice and success in STEM fields. They analyzed the data from Project TALENT, which included students' assessments of cognitive skills (mathematical, verbal, and spatial skills) from the 9th until the 12th grade. The sample included approximately 50,000 males and 50,000 females per grade level. After 11 years, they gathered follow-up data and found that most STEM graduates came from the group of students whose spatial skills were highly developed at age 13. This skill has shown to be the best indicator for future STEM success (especially for engineering) – even more so than the level of mathematical and verbal development.

1.1 Spatial Intervention

Findings from large-scale studies such as Project TALENT highlight the need to investigate the extent to which spatial skills training can facilitate improvements in performance in a range of STEM tasks. Motivated to explore the connection between spatial skills and success in engineering majors, Sorby and Baartmans [8] developed a spatial visualization course for first-year engineering students, which emphasized sketching and interacting with 3D models of geometric forms. Their data showed the course developed students' spatial skills, which were correlated with improved performance in graphics courses and an increase in the engineering major's retention rate (especially for female students) [8]. These very encouraging results led to another three-year study conducted with middle school students which showed that students who took part in the training significantly improved their spatial skills compared to those who did not [7].

Spatial skills are a primary factor of intelligence that is viewed as a combination of several separately measurable subfactors. Some of these, mental rotation in particular, typically reveals gender differences in favor of males. Since mental rotation and related factors are so highly correlated with performance in many STEM tasks and girls are often under-represented in STEM courses, improving spatial skills might play a significant role in reducing this gap in representation. One interesting result that emerged from the middle school intervention study was that female participants who improved their spatial skills through the training subsequently enrolled in more math and science courses than girls in a similarly identified comparison group [7]. This could suggest that the training reduced their spatial and math anxiety levels. A study from 2019 [8] demonstrated that spatial anxiety relates to spatial strategy avoidance in solving mathematical problems which negatively influences math success, math anxiety and math avoidance. There is also some evidence that girls who perform lower in maths may be at higher risk for developing math anxiety than are similarly performing boys [1]. Therefore, systematic development of spatial skills in the education system is needed and can be successfully implemented with middle school students where it still influences their choice of high school subjects and future career opportunities.

1.2 Rationale for the Study in the Irish Context

Results from a recent national study in Ireland [5] highlight the underdevelopment of spatial skills in grade 7, which is the 1st year of post-primary students, and that a relatively small gap in spatial skills in favor of males exists at this stage but grows quite significantly over the subsequent years in the second level through to grade 12. Also, the Irish STEM Education Policy Statement 2017–2026 emphasized the necessity to ensure that students' learning in STEM disciplines significantly improves and that more young people (especially females) choose and sustain their involvement in STEM education. To accomplish this goal, continuous efforts in initial Teacher Education and teachers' ongoing professional development (PD) are needed [2]. Since the Developing Spatial Thinking course yielded positive effects on middle school students' subject choice and STEM engagement, it has been chosen to be adapted for the Irish transition year (TY) students aged ~ 15 years.

2 METHODOLOGY

The purpose of the current small-scale pilot study is to test a project plan and research design that will be refined and used in a large-scale pilot study that will commence in September 2022 involving approximately 60 teachers in several secondary schools in Ireland. The data for the entire project are being collected from students and teachers – focusing on teachers' needs and requirements, and how to design the professional development (PD) to address these. The project is being designed and delivered in collaboration with the national in-service teacher training organization in Ireland, Professional Development Service for Teachers (PDST). After 2 years of gathering and analyzing teacher and student data on the effects and the structure of the intervention, the course and the PD will be refined and implemented on a national scale for the TY students.

2.1 Participants

Schools were canvassed by the PDST for interest in participating in the project and a small number of these schools were approached for participation in the small-scale pilot project. A total of 10 teachers were recruited as shown in Fig 1. One teacher did not complete the post-test and the post-interview, so their data cannot be included in the final pre- and post-differences examination process.

Participants	SMALL-scale pilot study 2021/22	LARGE-scale pilot study 2022/23
maths teachers	10	~ 40
TY students	~ 250	~ 1000

Fig. 1. *The small-scale pilot and large-scale pilot study participants.*

All participating teachers teach mathematics in grade 9 which is called transition year (TY) in the Irish school system. This is the year in which students undertake a wide variety of non-academic activities such as work experience and community care. However, much of their time is spent in school which gives teachers the flexibility in their timetable to trial novel educational experiences and interventions.

Description of the Spatial Course

The spatial course comprises 10 modules:

1. Surfaces and Solids of Revolution
2. Combining Solids
3. Isometric Sketching and Coded Plans*
4. Orthographic Projection*
5. Inclined and Curved Surfaces
6. Flat Patterns
7. Rotation of Objects about a Single Axis*
8. Rotation of Objects about Two or More Axes*
9. Reflection and Symmetry
10. Cutting Planes and Cross Sections

The four modules (marked with an asterisk) focus on developing students' sketching skills with the use of manipulatives (snap cubes). They require students to build a shape and sketch it from different perspectives. The importance of hands-on experiences for learning originates from Piaget's theory of cognitive development [4]. His theory claims that students need physical references to understand mathematical concepts, hence this element is an important feature of the course. In addition, sketches provide external representations of the visualizations formed by students which can then be examined and reflected on to check for accuracy and provide feedback on how they are visualizing. For this study, a website with online resources for individual modules was created, that includes:

- brief lectures with video demonstrations,
- interactive software,
- supplementary online teacher resources, and
- optional videos with additional exercises.

Physical workbooks with sketching exercises for each module were prepared for students. Teacher guides with lesson plans and pedagogical implications were arranged for teachers. Provided materials for fostering hands-on learning included:

- snap cubes to build and manipulate 3D shapes, and
- K'nex to represent the x, y, and z axes for demonstrating the rotation of objects around one or multiple axes.

2.2 Project Overview

The entire spatial project consists of three major steps. The first step (in the academic year 2021/22) is devoted to the small-scale pilot study, the second to the large-scale pilot study (the year 2022/23), and the third (from 2023/24) to the implementation of the spatial course in the transition year curriculum as shown in Fig. 2.

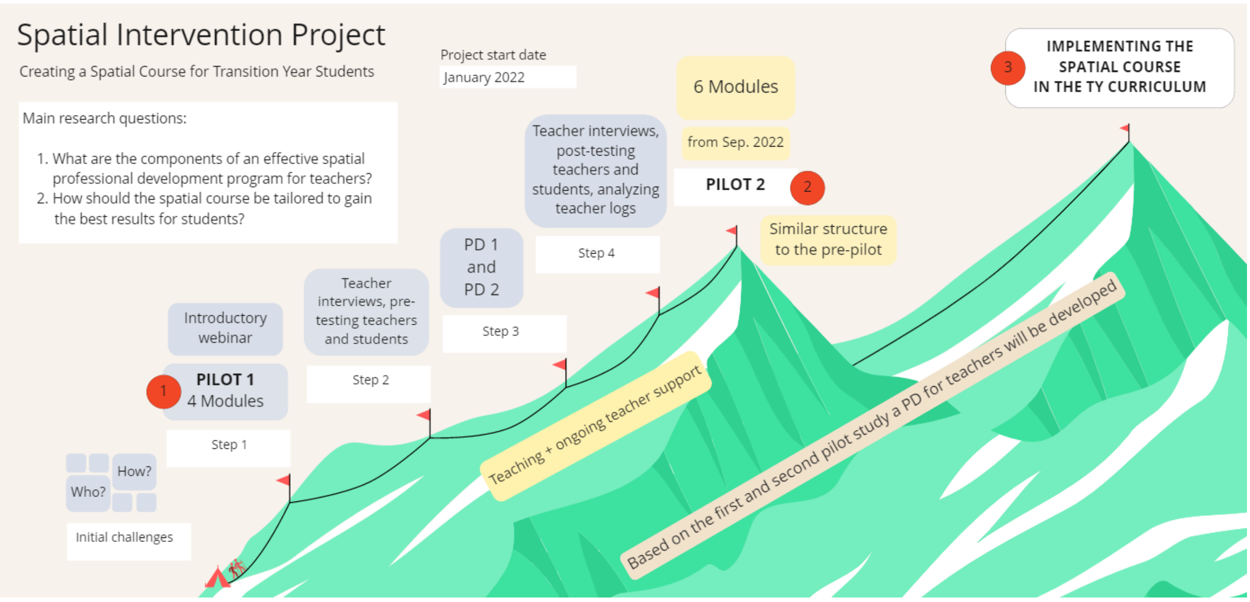

Fig. 2. *The structure of the Spatial Intervention Project: small-scale pilot, large-scale pilot study, and the nationwide implementation in the TY curriculum.*

Small-scale pilot structure

In January 2022, the small-scale pilot began. The initial challenges revolved around selecting which schools and how many teachers of which subject were going to be involved, which modules from the spatial course were going to be taught and how the entire process of the intervention was going to be organized. The purpose of the small-scale pilot was to assess all instruments and the quality of the PD for teachers to refine them and use them on a larger scale during the second pilot study.

Step 1 included the decision on which modules will be taught and the introduction of the study with the whole timeframe to the participants (teachers).

Step 2 describes the activities between the initial introduction and the first professional development day. Teachers were asked to take part in a pre-intervention interview where the researcher asked questions about their perception of spatial skills within the curriculum and their expectations of the spatial training. Teachers signed the consent forms for participation and completed the spatial test (PSVT: R Visualization of Rotations Test) with the incorporated feedback questionnaire on their experience of solving spatial tasks. Also, students were given the PSVT: R test to assess their skill level prior to the intervention.

Step 3 combines the two separately performed professional development days. The first one created a safe space for teachers from different schools to get to know each other and explore the fundamental module 3 (Isometric Sketching and Coded Plans) and module 7 (Rotation of Objects about a Single Axis) with an emphasis on pedagogy and on their content knowledge development through hands-on manipulation and sketching activities in student workbooks. After that, they started teaching the modules in their classroom. The second PD occurred a month after the first. Teachers shared their experiences of introducing the spatial course to their students and the students' initial reactions to the spatial tasks. During the PD, they worked on module 6 (Flat Patterns) and module 8 (Rotation of Objects about Two or More Axis), again with the emphasis on pedagogy and the use of multiple manipulatives.

The professional development days centered on fostering teachers' pedagogical content knowledge by improving their understanding of the skills' importance in STEM, and their skill level, and actively exploring ways of supporting their students in the future. Examples of student support discussed during the PD are:

- Use concrete examples to explain the isometric view by observing the corner of the room from different perspectives.
- Use the manipulatives (snap cubes, K'nex). Students who struggle must build the shapes first before sketching them. Start with the easiest examples and

give them time to explore the materials. Make sure they understand the isometric sketching and coded plans of module 3 before moving on.
- Students can cut out different shapes and fold them to get a better understanding of where the edges align.
- Make use of the online resources. Students can watch the videos and build along, solve additional examples and work with the interactive software.

While teachers were teaching the course, classroom observations and ongoing support were provided by the PDST. Teachers were also required to fill in a teacher log document after each lesson to reflect on their experience.

Step 4 describes the current and final stage of the small-scale pilot study. The researcher will conduct another set of teacher interviews regarding the implementation process, their recommendations for improvement, and their overall experience of teaching the course. The teacher logs will be collected for further analysis, and spatial tests will be given to teachers and students to measure the effects of the course on their skill development. Teachers will also answer questions on the questionnaire regarding their experience taking the test to compare the results with the first set of tests.

3 RESULTS AND DISCUSSION

The initial teacher pre-test spatial scores presented in the left graph in Fig. 3. show that the teachers' spatial skills before the intervention were relatively good. Seven participants out of nine scored from 65 % to 95 %. When observing their perceived difficulty level (from *very, very easy = 1*, until *very, very difficult = 9*) it is revealed that they all experienced it as difficult (*6 = rather difficult*, *7 = difficult*, and *8 = very difficult*), regardless of their skill level. An explanation for this could be the unfamiliarity with the spatial tasks. Perceived difficulty can influence teachers in spatial skill avoidance, where they are not actively seeking ways of incorporating it into their teaching. This provides a strong incentive to organize an effective PD to familiarize them with spatial activities and assessments with the goal of reducing the perceived difficulty level.

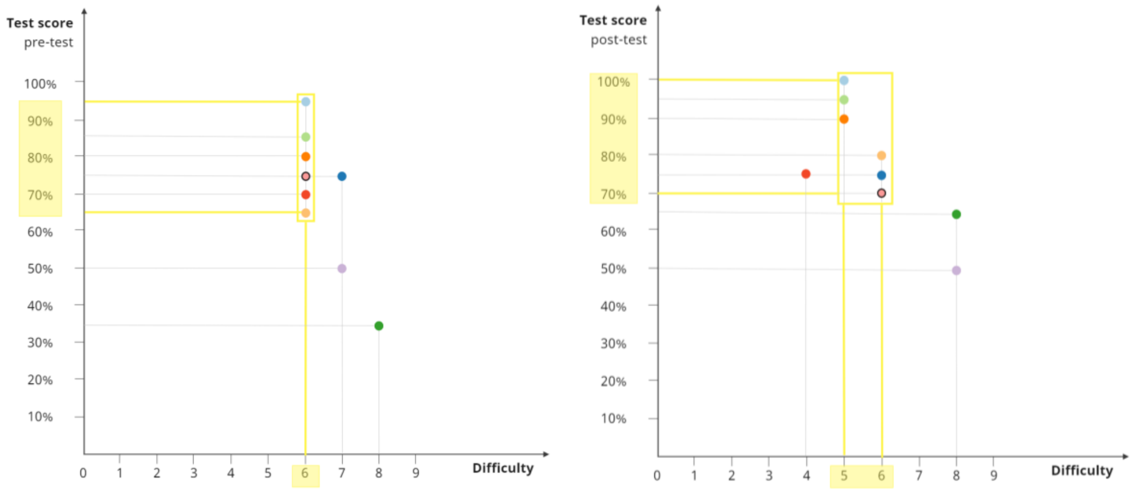

***Fig. 3.** The pre- and post-test results with the perceived difficulty level.*

The right graph in Fig. 3. shows the post-test results and perceived difficulty level after the spatial PD. The majority scored from 70 % to 100 % and experienced the difficulty levels 5 (neither easy nor difficult) and 6 (rather difficult). One teacher experienced it as rather easy (difficulty level 4), and two as very difficult (difficulty level 8). Four teachers (presented in colors: light blue, light green, dark orange, and red) improved their test scores and felt it to be less difficult compared to their pre-test experience. Two teachers (dark green and light orange) improved their test scores but experienced the post-test to be as difficult as the pre-test. Two teachers (purple and dark blue) received the same score but experienced a difference in the difficulty level. The first one (purple) experienced the post-test to be more difficult and the second one (dark blue) as less difficult than the pre-test. One teacher (light pink with a black circle) received a lower score on the post-test and experienced it to be as difficult as the pre-test. During the post-interview, it was discovered that this teacher took the time to focus on the pre-test but rushed through the post-test due to personal time restraints. Based on the teachers' pre- and post-test scores we can observe a general increase in their spatial skill development and a decrease in perceived difficulty level. This suggests that direct training of the skill through the spatial course and having the opportunity of teaching it to students can improve their skill and confidence level in teaching it.

Pre- and post-intervention teacher interviews are currently being analyzed and will be presented in the future. So far, they reflect the potential of this spatial intervention in secondary education based on teachers' experience of the small-scale pilot study. Teachers generally felt their spatial skills improved and gained a better understanding of how to develop them in their students – suggesting an improved pedagogical content knowledge for spatial thinking. It will be interesting to compare the effects of the small- and large-scale pilot study to find if these benefits improve with longer exposure to the intervention.

4 SUMMARY

Spatial skills have been linked to success in engineering. Since they are currently not being systematically developed in Irish pre-tertiary education, their development is being left to chance. Students with better developed spatial skills tend to choose more math and science subjects, which affects their career opportunities. To increase the number of students who could engage in engineering, a spatial intervention in Irish secondary schools is needed. The small-scale pilot study included teachers who wished to incorporate spatial skills in their lessons but needed guidance and support in the form of professional development to accomplish this goal. So far, the training proved to be beneficial in improving teachers' spatial skills and reducing the experienced difficulty level when working with spatial problems on the test. Through a small-scale and a large-scale pilot study, data on the quality of the PD for teachers and the effects of the spatial course on students will be gathered and used to improve it. Future work in Ireland will involve the implementation of the refined spatial intervention in transition years.

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Seminar as a way to educate engineering students on environmental challenges in the textile industry

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ABSTRACT

The Ecole Nationale Supérieure des Arts et Industries Textiles (ENSAIT) is one of the few schools specialising in materials for the textile industry. Each year it graduates around 110 engineers whose role is to meet the challenges of the sector while respecting the values of the companies and environmental standards. The ENSAIT engineer's course takes place over three years. From the first year of the engineering

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cycle, a seminar on sustainable development is offered. It is held in the second semester and lasts two full days. The first objective is to make them aware of corporate social responsibility (CSR) issues in companies. The second is to build on the knowledge acquired during the last 6 months to develop the life cycle of a garment and understand the associated impacts. Finally, it is to highlight the different possible strategies based on eco-design, fair trade, taking into account the regulatory constraints. This seminar is based on active pedagogy, where students work in teams and compare their results with each other. It also aims to provide the minimum tools to understand ecodesign strategies and to be an informed fashion consumer, and to become a textile engineer capable of participating in and technically supporting companies' CSR initiatives.

1 INTRODUCTION

The Ecole Nationale Supérieure des Arts et Industries Textiles (ENSAIT) is a public institution of a scientific and professional nature located in the heart of Roubaix. It is one of the few schools specialised in materials and processes for the textile industry. Each year, it trains around 110 engineers whose role will be to meet the challenges of the sector while respecting the values of the companies and environmental standards.

The ENSAIT engineer's training lasts three years and is available either through a full-time study course or through a block-release program. In the first year, the courses include engineering sciences and the basics of textile processing. Specialisation is then progressive, first with a range of 'majors' offered in the second year (technical textiles; fashion and luxury) and then with a range of application areas in the third year (supply chain, connected business, composites, smart textiles, and sustainable materials and processes).

Also, given the social, ethical, environmental and economic issues raised by the textile industry, the training program provides for all engineers to be aware of and prepared to meet the needs of companies on these subjects. For this purpose, and for more than fifteen years, courses related to the various aspects of sustainable development have been given at ENSAIT. Initially proposed in lecture form and practical work, the educational reform of 2015 has enabled them to be divided between a seminar given in the first year and the specialisation offer of the majors and application areas proposed in the third year. Initially, the lectures were disseminated through the year. However, given the volume of time dedicated to sustainability, this approach was not constructive enough to enable students to develop a sufficient skill. Thus, the solution was to concentrate the dedicated lectures time into a single seminar event. Finally, the aim of such an organisation is to enable all students to become aware of sustainability issues and, for those who wish to specialise, to deepen methodological and critical thinking issues.

In the following, we will focus on the seminar, named “Sustainable development awareness seminar”, and its pedagogical objectives, detail the programme (section 2) and go through its content (sections 3.1, 3.2, 3.3).

2 METHODOLOGY

2.1 Sustainable development awareness seminar

The Sustainable development awareness seminar is designed for about 90 students. It is held from the first year of the engineering cycle with the aim of raising awareness of corporate social responsibility (CSR) issues in companies.

By combining group and individual activities with expert presentations, the seminar aims to ensure that students:

- develop a critical mindset when faced with environmental claims,
- learn about the tools that are useful for addressing CSR issues (social audits, labels, environmental standards, environmental assessment methods),
- know how to understand, criticize and use the results of these tools,
- are fully aware of the regulatory and legal issues,
- understand the complexity of social issues and not making judgements.

2.2 Seminar structure

The seminar is held over 2 consecutive days and is awarded by 2 ECTS. To be awarded, students are evaluated on both, an individual basis and on a group activity:

- the individual evaluation consists in a quizz evaluation which cover the thematics addressed during the lectures and during the parallel workshops;
- the group activity assessment consists in a presentation of the work done during the self-directed activity which is further presented in section 3.3.

The seminar is mainly made of in class activities and is structured as follows:

- an introduction, given during the first half-day, provides a context for sustainable development with its many perspectives,
- learning the tools of CSR, carried out in groups over two half-days,
- a project to be carried out in groups and in autonomy during the last half-day.

In practice, it is as detailed in Table 1:

Table 1: Seminar structure

Duration	Content	Session type	Number of students
15 minutes	Academic introduction and program detail	Plenary session	90 students
45 minutes	Company's introduction about CSR	Plenary session	90 students
2 hours	Classroom lectures	Plenary session	90 students
1 hour	Exercices	Group sessions	45 students/group
4 * 1 hour and half	Parallel thematic Workshops	Group sessions	23 students/group
1 hour	Evaluation (quiz session)	Individually	90 students

Half a day	Self-directed activity	Group	6 to 8 students
From 20 to 45 minutes	Thematic interventions	Plenary sessions	90 students

In class activities This structure mixes lectures and active pedagogy. As discussed by Jouquan et al. [1], active pedagogy create the right conditions for students to engage and persist in learning situation. As mentioned by Jouquan et al. active pedagogy requires a high level of commitment from both, the students and lecturers. Thus, to engage students before the beginning of the seminar, a first out of class activity is committed. Students have to work in groups on the CSR policy of companies in the clothing sector. The companies are pre-selected to cover the field of possibilities: from mass market to luxury, including new brands "born from sustainable development values" (i.e. Bonobo, Burberry, C&A, Carrefour, Mudjeans, SKFK, ...). This activity, delivered in the form of a report, must be returned before the start of the seminar and is intended to provide an initial snapshot of the distance that students are able to stand back from the environmental claims made by companies. Such an exercice corresponds to a role-playing exercise that Lemaître mentioned [2]. The aim is to use observable practices from professional contexts into a training one. The training situation is as close as possible to a professional life situation, which should enable the student to project into a future activity. Such a learning situations supports meaning for the students, unlike courses centred on knowledge content seen as disembodied.

3 RESULTS

3.1 Seminar introduction

The beginning of the seminar is marked by an introduction which allows explaining the programme and most of all to set the scope of this course.

In the context of textiles, it highlights the variety of themes behind the term "sustainable development". As an illustration, professionals, consultants or companies are given the opportunity to present their views. The aim is to benefit from the experience of these players, to appreciate the existing dynamics and for the students to become aware of the expectations of the sector. Regarding these presentations, it is also interesting to notice that a more systematic use of video-conferencing has allowed more actors to intervene and therefore to cover more perspectives. As an example, during the 2020/2021 seminar, these presentations enabled both an approach to CSR, its meaning in companies (with the aim of showing the diversity of themes: social, societal, ethical, legal, environmental or even image) and to deal with specific topics, in this case the environmental labelling of textile clothing products (a topical subject that these engineers will be confronted with as soon as they leave school).

Alternating with these presentations, a first session of courses is held on eco-design, its principles and objectives, its tools and their advantages and limitations.

The aim of eco-design being to reduce the environmental impacts related to the life cycle of a product or a process, it is essential that the students understand these impact indicators. To do so, the students are actively involved in a group exercise. Each group has 1 impact indicator to choose between a list of 16. As an example, they can investigate the global warming potential or the eutrophication or the ecotoxicity and so on. The time dedicated being 20 minutes, they have to understand describe and prepare 2 slides maximum for presenting to all the students. At this stage, it is not requested to make any link with the textile value chain but rather to describe the impact indicators used in LCA.

3.2 Evaluation tools

The following two half-days are dedicated to developing students' skills regarding the tools that will enable them to monitor and respond to the social, environmental and legal aspects of sustainable development with:

- an initial exercise to familiarise themselves with single-criteria quantitative tools for the energy and carbon footprint of a textile product, the exercise being individual,
- four successive workshops dealing specifically with (1) social impact assessment tools, (2) environmental labels, claims and obligations, (3) the legislative and legal aspects of sustainable development and (4) life cycle assessment.

3.2.1. Energy and carbon footprint assessment of a product

A first individual activity is proposed before starting the four workshops. For one hour, students are divided into two groups and are asked to draw the outlines of a first eco-design case study. At this stage, the product (a cotton shirt) is virtual and relatively simple. The idea is to give concrete form to some of the statements made in the first part.

In practice, the approach consists of conducting an energy and a carbon assessment of the life cycle of this shirt. Using their skills in textile processing, the students are responsible for determining the manufacturing cycle of the shirt and its use.

As these two evaluations are single-criteria assessments, this exercise is an initial awareness-raising exercise and introduces the interest of Life Cycle Assessment (LCA) as a multi-criteria tool.

3.2.2. Social impact assessment tools

After a first sensitization to the social problems of the textile industry, the students are given a definition and an illustration of what a social audit is. They thus become familiar with the objective of the tool and its possible uses. Indeed, it is a tool for evaluating the conformity of practices, and the outcomes are part of a wider diagnostic and continuous improvement process. They can be used to meet the requirements of standards, for example in relation to responsible purchasing.

The audit practice is explained by covering the audit criteria (management system, transparency and traceability, minimum age, forced labour, non-discrimination ...) as well as the role and behaviour of the auditor.

A case study is included in this workshop. It gives the students the opportunity to experience a situation where they have to map the "supplier risks" on social impact maturity. The approach is to be validated by the construction of a rating scale and an example of a questionnaire to cover part of the audit criteria outlined earlier.

3.2.3. Environmental labels, claims and obligations

Standards and labels are abundant in the textile sector. They enable buyers to be informed about the environmental and/or social performance of a product or service. Thus, they are widely used. However, it is not easy to distinguish between a promising logo and the reality of the specifications.

To this end, this workshop enables students to:

- understand the principles of environmental communication and thus be able to better assess the transparency, relevance, credibility and clarity of a given communication
- to know the communication methodologies, specifically the categories of declarations developed in the ISO 14024 standard.

An additional exercise is to investigate and report on different labels. This teamwork should enable students to investigate the governance and the origin of the label, its objectives, the certification criteria and their link with the textile sector.

Attention is also paid to the REACH directive, which aims to regulate the use of chemical substances in Europe. As the list of substances is constantly being updated, it is crucial for students to be aware of it and to know how to find and relay such information.

3.2.4. Legal contribution to the sustainable development seminar

During this workshop, students are introduced to the legal instruments that support CSR. Indeed, CSR is framed by a number of national, European and international standards.

While the previous workshop (Environmental labels, claims and obligations) focused on voluntary labels and standards, this workshop focuses more on mandatory standards and the legal consequences of non-compliance.

Thus, binding tools such as the Commercial Code, the OECD principles, children's rights, the law on duty of care, the REACH regulation, the anti-waste law for a circular economy (AGEC) etc. are presented. This latter is also covered in an exercise to better understand the obligations of companies with regard to the regulation and what the penalties are in case of non-compliance.

In addition, the restrictive nature of the various legislative measures is illustrated with various case studies from forced labour to misleading advertisements to the non-respect of the right to strike in the textile value chain.

3.2.5. Environmental assessment tool: Life Cycle Assessment (LCA)

The last workshop focuses on life cycle assessment, a multi-criteria quantitative environmental assessment tool.

The aim is to enable students to grasp the LCA methodology, its vocabulary and what it requires.

The approach is similar to this presented by Viere et al. [3]. The teaching starts with an introduction and the positioning of LCA in a wider context. It is followed by an explanation of the principle, purposes and steps of LCA, regarding the ISO 14040 and ISO 14044. It is followed by the use of the simplified LCA software, EIME proposed by CODDE Bureau Veritas. This online tool corresponds to the students' area of study and benefits from textile-specific databases. Practice is carried out individually on a common case study, the cotton shirt mentioned above, whose life cycle has been determined. The purpose of this exercise is to enable students to identify the "hot spots" in the life cycle of a garment, to be able to monitor future design choices and to understand the concept of life cycle thinking.

3.3 Ecodesign - Self-directed project

The final phase of the seminar is devoted to a student-led project. Entitled "CSR and eco-design strategies", it allows students to put into practice the tools they developed during the seminar. In groups of 6 to 8 students, they are asked to represent the same company whose main product is a cotton shirt, produced in a globalized manner. The company's objective is to improve its CSR strategy, particularly in terms of environmental and social issues. The statement is given as a problem situation more than an exercice. As mentioned by Fayolle et al. [4], it enables to provide a more open but also more realistic context for empowerment and reflection.

An eco-design wheel and guiding questions are provided to assist students. They are expected to choose improvement strategies and to describe how they will implement, monitor and control the success of the strategy.

This experience is punctuated by thematic interventions given by professionals, consultants or companies. The themes covered include end-of-life textile management, the circular economy and the economy of functionality. They are proposed in short formats, 20 minutes long, and should stimulate reflection in the framework of the self-led project.

4 REFLEXIVE FEEDBACK

As previously mentioned, the current seminar format aims to replace previous lectures which were disseminated through the year. This previous approach was not constructive enough to enable students to develop a sufficient skill. Given the volume of time dedicated to sustainability, this approach required constant revisiting of course material as a reminder. By concentrating the sustainability related lectures in two consecutive days, the seminar approach enabled us to better engage students in an intensive learning process and to add some active pedagogy practices. However, by working over two consecutive days, we are experiencing the advantages and disadvantages of such an approach. It is quite clear that the concentration of topics and content is high and it requires a quick involvement of students. However, as some students will not pursue a specialization in sustainability, it is an opportunity for them to deal with diversified topics. It also enable them to increase their critical mindset from regulatory aspects to environmental and social assessment methodologies and communication. As future engineers, whether specialised or not, it is essential they gather knowledges so that they can think constructively about the issues of sustainability.

As lecturers, the preparation workload is quite similar to the one required for traditional lectures. The additional steps are spent on organising and on meeting with companies, specific organisms and NGO to get them involved. It appears that these external interventions are particularly appreciated by students and require our full attention.

During the seminar, we also have:

- To play as a time keeper. The agenda of the seminar is full of activities, some of which may run over. Thus, in order to tackle the whole of the planned programme, it is important to be careful with time management.
- To deal with a diversity of students profiles. The students arriving at ENSAIT come from relatively varied backgrounds and for this reason, the skills are relatively heterogeneous. Facing new activity and knowledges, this diversity of profile is remarkable and requires adaptation and, as far as possible, individualisation.

As mentioned above, the students work individually or in sub-groups. So far, the students groups were made relatively to an other project. Since the students well know each other, we noticed different dynamic nature of each group. At the moment, it is up to us to compensate the weakest dynamic going from group to group. There is probably a way to make it more efficient, perhaps by assigning roles to the students or by setting a time for exchange per group.

This seminar format is led for more than five years. After each, a survey is conducted to know more about the students opinion. It appears that the satisfaction level is quite high with more than 75% of satisfied students. Compared to a traditional lecture, students highlight the changes in the rhythm of each activity, the interactivity and the group activity, the self-directed one specifically. Regarding students opinion, the strongest elements of this seminar are:

- The involvements of companies and association;
- The diversity of intervention methods.

Regarding students' opinion, the areas of improvement are about the time, more time should be spent on the topic in general and on the different activities. This would help them to better appropriate the tools. The imposed nature of the groups was also discussed. Indeed, group work remains a challenge and it is sometimes difficult to involve 6 to 8 students in the same activity. The activity we are proposing is no exception and students would like to be grouped by affinity. This is a choice that we have already experienced with in other situations and which also has its drawbacks (group harmony, heterogeneity of skills, etc.)

5 SUMMARY AND ACKNOWLEDGMENTS

In order to address the sustainable development issues of the textile-apparel sector, a sustainable development awareness seminar is provided in the first year of the ENSAIT engineering course. This seminar covers more than just environmental aspects, it also introduces social issues and social impact assessment tool, environmental labels and communications, vigilance towards claims as well as legal aspects behind sustainability. Students are frequently put into active situations, either individually or in groups, in order to better understand the tools, their implementation and their limits. This format enables a positive group dynamic which is supported by strong individual motivations.

Students learn to step back from sustainable development issues, and sharpen their critical eye. They become aware of how the textile industry is involved in sustainable development actions, and that they have a crucial role to play in transforming the textile industry.

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ESTABLISHING A NEW SEMINAR TO COMBINE LEARNING ABOUT TECHNOLOGY AND SOCIETY

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Conference Key Areas: *Sustainability and Ethics in Engineering Education, Teaching methods*
Keywords: *Problem Based Learning, Public Participation, online collaboration, Interdisciplinarity*

ABSTRACT

For the transformation we face in industry and society, a broad societal consensus and collaboration between different stakeholders are vitally important. With this in mind, the Environmental Engineering program focuses on environmentally relevant technical developments and the consideration of systemic interrelationships while incorporating societal frameworks.

The recently implemented course Technology – Dialogue – Society was developed as an introduction to these complex tasks for first-year students. It focusses on topics of the energy transition sector and public participation. The learning objectives of the course are the acquisition of methodological competencies as well as the promotion of communication, teamwork and the ability to reflect. An overarching goal of the course is also onboarding of students in the program.

A wide set of teaching-learning methods is used to achieve this broad objectives. In addition to lectures, collaborative and dialogue-oriented teaching-learning methods such as problem-based learning, peer review of student work, conversational simulations and reflection assignments are used. A particular challenge of

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implementation was the course size of approximately 100 students and the need for online teaching due to the Covid-19 pandemic.

The structure of the course is described and the evaluation results of the first run are presented.

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1 INTRODUCTION

1.1 Background

In light of the climate crisis, issues of sustainability and rapid decarbonization of our energy supply are becoming increasingly urgent. The changes required go hand in hand with fundamental social and technical transformations that can only succeed if technical developments are also socially viable. Precisely because engineers are the ones who develop and implement technology, awareness of societal problems and interrelationships is also of particular importance to them and should be integrated into engineering curricula.

As part of the restructuring of the Environmental Engineering program (formerly Environmental Engineering and Resource Management), a new module was developed and intergrated in the curriculum to address these challenges in the program. A particular goal of the module is that students are confronted with this kind of profession-related topics from the very beginning and experience the consideration of societal concerns as belonging to the subject.

The module consists of two parts: The first part, the course *technology - dialogue - society (TDS)* deals with challenges and methods of public participation in industrial and infrastructure projects. The construction or reconstruction of infrastructure as well as the use of technologies is always accompanied by questions of acceptance. In Germany (as in many other countries), there are increasingly massive disputes about the realization of energy transition projects like wind turbines and transmission grids. Finding viable solutions and creating acceptance is a task for society as a whole [1] and this challenge is a well-suited topic to promote the necessary attitudes and competencies in an engineering course.

The second part, the course *environmental ethics for engineers*, focuses on philosophical methods and the analysis of environmental ethical issues. This paper presents the design of the TDS-course and discusses the results of the first run.

1.2 Goals of the TDS-course

The TDS-course deals with environmentally relevant technical issues and social application references. Solving such complex problems requires a variety of knowlege as well as personal and social skills, such as communication skills and the ability to work together in an interdisciplinary manner. These personal and social competencies should be fostered in the course and the development of values and attitude should be stimulated.

The content-focused learning objectives are the acquisition of technical and methodological skills for public participation. The Association of German Engineers (VDI) has developed a guideline that provides support for organisations in the planning, organisation and execution of early public participation, as well as recommendations in the form of a structured process [2]. The methods taught in the course refer to this standard.

This broad set of learning objectives aims at developing competencies based on the T-shaped model [4] and the Future Skills concept. "*Future Skills* are competences that allow individuals to solve complex problems in highly emergent contexts of action in a self-organised way and enable them to act (successfully). They are based on cognitive, motivational, volitional and social resources, are value-based and can be acquired in a learning process." [5] Obviously, these competencies cannot be covered comprehensively or at a high level in such an introductory course, but serious engagement can be initiated and an awareness of the approaches and importance of these competencies and topics can be fostered.

With regard to the observation, that students who do not have a positive experience with social transition at the university have greater difficulty coping with the challenges of the first year of study [6], this course is also intended to promote arrival at the university. This aspect became particularly important in the first run due to the Corona contact-restrictions and limited opportunities for social interaction on the campus.

2 STRUCTURE AND DIDACTIC ELEMENTS OF THE TDS-COURSE

The objectives explained above were transformed into a course concept under the following framework conditions. The TDS-course is a required course in the first semester of the Environmental Engineering degree program and encompasses a workload of 2 credits. The number of expected participants, based on the number of new students, has fluctuated between 50 and 120 in recent years.

The development of the TDS-course is based on the experience with the topic of public participation from interdisciplinary seminars for advanced students and the successful use of problem-based learning (PBL) and conversational simulations therein [3]. The PBL-method forms a core element in this new course as well and the case work drives the thematic discussion and structures the weekly sessions. Problem-based learning (Maastricht model) is process-oriented, promotes communicative skills and collaboration, encourages reflection, and is very well suited to deal with interdisciplinary tasks [7]. Case studies from everyday (work-) life are the starting point. These are worked on in groups and the PBL-process takes place in predetermined steps:

- Case analysis and derivation of research tasks in the group
- Research phase (usually until the next session)
- Presentation and discussion of the results in the group,
  development of solution approaches and feedback [8, 9]

Experiences with the use of PBL with student groups that are not familiar with this form of learning show that it is very helpful for students to receive a relatively high level of content support and reflection. Therefore, basic knowledge is conveyed in short lectures (30 min) or instructional videos and the results and solution approaches from the group case work are also reflected on again in the plenary.

Since students in the first semester have little experience with scientific work, feedback on their writing is very important. Therefore, a peer review of the students' research questions was introduced as an additional step. This is handled via the Moodle learning platform. The peer review offers the great advantage that the students also change into the role of the commentator. They see the work of their fellow students and have to give feedback on certain criteria. Furthermore, they receive feedback on their own work.

The problem-oriented approach is continued during the two seminar sessions, the format also encompasses. These seminars serves as an exemplary application of learned methods. It is also a deep dive into communication situations that occur in public participation. In the second seminar a participation format will be carried out as a simulated conversation (role play). The structure of the course is shown in Figure 1.

Fig.1. Structure of TDS-course

In line with the methods, different types of written performance are required:

- - Elaborations on the "own" PBL research questions.
- - Peer reviews on elaborations by other students
- - Written reflections on findings, processes, or discussions.

In the run-up of this course it was intensively discussed in which form the learning process can be secured and wether and how the performance of the students could be measured. The learning objectives focus on the development of personal and social competencies. Measuring such competencies is generally demanding and time-consuming. Taking into consideration that the course is also about raising awareness for complex issues and stimulating personal development, testing and grading seems counterproductive. Like Reimann says, rather "*potential educational spaces"* are needed: "However, these can only unfold if not every performance shown (and not shown) is recorded and evaluated" [10]. In addition, the course is also intended to support onboarding. Therefore, the course does not include a traditional exam or grading. The workload is secured by checking and documenting the weekly work assignments.

3 IMPLEMENTATION

The first run of the course took place under two special conditions. First, a high number of students from the third or fifth semester of the former study program, who had switched to the modified program, were obligated to attend according to examination law. Their share of the total number of student paricipants was about 50%. The second special condition is that, due to the pandemic, it had to be conducted entirely as online-remote teaching.

About 100 students participated in the course. They were divided into 14 groups of 6-8 participants. As shown in Figure 1, the weekly Zoom Online sessions consisted of different phases. They usually began with a short plenary lecture. Then, students worked on PBL cases in breakout sessions in their groups. At the end of the group-session, there was another plenary phase in which the results were reflected on together and the work assignments for the following week were concretized.

At the beginning of the course, the objectives and methods were made transparent and in particular the PBL method was explained and practiced. Extensive templates were provided in the online whiteboard Miro for collaborative processing of the tasks. With the help of the pre-structured templates, the students were able to work autonomously in the group phases, i.e. without tutorial guidance. In case of questions, tutors were available in the plenum. Students had a work assignment to complete by each of the weekly deadlines during the current semester. The assignments were uploaded to or worked on in the accompanying course on the learning platform Moodle.

In addition to the weekly meetings, two seminars took place. The first seminar was conducted with one group and lasted two hours each. In the second seminar, three groups were combined. In this four-hour seminar, students assumed specific stakeholder roles and simulated participation situations.

4 EXPERIENCES, EVALUATION AND DISCUSSION

Overall, the implementation of this methodologically complex and organizationally extensive course worked well. 104 people registered and 99 successfully completed the course. From the teachers point of view, it was possible to create a good working atmosphere in which an intensive exchange was possible. On the basis of the submitted work assingnments, the documentet work processes and results in the Miro-Boards and the high level of commitment in the two seminars, we can conclude that a comprehensive examination of the topics took place. Basic knowledge and methods were acquired, which all groups were able to demonstrate, especially in the two seminars. Nevertheless, the level of goal achievement varies on the individual level.

Student evaluation of the course was assessed using a standardized questionnaire of the faculty of mechanical engineering. A total of 92 students participated in the evaluation and the course was rated good to very good overall. (mw: 4.5 on a scale of 1-5 (5 = very good) N=92)

The students' responses to open-ended questions are particularly revealing. More than 50 students described in their own words what they particularly liked about the course and where they see potential for improvement. For a differentiated analysis, the students' responses were split into individual statements and these were then assigned to thematic categories. The numbers of mentions per category are shown in Figure 2.

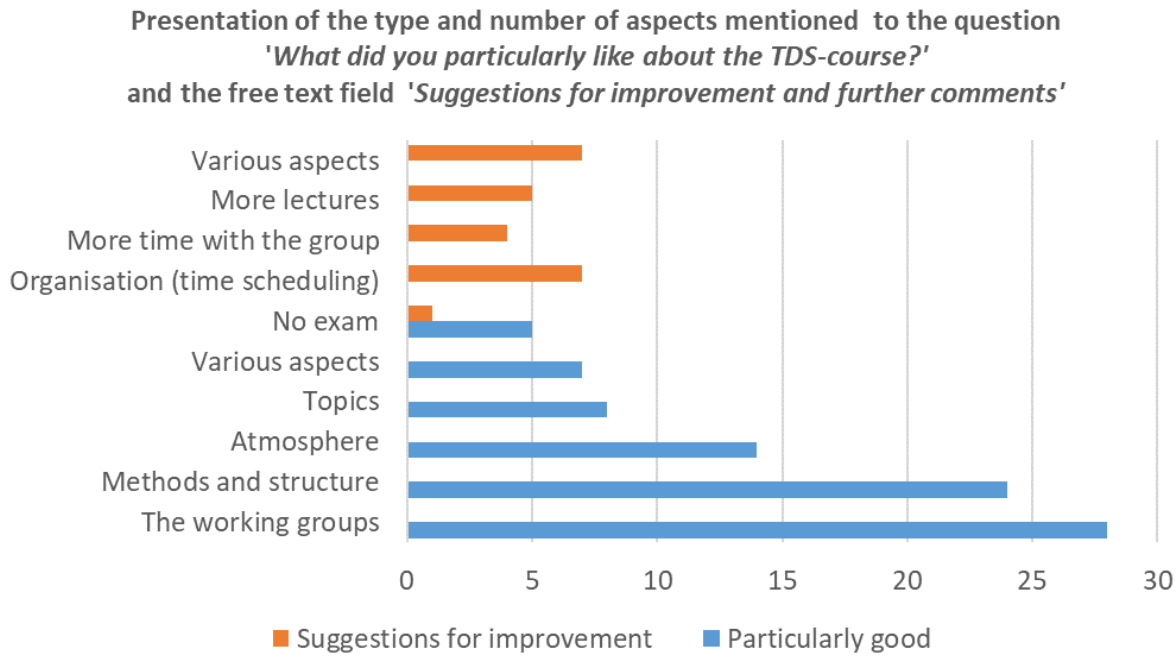

Fig. 2 Evaluation outcomes: Number of mentions per category

The high number of comments suggests that the course has succeeded in engaging students well and that a good level of ownership of the course has emerged. This is also matched by the observation that the comments on the potential for improvement were all constructively formulated and appropriate in terms of content.

The analysis of the free text fields shows that many participants especially liked the group work in the course. More than a quarter of the students explicitly name the group or the group work as *"a highlight of the course"*. The good and open atmosphere in the course is also mentioned as particularly positive.

Suggestions for improvement often relate to organizational aspects, such as the scheduling of seminars or implementation problems in the Moodle course, which should be improved in the next run. Further suggestions concern the wish that the seminars should take place face-to-face on campus - which hopefully can be realized in the future.

About a quarter of the participants explicitly described the methods of the course as particularly good. Students frequently remark that a good mix of methods was used and that this type of teaching was inspiring. The topic of public participation and dealing with societal challenges such as the acceptance of the energy transition are described as interesting and important.

However, individual differences are also apparent from the comments. While some participants would have liked clearer guidelines, less group work and more input, others call for the exact opposite, i.e. less input and more group work. These different assessments can be attributed to personal preferences on the one hand, and group effects on the other hand. Depending on the composition of the group, different dynamics can develop that have a significant impact on cooperation and learning. This is also evident in the individual responses. While some students regret that there was sometimes little talk in the group, others say that they *"had a lot of fun"*, *"rarely met such dedicated people"* and had a *"very motivated and friendly group"*. But even with a less motivated group, the course was considered to be successful: *"Unfortunately, my group wasn't very communicative ... but it worked out anyway"*.

Special condition: no written exam. There were also comments on this topic. These were mostly positive, such as *"I felt like I was attending the course to learn something and not, as in other courses, just to get my certificate of achievement... "*. Two comments criticized the fact that there was no written exam at the end. The lack of the self-disciplining effect of an exam was referred to as a negative one, and another student pointed out a danger of *"cheating through"*.

Particulary interesting is students' view on the amount of work. With regard to the amout of credit points this was seen as appropriate by most students, but is estimated as too high by some. In particular, the extensive research tasks are criticized for being too time-consuming. It is clear that in this course students' own motivation is of great importance. But this can also be seen as an opportunity. The question is whether the majority of the students worked continuously and used this opportunity. In this regard the comparison with other courses is interesting. From the faculty's area-wide course evaluation aggregated comparative data is available. In the answers to the question *"I regularly prepare/review the session/work units"*, the TDS-course actually scores slightly better with a value of 3.6 (agreement on a scale of 5) in comparison to the average in the mechanical engineering courses value of 3.3.

What also became clear in reviewing the feedback is that for some students participation in the course helped quite explicitly in arriving at their studies in dealing with distance teaching: *"I was part of a really motivated and sympathetic group that I will continue to work with. In this Corona time, this has been very helpful for me.", "The TDS-course has also been an anchor point for me in an otherwise spongy asynchronous semester and has helped me structurally as a result."*

5 SUMMARY

This paper describes the structure and experiences of the first run of a course for first-year students in environmental engineering. Using the example of acceptance problems in energy transition projects, technical and societal issues are discussed and methods of public participation are addressed.

The teaching concept has proven to be viable for a group of around 100 participants and was conducted entirely online in the first run. Through the use of various coordinated collaborative teaching methods, it has been achieved that the students have intensively dealt with different perspectives of energy transition projects. The students have systematically worked together in groups and comprehensively reflected on their work results. The openness of the course, which was also due to the fact that there was no assessment and grading at the end, was very positively received and engaged by the vast majority of students. The course was also able to make a valuable contribution to students onboarding.

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Integrated Programming and Mathematics in Schools - A Solid Foundation for a Future Engineering Education?

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ABSTRACT

The interest in programming in schools has the last decade increased, and many countries have introduced programming as part of the school curriculum. Teaching of programming to students in primary and secondary school is often focused on the computer sciences aspect of programming. The current study is a part of the recently initiated research project "Programming for understanding mathematics" which has a different emphasis; the project investigates how the mathematical competence of the students are affected by actively using programming in mathematics lessons. In this paper, a recognized analytical framework for analysing the cognitive demand of mathematical tasks is presented. We extend the framework to include the analysis of tasks that utilize programming, allowing us to distinguish between tasks that are demanding due to the mathematical content, but the programming aspect of the task is trivial, and tasks that are cognitive demanding due to complex programming, but the mathematics is simple. We use the extended framework to analyse tasks in four mathematics textbooks written for 16-17 year old students by two major publishers in Norway. The results show that the tasks provided in the textbooks mainly focus on elementary programming skills, and the tasks give limited experiences with cognitive demanding programming tasks.

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1 INTRODUCTION

We have entered the era of computation. High speed calculations have become such an integral part of our life that we do not even notice; path finding algorithms show us the direction on our phones, assisted driving increases the safety on the roads, and the weather forecast allows us to know if it will rain next weekend. Behind these features, are complex mathematical models and algorithms that are solved by computers. In the professional world, especially in Science, Technology, Engineering, and Mathematics (STEM), this can be seen as a rapid change in the use of computers and computing over the last decades.

As a response to this shift in technology, programming has been introduced in the school curriculums of most European countries [1]. Most countries that introduce programming in schools argue that programming enhances logical skills and problem-solving skills [1]. For mathematics, programming is often claimed to enhance computational thinking, which can be defined as a thought process and problem-solving approach that can provide the means to translate problems into formulations that can be solved computationally (either by a computer or human) [2]. The set of skills learned from computational thinking can be promoted when tackling difficult problems. It includes decomposition (breaking a problem into smaller parts), pattern recognition (analyse and find connections in data), abstraction (identify relevant information and eliminate the extraneous details), and algorithmic thinking (develop step-by-step processes) [3], which are concepts also related to programming.

The introduction of programming in schools will change the competence of students starting at engineering education. To take advantage of the changes, it is necessary to understand how these changes are in practice implemented in schools. In this paper, we present initial results from the recently initiated research project “Programming for understanding mathematics”. The project focuses on programming at primary through secondary school, and the aim of the project is to investigate how programming can be used to enhance mathematical understanding.

While programming is introduced in schools on a higher level based on developing the computational thinking and 21st century skills of students [1], it is interesting to see how these new curriculum changes are implemented in practice. Thus, in this paper we take a closer look at how programming is introduced in the Norwegian upper-secondary school. There are mainly two different approaches that are taken when programming is introduced in schools. In many countries, programming is either introduced as a separate subject or part of an information technology course [1]. However, increasingly programming is introduced as part of traditional school courses, usually mathematics. In Norway the second approach is taken; programming is treated in several subjects, but mathematics has been given a key role in developing the students’ competence in programming. Similar tendencies can be seen in other Scandinavian countries, see e.g., [4] for an overview.

From a long tradition in mathematics, the textbook is important as a curriculum resource for teachers [5]. The tasks and how they are presented in the textbooks impact how teachers and students work with the subject. When introducing a new topic in mathematics lessons, which many teachers also are feeling unconfident about, we suppose that the textbooks may be even more important, and the content of the textbooks lay the foundation for the students' outcome of mathematics courses. Although tasks can be used differently by teachers, the way it is presented in textbooks are anyhow important for how challenging the tasks will be.

2 METHODOLOGY

In this paper we analyse how programming is treated in two different Norwegian textbook series, Mønster [6,7] and Sinus [8,9], for upper-secondary mathematics. The textbooks cover the mathematics courses of 11th and 12th grade students (age 16-17) aiming towards STEM programs at university.

2.1 Analytical framework

Boston & Smith [10] present a framework for analysing mathematical tasks. Tasks are assigned a number 0-4 based on the mathematical potential of the task. Level 0 is a task that does not contain mathematics, level 1 or 2 is given to a task that requires the execution of known routines or procedures while level 3 or 4 is given to highly cognitive demanding tasks that require the student to do mathematics.

In this work, we are interested in analysing tasks that include both mathematics and programming. A task can be cognitively demanding both in terms of the programming aspect and the mathematical aspect. Another task can be demanding due to the mathematical content, but the programming aspect of the task is trivial, e.g., running provided programs. Yet another task can be cognitive demanding due to complex programming, but the mathematics is simple. Thus, we extend the framework of Boston & Smith [10] to include a second axis that specify the programming potential of the task, shown on the right side of the table below. Note that a task will in general be given different levels in mathematics and programming.

Level	Mathematics (see, [10])	Programming
4	The task asks students to engage in the disciplinary activities of explanation, justification, and generalization or to use procedures to solve tasks that are somewhat open-ended in nature.	The task has the potential for the students to engage in programming. Solving the task requires an iterative process that is not predictable to the students. Building a solution must be done in a stepwise and cyclic manner with prototyping, and testing.
3	The task requires students to make connections to underlying mathematical ideas but does not	The task has the potential to challenge the thinking of students or to engage the students in making connections

	include explicit requests for generalization or justification.	between programming concepts or procedures. The student must combine several concepts in programming to solve the problem.
2	The task requires students to perform relatively routine procedures without making connections to the underlying mathematical ideas.	The task is limited to engaging students in known procedures, either specifically called for or known from prior knowledge. There is little to no ambiguity about what needs to be done or how to do it.
1	The task requires only memorization or the reproduction of facts.	The task is limited to engaging students in memorizing simple concepts or syntax. There is no need for the students to understand or make connections between the implemented code and facts.
0	There is no mathematics in the task.	The task requires no programming skills. This includes running code without the need to understand the code.

As an illustration of a typical task that is categorized to level 1 or 2 in programming, Chapter 6 in [8] gives an example of solving an equation with Newton's method (all example tasks are translated to English):

```
def f(x):
    return x**2 + 2*x - 1 # Enter function here
def d(x):
    return 2*x + 2 # Enter the derivative here
x = float(input("Choose a starting value for x: "))
while abs(f(x)) > 0.0000001:
    x = x - f(x) / d(x)
print("The answer is x = ", round(x,  5))
```

In this chapter the textbook proceeds to give 6 tasks that ask the student to solve different equations with the Newton method, e.g.,

> Find approximations of the two zeros of the function:
>
> $$f(x) = x^2 - 5x - 5$$
>
> by using Newton's method and Python.

These tasks are therefore classified as level 1 in programming because the student should only replace the expression for the function and its derivative. It is classified to level 2 in mathematics because the student must use known procedures to calculate the derivative of the function. Similar tasks are classified to level 2 in programming if the modification to the provided program is more demanding.

An example of a task that is classified to level 3 in programming is given by task 4.92 in [6]:

Let f be given by $f(x) = \frac{1}{5}x^2 - x - 1$ Write a program that finds the smallest whole number, n, such that $f(n)$ and $f(0)$ have different signs.

Here the student should recognize that the task can be solved by a combination of a while loop and an if-statement. The complexity of a script that solves this task is similar to the Newton problem above, however, in this task no examples of similar worked tasks are provided. The task is categorized to level 2 in mathematics.

2.2 Textbook analysis

First, two of the authors read all tasks given in the textbooks and sorted out the tasks that explicitly asks to be solved by programming. There are other tasks that have the potential to be solved using programming, but we only included tasks explicitly asking the student to use programming. Further, we did not include tasks that are to be solved by other digital tools, such as Computer Algebra System or graphical computer software (e.g., GeoGebra). Both textbook series use Python as a programming language. The 11th grade textbook of Mønster [6] has a dedicated appendix that is an introduction to Python. Tasks in this appendix were not included in the analysis as it mainly focuses on basic programming skills and not mathematics.

The programming tasks were then classified according to the five levels of cognitive demand along the two axes of mathematics and programming. All tasks were classified independently by two authors that have different background and competence; one author has a background from engineering and applied mathematics with considerable knowledge about programming, and the other author has extensive experience from teaching of mathematics in upper-secondary education, with less knowledge about programming. Tasks that were classified to different levels by the authors were discussed until an agreement was reached.

3 RESULTS

Table 1 shows the number of tasks categorized for the two textbook series at 11th and 12th grade (16-17 year old students). In both series the number of programming tasks is more than doubled in the second book (12th grade) compared to the first book (11th grade). Furthermore, programming related tasks cover a wide range of mathematical topics and are given in almost all book chapters of both series. Fig. 1 shows how the programming tasks are classified for the 11th and 12th grade textbooks. The average programming level is 1.9 and 1.8 in the 11th and 12th grade textbooks, respectively, and the average mathematics level is 1.6 and 1.9 in 11th and 12th grade textbooks, respectively.

Table 1. The number of tasks in the four textbooks that include programming. The parentheses give the ratio of programming tasks to the total number of tasks for each textbook.

Name of textbook series	*11th grade*	*12th grade*
Sinus	20 (1.7 %)	46 (4.5 %)
Mønster	24 (2.2 %)	60 (7.9 %)

Table 2 shows how all tasks in the two textbook series are classified. 105 of the 156 tasks are classified as having a low cognitive demand (level 2 or lower) in both mathematics and programming. There are 35 tasks that are classified to level 3 or 4 in mathematics and 26 tasks that are classified to level 3 or 4 programming.

Even though the majority of tasks are classified as less demanding (level 0-2), many of these tasks do include relatively complex programming and mathematics. The reason they are given a lower level is that examples shown previously in the text are very similar to the tasks given the student. Both textbook series extensively give tasks that require the student to modify provided examples. These tasks are mainly classified to level 1 or 2, depending on the complexity of the modifications.

We will now study two selected tasks in depth. Task 1.32 in Mønster [7] is translated as follows:

> The sum below converges to Euler's number e quickly:
>
> $$1 + \frac{1}{1} + \frac{1}{1 \cdot 2} + \frac{1}{1 \cdot 2 \cdot 3} + \frac{1}{1 \cdot 2 \cdot 3 \cdot 4} + \cdots$$
>
> Write a program that asks the user for the number of terms in the sum and then calculate the sum of these first terms.

This task can be solved by a double loop (or a single loop and using the factorial function in the Python *math* library) and the students are not given any similar examples. The task is classified to level 3 in programming, and in terms of mathematics it is classified as level 2. The other textbook series, Sinus [9], gives an equivalent task (1.306) where the students are asked to study different series

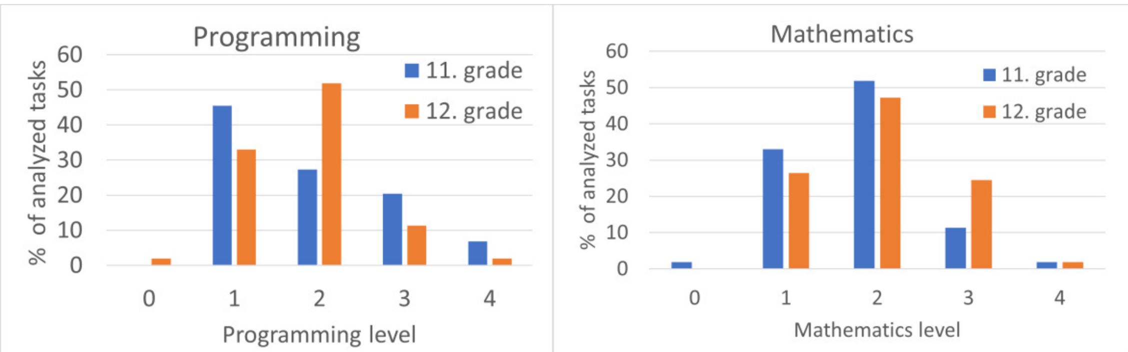

Fig. 1. The fraction of programming tasks at each cognitive level for programming and mathematics.

Table 2. The number of tasks classified to the different levels for programming and mathematics. E.g., there are 36 tasks classified to level 2 in both programming and mathematics and 20 tasks that are classified to level 2 in programming and level 3 in mathematics. The top row and rightmost column give the column sum and row sum, respectively.

Programming level \ Mathematics level	0	1	2	3	4	Sum
Sum	3	44	74	33	2	156
4	1	0	0	3	1	5
3	0	3	12	5	1	21
2	2	15	36	20	0	73
1	0	24	26	5	0	55
0	0	2	0	0	0	2

expansions of the Euler number. However, this textbook takes a different approach; Here the task provides the students with a script for calculating the sum given in the task above. The students are then asked to modify the program by trying different approximations of e, e.g.,

$$e = \frac{1}{2}\left(\frac{1}{0!} + \frac{2}{1!} + \frac{3}{2!} + \frac{4}{3!} + \frac{5}{4!} + \cdots\right),$$

and compare the different approximations and reflect, discuss, and evaluate the different convergence rates of the sums. This task is classified as level 2 in programming and level 3 in mathematics. This illustrates how different formulations of a task may change the classification of the task. In Mønster, the focus is on the implementation of the task in Python, while Sinus uses programming as a tool for studying and understanding different convergent sums.

Both textbook series use programming to motivate concepts in mathematics. In task 2.72 in [9], programming is used to investigate the derivative of the natural logarithm. Both derivatives and numerical approximations (including Python implementation) are presented previously in the chapter, however, the analytical derivative of $\ln x$ is unknown at this point:

> We will now look at the function:
>
> $$f(x) = \ln(x)$$
>
> Make a program in Python that prints out a and a numerical approximation of $f'(a)$ for $a = 1, a = 2, a = 3, \ldots, a = 10$.
>
> Can you generalize a rule that seem to be true?

The purpose of this task is to let the student discover the relation between the natural logarithm and its derivative, and the students must themselves make conjectures. This task is given a programming level of 2 because the students have previously been exposed to numerical derivatives and making tables of function values using a loop. The task is classified to level 3 in mathematics.

4 DISCUSSION AND CONCLUDING REMARKS

One of the main arguments for introducing programming in mathematics education is to improve the computational thinking and problem-solving skills of students. From the analysis of the textbooks in Section 3, however, we show that most of the given tasks do not require a higher cognitive demand of the students. Only occasionally do the tasks ask the student to explore, investigate or evaluate the answer obtained by programming. Of course, not all tasks in a textbook should require a higher cognitive demand, and drill and routine tasks should also be provided in a textbook. The optimal ratio of cognitive demanding tasks and practice tasks is an open area of study. A line of further research is to investigate if tasks that include programming are in general scored at a lower or higher level than the tasks that do not include programming.

In our analysis we use the presented two-dimensional framework on the programming tasks provided in four mathematics textbooks. We find the framework useful when discussing these tasks, and the framework works as a communication bridge between the two authors with substantial different programming and mathematics background. Labelling the tasks also initiated reflections upon how tasks could be improved and extended. While the framework is tested on upper-secondary textbooks in this paper, we believe that it can also be used in both higher and lower educations as well.

When classifying the tasks in textbooks we assume the students to follow the progression of the textbook. In a classroom, the teacher can use the textbooks in different ways, e.g., carefully selecting or adapting textbook tasks. This will, however, require teachers that are confident in their programming skills. The original framework in [10] has been used as a tool for selecting and adapting mathematical tasks. We believe that the extension presented in this paper can be used to select and adapt mathematical tasks that include programming. Further research is planned in the “Programming for understanding mathematics” project to study how these textbooks are used in practice by teachers.

For the engineering educations, the introduction of programming in schools will have an impact on the background of new students. As shown in this paper, Norwegian students will probably learn elementary programming with Python, but they will have limited experiences with cognitive demanding programming tasks, also on the highest level of mathematics courses in school. In most countries, programming is a new topic in the school curriculum. If the aim is to give students problem solving skills, in mathematics, or in programming, this paper shows that the curriculum resources given the teacher may be insufficient to stimulate this. For the engineering educations, it is therefore necessary to investigate both the curriculum changes and the curriculum resources such as textbooks, to understand how programming is implemented, in the respective countries, and how this might affect student outcome. Based on our experience, the proposed framework can be used as a tool to analyse tasks given in upper-secondary education.

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INTRODUCING AUTONOMOUS VEHICLES INTO AN UNERGRADUATE ENGINEERING COURSE

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ABSTRACT

Autonomous vehicles (AVs) are of great interest for the automotive industry and are expected to revolutionize mobility and public transportation. The university can contribute to the design and development of autonomous vehicles both in the field of teaching and in research and technology transfer. In this paper, it is described how this topic is introduced in an undergraduate engineering course, "Implementation of Automatic Control Systems (IACS)". The IACS course is based on project based learning (PBL) and learning by doing methodologies. Several practical examples that correspond to real automatic systems are discussed throughout the course and one of them, a low-cost AV to which a Raspberry pi has been adapted, forms the basis for a final project of the course. The control algorithms are developed on MATLAB/SIMULINK and are sent to the Raspberry through a wireless communication network. The control objective of the system is the automatic guidance of the vehicle through a single lane indoor closed circuit, the detection and identification of different traffic signals and the automatic response to these signals. Students check the behavior of the vehicle and proceed to make improvements. Based on the assessment of the students and the robustness of the autonomous vehicles, it is time to consolidate this type of project within the course. Students that want to get deeper into the matter have the opportunity to do a final degree project related with the AV.

1 INTRODUCTION

1.1 Autonomous vehicles

Autonomous vehicles (AVs) are expected to revolutionize mobility and public transportation [1]. There are different types of autonomous vehicles for research and academic purposes. A system classification is required. The most system classification is the one proposed by the Society of Automotive Engineers (SAE) [2]. In this classification there are five levels of automation: from low levels related to human drivers assistance to high levels are related to high automation or fully automation (the autonomous vehicle has the functionality of fault tolerant hardware).

The context of this classification is operate an AV in on-road traffic and developing dynamic driving tasks. The driving automated systems is capable of guiding the AV throughout complete trip, interacting with other AV, solving contingencies, minimizing risk, diverse traffic and weather conditions.

In this paper autonomous vehicles are related to low cost autonomous vehicles with the flexibility to incorporate control electronics, communications with the environment and scalable functionality to generate a wide range of experimental tasks. In a first approach the context of use is in laboratory conditions. The dynamic driving tasks of the SAE must be adapted in this scenario. The main objective is the design and development of a robust AV and proof that this AV can perform dynamic driving tasks with high effectiveness.

2 METHODOLOGY

2.1 Academic aspects

In the university industrial bachelor degrees of the Barcelona East School of Engineering (EEBE) on the Diagonal-Besòs Campus of the Universitat Politècnica de Catalunya (UPC), authors develop the course "Implementation of Automatic Control Systems (IACS)". This course is an elective course in the last semester of the industrial degrees with 6 European Credit Transfer and Accumulation System (ECTS).

This course applies the control theory in the development of electronic prototypes and using tools and devices as MATLAB and Raspbebrry pi.

It is an interdisciplinary course since students come from all areas of engineering that are taught in the teaching center (mainly industrial electronics and automatic control, electrical and mechanical engineers). The prerequisites of electronics, programming and linear control theory that are necessary for student success are provided in previous core courses. Good skills in team work are required for the design, development, programming and evaluation of autonomous vehicles prototypes. The course is also available to Erasmus / Exchange students that can have different backgrounds.

The appearance of failures, unexpected vehicle behavior, battery performance, performance of programmed algorithms, require the group to show its ability to resolve contingencies and obtain good vehicle performance.

Authors are driving too final degree projects with the aim to develop first autonomous prototypes with help of the maintenance staff. With the idea of building scalable systems in mind, the student's training is focused on recommending that they first take the course and secondly that they can develop the final degree project.

For the development of fully AV, more capabilities are required. In this sense, the approach presented in this paper should be extended to engineering master's courses and research activities. The authors are developing active work in the development of fault tolerant and safety AV and can provide feedback. The research is developed in a research laboratory and there is a relationship with the academic laboratory commented in this paper.

2.2 Laboratory Practices

The IACS course is based on PBL [3] and learning by doing [4] methodologies. Several practical examples that correspond to real systems are discussed throughout the course and one of them, an AV, forms the basis for a final project. There is a student teaching guide for every practical example with the description of the steps to follow to success in the implementation of an automatic control in a real system (modeling, identification, design, implementation and assessment of the performance) and a description of the results that the student should obtain.

In particular, in the AV example, the implementation of a simple driving automated system in an adapted Van vehicle (shown in Figure 1) is proposed. The vehicle is equipped with a Raspberry Pi 3 B board, a servomotor (steering angle), a DC motor (forward and reverse speed of the vehicle) and a camera. The power supply of the module consist of 5 AA rechargeable batteries and a voltage regulator of 5 Volts. The total cost of the components of the adapted Van vehicle is around 200€.

Fig. 1. Van vehicle adapted with Raspberry Pi 3 B+.

The system is presented as a particular automatic control system composed by the different elements: plant (Van), controller (Raspberry board), actuators (motors) and sensor (Camera). And the control objective is defined as the automatic guidance of the vehicle through the single lane closed indoor circuit depicted in Figure 2.

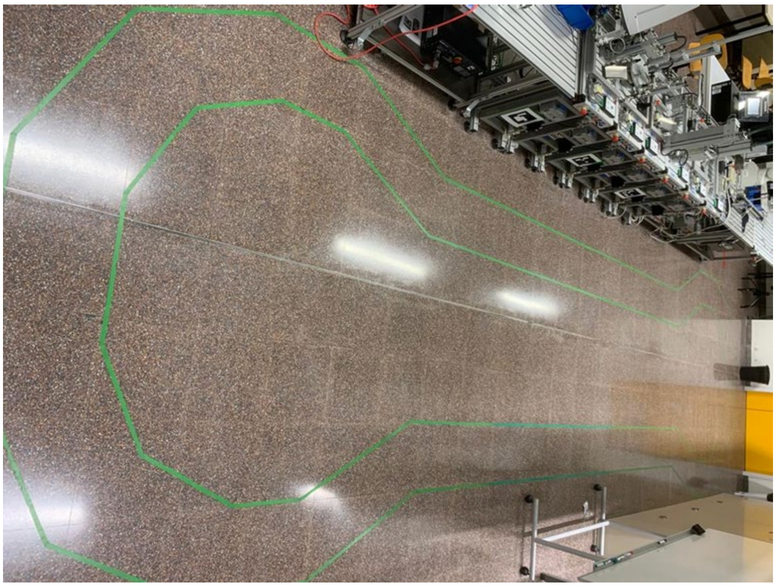

Fig. 2. Single lane closed circuit in the Automation and Indsutrial Robotics Lab. of the EEBE

The AV guided practice consist in three different steps:

a) connecting the vehicle with MATLAB/Simulink through a wireless communication network WIFI conection (router WLAN connected in the Cisco Switch of the laboratory) in such a way it is possible to process the images captured by the camera and control the steering angle and speed of the vehicle.
b) how to extract the bounds of the circuit lane (in green color) from the images of the camera.
c) how to use the information extracted from the circuit lane bounds to try to align the vehicle with the lane of the circuit.

For this last step, the filtered image that contains the bounds of the lanes is binarized and the centroid of the image is computed (Figure 3). When the vehicle is completely aligned with the lane, the centroid will be aligned with the vertical axis of the image. Therefore, the angle of the centroid with the vertical axis is used as the controlled variable in a close loop system where the controlled variable is the direction of the vehicle and the control objective is to maintain as close as possible the controlled variable to zero (vehicle aligned with the lane).

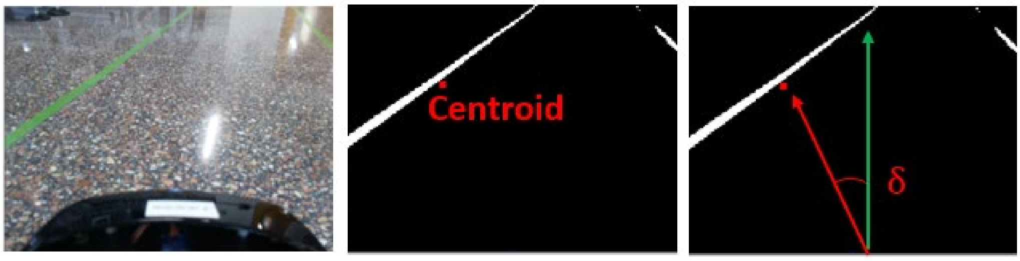

Fig. 3. Raw and binarized images with centroid and angle deviation δ computations.

In this control system there is another variable that has an important role in the performance of the system, the speed of the vehicle. In this first approximation of the automatic guidance it is considered to be constant. Finally, students are encouraged to detect the limitations of this first approximation of the automatic guidance of the vehicle and the final project of the course is proposed as the implementation of a new (and original) solution. This solution should be robust, reliable, stable and should include other capabilities as the detection and identification of different traffic signals and the automatic response to these signals.

2.3 Project development.

When defining the course content, professors discussed about the software to be used in the laboratories. As all students of EEBE school and most of Erasmus students have used MATLAB program in previous courses and some of them even have used Simulink, the election was clear. In addition, the interface of this software makes programming and learning easy and it is relatively easy to implement complex systems as the one depicted in Figure 4 that implements a possible solution to the AV system.

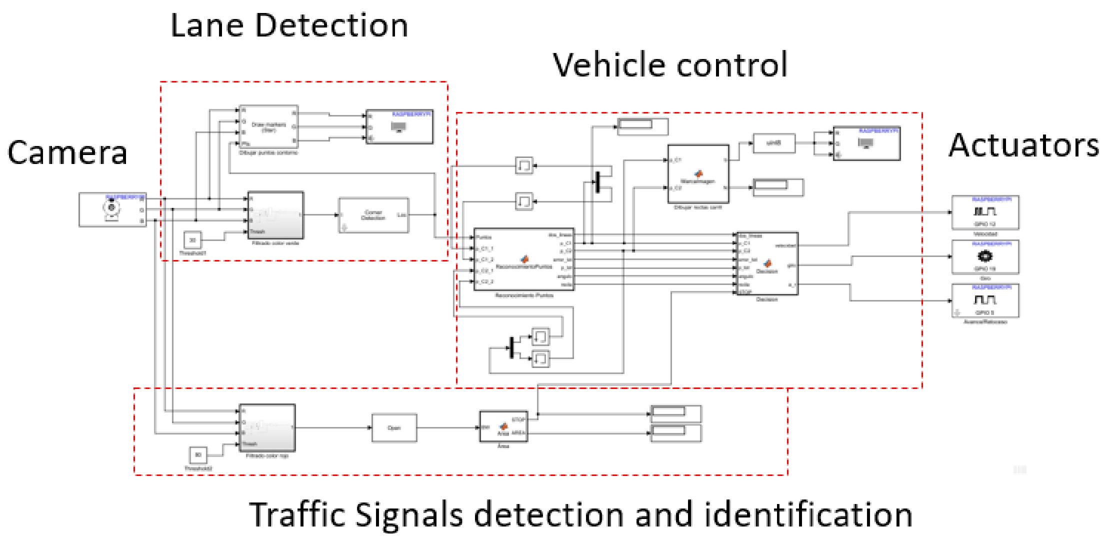

Fig. 4. Blocs of Simulink circuit that implements AV solution

Red boxes in Figure 4 show how is possible to develop scalable functionality using Simulink (lane detection phase, vehicle control phase, etc.).

To develop the project, the students work in groups of two or three and they have 12 hours of experimental sessions to carry out all the work. The professor discuss with the student team and helps to identify the correct solutions but the final solution and the features to be improved are completely proposed and developed by the students. In the last lab session, each student team presents a summary of the project as well as a demonstration of how the AV system works. After this presentation, professors ask some questions in order to clarify possible confusing points and to assess that all the members of the team group know in deep the final design. The evaluation of the final project is done considering the oral exam and the report of the project. This final evaluation of the overall project counts for 40% of the final mark of the course.

2.4 Final degree project.

Students that want to get deeper into the matter have the opportunity to do a final degree project related with the topic improving the vehicle used in the IACS course and using more professional programming enviroments as the Robot Operating System (ROS). ROS requires lower-level concepts and a steeper learning curve than MATLAB/Simulink enviroment but allows the use of powerful vision libraries as OpenCV [5] and the implementation of advanced artificial intelligence algorithms for the control of the AV as in current professional solutions [6][7].

Figure 5 shows the graph diagram that implements a possible solution to the AV system: From the initial nodes *raspicam_node* and *controller* that allow the capture of images and the implementation of manual/automatic mode selection respectively. To the final node *car_control* that implements the auntonomous control considering the environment information obtained from the image processing steps and the controller state. This solution was proposed in a final degree project [8].

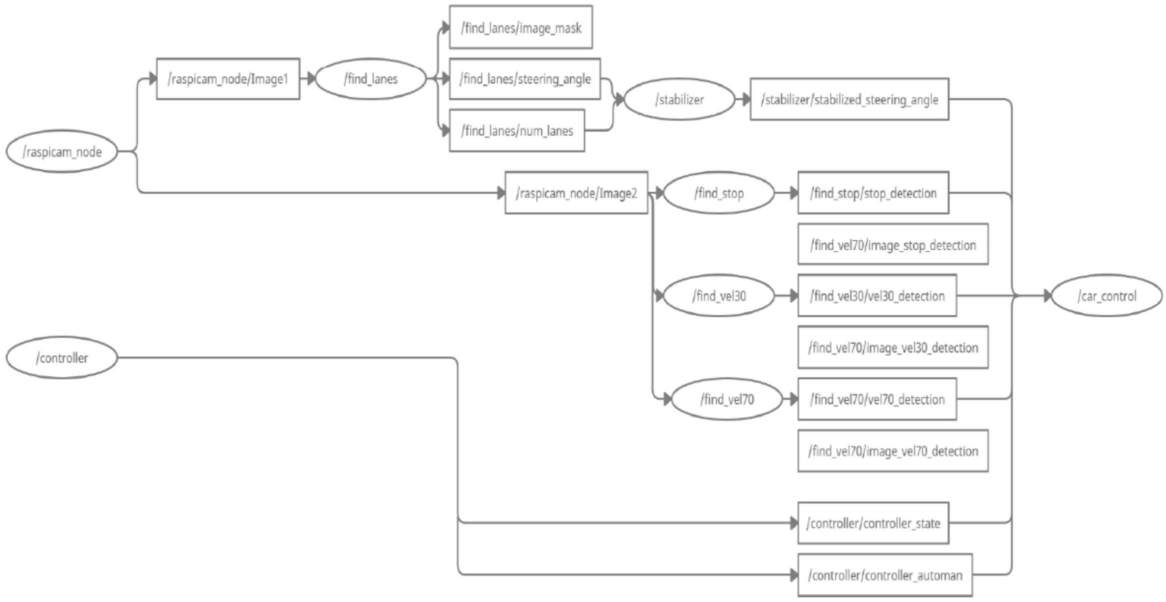

Fig. 5. ROS graph diagram showing nodes and topics to control the AV.

Taking into account the students'experience and feedback, new and more complex solutions usually require modifications not only in the programming but also in the hardware setup as for example the use of more powerful Boards that can require a enhanced power supply. For example, ROS software requires at least Rasberry Pi 4 B board that increases the current consumption. Therefore, the new AV requires a more complex power supply unit. In [8] a lithium polymer battery (LIPO) was selected as a suitable solution intead of the original AA rechargeable batteries solution as it is shown in Figure 6.

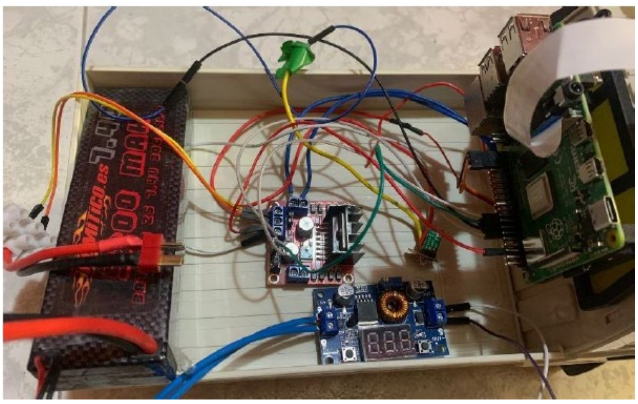

Fig. 6. Van vehicle adapted with Raspberry Pi 4 B.

3 RESULTS

At the end of every quarter, an anonymous survey is conducted by the UPC to obtain feedback from the students of the different courses. In particular, two questions are asked: “1. The contents of the course seemed interesting to me” and “2. Overall, I am satisfied with the course”. Both questions are scored from 1 (strongly disagree) to 5 (strongly agree) and in the case of IACS course the students have graded an average score of 4.14 and 4.43 to the first and second questions respectively. That is a score 0.3 and 0.9 points above the score obtained in average for all the courses offered by the UPC. In addition, more than a halft of the students that take the IACS course are interested in doing the finall degree project related with the topics of the course. Regarding academic results, 13% of the students have satisfactory results [5,7), 40% very good results [7-9) and 40% very good results. Finally, only 7% of students have not satisfactory results [0,5) because they have problems to attend to the experimental sessions.

4 SUMMARY AND ACKNOWLEDGMENTS

This article presents an example of how Autonomous Vehicles have been included in an undergraduated engineering course in a motivating way, in particular, in an elective course of the industrial bachelor degrees of the Barcelona East School of Engineering at UPC. AV have been introduced first in an introductory guided practical lab and after following learning by doing methodology to solve a real-world problem. Learning by doing is used to increase students’ interest and at the same time help them to acquire and apply new knowledge in a problem-solving context. Student surveys and assessment results confirm the student’s great interest and success in the course.

As future lines, the authors want to introduce AV in other courses. In particular, in an advanced control elective course in the last semester of the Bachelor's degree in Industrial Electronics and Automatic Control Engineering. Previous background of students in automatic control, programming and electronics will be deeper than the one of average students in IACS course. This circumstance will allow the use of ROS environment in the implementation of AV algorithms. However, a key point to obtain satisfactory results will be the design of educational modules to simplify learning about this environment. Because ROS is not in the curricula of previous courses of this Bachelor degree.

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A RESEARCH PROGRAM ABOUT A SHORT-TERM PBL APPROACH BASED ON THE SDG

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***Keywords**: PbL, Sustainability, Short-term PbL, Assessment, Innovation*

ABSTRACT

Increasing populations in urban areas create complex problems, such as access to drinking water, sanitation, housing, and traffic. Today's engineers are prototyping solutions for future cities. Engineering education must meet this challenge, with students developing knowledge in their engineering field while addressing Sustainable Development Goals (SDG). Problem-based learning (PbL) is a valuable tool in engineering education, particularly for sustainable development. In PbL, students solve engineering problems by developing projects. For example, students in early courses can confront problems demanding low-tech solutions. The Federal Center for Engineering Education in Rio de Janeiro, Brazil, offers short-term project experience (PbL) focusing on SDG in cities. For 48h, students tackle SDG problems from urban communities and are challenged to create low-cost solutions. In the end, they pitch their solutions to experts from NGOs, governments, and corporations. This article presents a short-term PbL approach for SDG supported by one case developed by the students and concludes with recommendations for a research

program, aiming to understand the process and transform the projects into concrete, sustainable, social innovation actions applied to communities.

1 INTRODUCTION

With the global population increasing and natural resources limited, learning about sustainable living is essential since sustainable development is society's responsibility.

There are several models for sustainable development, the most common being Elkington (1994). In this model, sustainable development is based on a Triple Bottom Line (TBL), where projects must be: (a) financially profitable; (b) environmentally sustainable; (c) and socially fair. TBL amplifies the concept of sustainability to a broader view.

In general, when people are being educated and training to performance in a given professional field, some skills and competencies are required to be developed in early stages of the education, or training program. They constitute the fundamentals of a given knowledge area, disciplinary field, or professional practice. See for example the specific case of engineering design and the development of technical solutions. In this context, engineers must be able to identify community problems and find creative solutions. In this context, and to integrate sustainable development, they should be able to take TBL into account and integrate it when identifying, formulating and solving such problems.

Engineering education plays a significant role through training that creates a design mindset for sustainable development through the integration of UN's Sustainable Development Goals (SDG) and TBL perspectives in the design processes. In addition, it is necessary to encourage behavioral changes through a better understanding of the world, and that problems are complex and interrelated, such as poverty, predatory consumption, public health, and conflicts. This calls for competences such as complex problem solving, interdisciplinarity, systems thinking (Guerra, 2017).

According to UNESCO (UNESCO, 2022), this requires a new view of education, grounded in democratic and emancipatory values, contextual and experiential learning, students' centeredness and active learning, capable to motivate students to, for example change their behavior, take on attitudes, solve challenges, reflect on future scenarios, and contribute to sustainable development across the three axes of TBL.

One methodology that has been used is Problem Based Learning (PbL) to educate engineers for sustainable development. This is a student-centered methodology, where team of students learn by solving real authentic problems through projects. Students and teachers seek to analyze, understand and propose solutions to situations designed to ensure the acquisition of certain skills provided for in the school curriculum. These situations are scenarios that involve students with facts from their daily lives (Graaff & Kolmos, 2007; Kokotsaky et al., 2016) There are several approaches on how PBL process is organized around projects. One example is the short-term projects. In this approach, learning is carry out through learning cycles (sprints), with small teams supervised by mentors, so that at the end of the process, students present a prototype of the solution to the proposed problem. The process develops skills that range from identifying and solving real and authentic problems to the implementation and evaluation of the solution. The problems call to be researched and solved enabling, in simultaneous the acquisition of engineering knowledge and development of professional skills resulting in collective knowledge. Additionally, PbL process creates collective knowledge and sharing as result of students' collaborative experiences which are proven essential in the development of their curiosity and inquiry skills for their and for engineering courses (Freire, 1987;).

In this line of thinking, there are hackathons or bootcamps as a strategy for the creation of new ideas, products or processes. In overall, these events start with a challenge which is addressed through a projects and in a short period of time.

In the context of higher education, engineers have a direct relationship with the knowledge and technologies production that directly impact in society and the environment. In this way, it is necessary that the engineer formation, in addition to being based on solid technical knowledge, is also associated with non-technical knowledge, so that they are aware of their social role so that they can deal with social and environmental aspects of technologies.

PBL is a powerful tool for developing skills related to sustainability, by associating the production of technical knowledge with sustainable development.

It would be interesting to apply a PbL approach to be applied quickly, in a hackathon model. This can serve as a strategy to be developed with students several times throughout the course.

1.1 Expin 48: Short-PbL approach to educate for sustainability

An educational event called Short-Term PbL was developed based on the PbL concept at the Federal Center for Technological Education of Rio de Janeiro *(CEFET/RJ)*. It is a PbL activity carried out in 48 hours, outside class time, which can be used to activate essential skills required for engineering projects, such as teamwork, leadership, and creativity (d'Escoffier et al., 2021a).

CEFET/RJ is a Technology Education Center based in the city of Rio de Janeiro/Brazil, with campuses in 7 other cities in the State of Rio de Janeiro. The Short-Term PbL event was titled *Expin48* (Experience in Innovation Projects – 48 hours). In this event, undergraduate and graduate engineering students and vocational course students are brought together for 48 hours to create solutions to real problems based on existing issues in urban communities focused on the SDG.

During the development of a project, the initial ideas are transformed and matured until the generation of a product or process that addresses the identified problem. Thus, it is to be expected that different products are at different levels of maturation at a given time. It is also understandable that the same product has different levels of maturity in different aspects. Hence the importance of measuring the level of maturity of a product, as it locates the stage of reflection in this aspect, indicating the points that need more attention, assisting in decision making in the development of the project. Solutions planned in this event can be continued later for more in-depth knowledge and better-developed skills. Therefore, the whole process has several stages of maturation. The first stage of this maturation is the presentation made after 48 hours to representatives of companies, research institutions, and NGOs.

Therefore, the projects developed during *Expin48* are not considered finished solutions due to their short incubation time. Indeed, the solutions that come from this initial stage are presented to external evaluators at various stages of maturity, even with the short development time.

1.2 The Problem

PbL is a transdisciplinary approach with complex objectives involving analyzing and resolving heterogeneous problems. Therefore, in parallel to activating and developing skills and competencies, PbL must ensure that theoretical curricular content is transmitted through collective work involving cultural and social aspects.

Although the overloaded and rigid education curriculum for sustainable development makes it difficult to integrate with PbL, this methodology seems to be the answer to incorporating sustainability into engineering curricula (Guerra, 2017).

However, since PbL is a curricular activity, the student must be evaluated at the end of the process. Therefore, the strengths and weaknesses of evaluating projects based on SDG must be addressed.

Sustainability is difficult to measure because it is an extensive topic and mainly depends on the reality of a context. Moreover, this context is usually dynamic and multifaceted, making it difficult to identify common characteristics and ways to measure them.

There is little in the literature regarding metrics for objectively evaluating PbL projects. Assessments are often subjective, where students are assessed by self-assessment or peer reviews. Although these methodologies should not be overlooked, serving as a basis for the teacher's judgment, it is essential to make what is implicit, explicit.

Therefore, this calls for the development of an instrument to evaluate Short-term PbL projects, focusing not only in the engineering learning acquired but also the three axes of sustainability. In the following section, we present the design of PbL intervention, entitled *Expin48*, the evaluation instrument and its preliminary results.

The objective of this study is to reflect on an evaluation proposal for short-term PbL projects based on the three SDG axes of sustainability

2 RESEARCH PROPOSAL

The working hypothesis is that different projects will have reached different maturity levels across various dimensions by the end of the process. For example, in the case of SDG, these dimensions would be the 3 axes of sustainability: financial, environmental, and social. By establishing the project's maturity level along each axis, the degree to which students could assimilate sustainability concepts and concretize them in products can be measured. Furthermore, projects can be given continuity by projecting future goals, potentially reaching a level where the project can be implemented in the reality.

3 METHODOLOGY

3.1 The idea

The process of how the students built the knowledge and the product presented at the end must be understood to determine a project's maturity level across the SDG dimensions. Therefore, indicators of the production of conceptual knowledge need to be created, and scales where values that represent the desired effects need to be defined. This data can facilitate a global assessment of the project's maturity from both the process and product points of view.

3.2 How?

The construction of the assessment instrument comprises two phases: a qualitative phase, conducted using an ethnographic approach; and a quantitative approach, using a maturity map. The first is an ethnographic methodology, where a researcher in the field will accompany the team throughout the project's development. This entire process will take place through observation and description of the process of how students deal with the difficulties imposed by the project, how they interact with mentors, and how they seek solutions. This research will reveal previous knowledge about the SDG dimensions, new knowledge learned, and how teams built their knowledge networks (Braga et al., 2021b; Braga & Guttmann, 2019).

The second will have a more quantitative character. A maturity map will be constructed for this data collection based on the SDG axes (environmental, financial, and social). Previous work on developing the short-term PbL will be leveraged to build this map. These tools will allow the team to document each project's final level of maturity.

The evaluation instruments where pilot in the specific case of a short-term PbL developed in 2020.

4 PRELIMINARY RESULTS

4.1 The problem

In 2020, the winning team of *Expin48* chose the theme "Renewable Energies." The students visualized energy generation as a problem for communities on the banks of the Amazon River system in the northern region of Brazil.

A researcher followed all the group's work as a silent observer, and the students accepted their presence in one of the rooms of the Microsoft Teams platform. From these observations, some questions were raised that can be used to build a project maturity assessment model.

4.2 The context

The group defined 5 basic requirements that the solutions should meet: low cost, clean energy, practical transport, easy to install, and durable. Then, they proposed three alternative solutions: an electric generator that uses the current of the rivers, a system of solar panels with surplus energy credits returned to residents, and a generator that uses reusable oil as fuel.

The group chose to use the river current to generate electricity. Some communities partially use solar energy, but the communities are so isolated that there is no use for the surplus power they generate. Oil was also rejected due to transportation issues and environmental risks. It should be noted that many communities are supplied with energy via a diesel generator.

Brazil is a continental country, with 80% of its population concentrated in coastal cities, interconnected by various means of transport. The Amazon is a region with forests and rivers spread across 9 countries in South America, 60% of which are in Brazil. Almost all communities are located along rivers with different volumes of water. These rivers are the region's roads since the jungle terrain is soaked by daily rains, making maintaining roads in the area impossible. Using rivers to generate electricity acknowledges that all technology has to adapt to the characteristics of each region. There is no standard solution. Therefore, by choosing to invest in this vast river system, a territory offered freely for engineering, the students showed maturity in adapting the project to the problem. In evaluating sustainable engineering projects, they demonstrated the suitability of the Triple Bottom Line in focusing the main project on environmental, financial, and social sustainability.

4.3 The design

After an in-depth theoretical study verifying the technical and budgetary feasibility of the options, the students designed a generator connected to a rotor in the style of old mills. In this generator, the blades are rotated using the river current. These blades are coupled to a generator and an alternator. In addition, there is also a photovoltaic kit consisting of a battery, a 60Wp module, an inverter, and a charge controller capable of capturing the solar energy that falls on the water sluice. Finally, the entire system is coupled to a support structure for stability and buoyancy, as shown in Figure 1. The students calculated that the system generates less energy than a diesel-powered generator, but the installed capacity can generate the same power for a much lower cost since a higher average river speed can generate a higher amount of electricity.

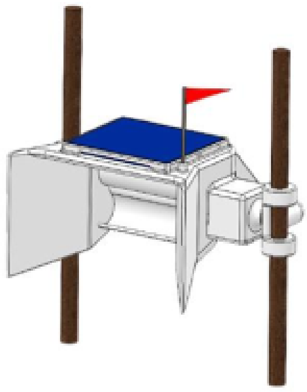

Fig. 1: Prototype modeled in CAD

4.4 Secondary problems

After having the general topics of the project approved by the mentors, they began to face secondary problems that were not part of the reality of the region where they lived.

- Water level variation throughout the year

In the southeastern region of the country, where the students come from, the water level does not vary significantly throughout the year. The original project envisioned the generator floating on the water with axes that allowed it to go up and down. At the same time, this water level variation is critical in the Amazon. The difference in the height of the waterline between the high and low seasons reaches 15m. As a result, the riverbank can recede around 100m from where it was in high water, creating a dry region where the river once flowed. Therefore, any artifact created must float and be installed far enough away from the riverbank to follow the level of the river. This problem was not resolved within 48 hours of the event, but it became clear that it would be an obstacle to the project's economic viability.

- Risk to native species

There was a perception among the students that the rivers in the region do not have clean water. Debris from trees and leaves can prevent water from passing through the rotor. The rotor can also kill fish. This risk analysis was considered during the event. They arrived at a mechanism composed of blades with an angle that promotes self-cleaning and would tend to throw the fish back into the water if the rotor captured them. There was a high level of project maturity regarding the analysis of risks to regional fauna and flora.

5 DISCUSSION

Although there is still no defined scales, some conclusions can be drawn regarding the work presented by the group considering the SDG since some of the authors participated as mentors at the event and followed the process of building the product.

In terms of the environmental axis, the project was reasonably mature. The choice of a renewable and abundant energy source in the region (river currents) and the concern for flora and fauna present in that ecosystem favors a good score in this regard. On the other hand, field observations suggest that the mentors may have driven progress on this issue during the event.

The group did not achieve a good score concerning the financial axis. Although they considered the cost of the generator and the seasonal variation of river levels (even if they did not solve the problem due to the short time), they did not consider, for example, the issue of maintenance. Maintenance can make the project unfeasible since defective equipment can leave the resident without electricity for days or even weeks.

In the same way, the social pillar was not mature either, although local demands for a better quality of life for riverside residents could potentially be met. For example, the students could have included involving the local community in energy issues or creating a network of local workers trained to maintain equipment, generating work and income.

6 CONCLUSION

This article presents a starting point for discussing a methodology for evaluating PbL and PbL short-term events focused on SDG consciousness. The case described offers a new point of view on evaluating PbL projects, making the qualitative and quantitative evaluations. The goal is to build a maturity map about the learning complexity of sustainability, joining of the environment, economy, and social approaches during the project's development. Here, engineering students developed short-term PbL focused on the SDG. However, this methodology could be applied in any PbL, correcting deviations and implementing improvements that can promote projects transforming into concrete, sustainable social innovation actions in communities and positively impact the evaluation of PbL projects.

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How do students transform good solutions from an educational challenge in a startup? A case study to entrepreneurship education

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Abstract

In many universities around the world several events of short term PbL are taking place. These are challenges proposed to the engineering students from concrete problems given by NGOs, governmental institutions, or enterprises. In general, they are named hackathons or bootcamps. The goal is to spark interest and develop skills linked to the design and the engineering project development in short-time sprints. However, most of these solutions are never implemented in practice by the teams that created them. The universities consider these practices as part of the education in engineering. Two Brazilian institutions (CEFET/RJ-Federal Center for Engineering Education-Rio de Janeiro and UFRJ-Federal University of Rio de Janeiro - Brazil) participated and won the

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international event named "Invent for the Planet" organized by Texas A&M University in 2019. The students developed an interface for blind people to walk on the streets avoiding obstacles. Back in Brazil, these students patented the product and created a startup to produce and introduce that solution in the market. Today they have an accessibility startup with several other solutions in addition to the one created at the event. This research has the goal to understand the ways that made these students transform an educational project into a feasible/successful entrepreneurial action. What was the motivation of these students? Where did they get additional entrepreneurship training? What lessons does this case can provide to engineering education? A set of interviews has been carried out to understand the process that can contribute to engineering entrepreneurship education in the universities.

Introduction

In many universities around the world, short-term events are taking place to challenge students to solve problems in the field of engineering. Many call such events educational hackathons. This type of event aims to spark interest and develop different skills and competences in the field of innovation and entrepreneurship.

The College of Engineering at Texas A&M University had already been developing short-term events aimed at training in innovation and entrepreneurship for some time (Boehm, 2020). These events are called "Aggies" and aim to create student immersion in a structured, intensive, and innovative design experience. Within 48 hours, after creating and prototyping a solution, students must "sell" their projects to a panel of judges from different companies and different types of institutions.

In 2018, TAMU decided to expand this event model, which was already working with its students, to the whole world. It was then that the "Invent for the Planet" (IFTP) was created based on the Aggies model. This event aims to challenge students from around the world to find solutions to problems provided by international institutions problems ranging from providing access to safe drinking water in vulnerable communities (USAID) to protection against damage to aircraft structures subjected to bad weather at airports (Airbus-USA).

The IFTP started in 2018 with 14 universities and in 2020 it already had approximately 40 universities from other countries around the world. The event takes place over a weekend in February. Each country holds its own event, but at the same time as all the others. It is possible to observe through cameras what is happening live in each country ~~live~~. While the sun sets in one region of the globe, in another it is already rising. You could say that during that weekend "The Sun Never sets on Innovation".

The event has a dynamic based on sprints with deliveries demarcated over time (status review). Mentors can interact with teams discussing the direction of the project without providing ready-made answers or solutions. At the end of the 48 hours, the teams must present the project results to a panel of judges in 3 different ways: a 90s video elevator pitch, a 10min presentation followed by questions from the judges, and a White Paper with the technical characteristics of the project.

Brazil started its participation in the IFTP 2019, when there were 6 teams involved with the proposed themes. The team called Tupan won the Brazilian section of the event with an accessibility project formed by 2 artifacts to guide the blind during walks. The first was a cap with sensors that allows the identification of obstacles ahead. The other was a sensor that, when pointed in certain directions, allows for the detection of holes (electronic walking stick). Both were inexpensively constructed artifacts. In 48 hours, the Tupan team was able to propose the idea, build a prototype and test the product with blindfolded and visually impaired people. The fact of developing a project with rapid maturity gave the team victory.

The elevator pitch and project description were sent to Texas A&M University. In 2 weeks, the team was informed that it had been selected for the final stage in Texas, along with 5 other teams from other universities. At that moment, the team was faced with a new problem that needed a quick solution: how to pay for the trip? After discussions, the team decided to create a crowdfunding on social media to raise contributions for the trip. The goal was reached in another 2 weeks. Arriving in Texas, the Tupan team presented and discussed the project with local mentors. In the end, it was crowned champion of Invent for the Planet 2019. Upon returning to Brazil, they decided to create a startup called Tupan to market that product (https://www.youtube.com/watch?v=g8trcNd7ogU)

In 2020, they expanded their concept to an accessibility solutions company.

As a result, some questions arose:

(a) What motivated the jump from the condition of a winning team in an engineering challenge to the creation of a startup?

Did the students have any training for entrepreneurship at the university? YES. How was it? NOT. How could such training be incorporated into curricula?

(b) Did smart money participate in this process?

We know that thousands of other teams go through the same process at many similar events around the world. However, it takes several steps with the acquisition of skills and new knowledge to make this leap. The big question is whether these skills were acquired at university or elsewhere before the IFTP. If not, it would be interesting to see if, in their view, there is any possible action to be taken in this regard in terms of building a new curriculum for engineering courses. Finally, it is important to know if the team sought this expertise elsewhere in the startup creation process. There are now several courses being offered for this purpose, mainly from SEBRAE, an institution in Brazil that brings together business and government associations to support entrepreneurship. In addition, there could also be the possibility of mentoring with an angel investor (smart money).

The purpose of this concept paper is to gather elements for the creation of a support program for projects that win short-term challenges of the IFTP type. These programs would aim to increase the "Technology Readiness Level" of projects (Mankins,1995), by bridging the gap between the events and the business incubators, both technological and social.

Methodology

During the event, the Tupan team was formed by 6 students, 5 from CEFET/RJ (Federal Center of Engineering Education – Rio de Janeiro) and 1 from UFRJ (Federal University of Rio de Janeiro). Of the 6 students, 4 were undergraduate students and 2 were graduate students. Only one of the undergraduate students was from Electrical Engineering, the others were from Mechanical Engineering.

After the victory of the Tupan team in Texas, the UFRJ student left the group. The rest remained in their courses, dedicating their free time to the construction project (planning?) of the startup Tupan.

The victory of the Tupan team in the IFTP took place in April 2019. The collection of information carried out for this work occurred in two stages between September and October 2021.

a) The first step of data collection was an interview with one of the team members who had a leadership role in the process. ~~In~~ During the interview, we sought to know the experience from the point of view of this student. Based on the information provided by him, a focus-group was scheduled with all 5 participants of the startup Tupan.

b) The second step consisted of a focus group including all the participants. The meeting was held virtually in October 2021. The questions were organized from the information given in the interview using a semi-structured model of questions. The use of the focus group aimed to obtain a collective mental reconstruction of the process through which the students went. During this process, each student could talk about their experience in the process and compare it with those of their colleagues. This information gathering technique allows a more reliable reconstruction of the facts, as it is shared by all those who have lived the experience.

c) The report was divided into 3 moments: (1) Before (2) During (3) After.

Experience Reconstruction

(1) Before

Participants reported that they had no background in entrepreneurship. During their university education, they were always more directed and focused on the technical aspects of the courses to which they related to. Participation in the IFTP was encouraged through the suggestion of professors. Despite this effort, there was no immediate interest. At first, they believed that they were going to participate in some type of training activity where their hard skills would be required. The entrepreneurial perspective or becoming a startup never crossed their minds, although the subject of entrepreneurship arouses some curiosity. In essence, they attended the event out of respect for their professors.

(2) During

The idea of the emergence of the product came from the ability of the components in (the team members' familiarity with ???) the use of sensors. From the definition of the problem and of the requirements for the solution, the development of the product occurred quickly. The construction of the prototype did not come across many difficulties.

The effectiveness of the proposal (The proposal was effective ??) and the built prototype was tested with a blind person, who used the product with relative ease. This immediately beckoned to (signaled) the usefulness and practicality of what they were developing. It is possible to consider that the moment of approval of the product by a blind person was fundamental for them to perceive the meaning (relevance ??) of the event. Winning the Brazilian stage was considered the apex of the process. The team did not expect to be in the finals.

People's adherence to crowdfunding on social networks was another incentive. In the United States, they participated collaboratively in preparatory activities for the final pitches. Despite being a competition, the Tupan team quickly realized the spirit of collaboration, one of the pillars of the event. All teams are encouraged to collaborate with each other.

When the winners were chosen by the judging committee, the Tupan team was taken to visit and present their prototype to companies and potential investors to make the product commercial on a larger scale. One of the companies visited, a company offering products for the visually impaired, commented that they regularly received product ideas and that few were relevant. She put to the group the challenge of delivering 10 prototypes to be tested with a greater number of blind people daily. At that moment, the team was faced with a new challenge: the ability to scale production in a short period of time. The prototypes were built and delivered on time. It was understood that there was an interest in the prototype and that the product was economically viable.

As a result of meeting and the demands of the interested company, the team received an offer to purchase the product patent for US$ 10,000.00. Dazzled by the offer and realizing the arising interest sparked by the prototype, they refused to sell the patent and decided to apply for a patent and develop the product upon their return to Brazil. At no time where they guided by the educational institution about business possibilities with the registration, sale, or percentage in the patent registration. It was their experience in the IFTP that led them to the decision of undertaking such initiative.

(3) After

After the decision to become entrepreneurs and start the activities that would characterize a business proposal, the members of Tupan team found at least two specific facts:

1. They had not received, in university education, knowledge that would prepare them for the business environment in the role of entrepreneurs. They were knowledgeable about engineering tools and techniques, but not about business management skills and, above all, how to build a business model.

2. They did not have access to financial, physical, and material resources that would enable the initial steps of the business: Although there is a technology-based business

incubator at CEFET/RJ, neither they knew about this fact, nor was the incubator informed of their desire to create the startup.

Regarding training for the new reality that they began to experience, the new entrepreneurs began to deal with issues that they were not used to, such as: finding suppliers, determining sale prices, establishing profit margins, determining delivery times, and choosing distribution channels. In terms of resources, they began to deal with a constant difficulty for any entrepreneur; for instance, getting smart money and angel investors. They chose to keep and run the business~~,~~ with their own resources. ~~In~~ At that initial moment, the startup became a side project in their personal lives. They sought personal financial support ~~in~~ from other projects and jobs while structuring the company with the proceeds from the sales of the first units that were being commercialized. To increase revenue, they created another product–the accessible personal card– to have one more way to generate resources. The company started to have a concept based on accessibility.

Highlight points from the focus group

Today the startup Tupan already has two products in its portfolio. The first is EVA, winner of the IFTP 2019. The second is a card with data on persons with disabilities that can be accessed by those who wish to obtain information about the person, without having to fill in forms or speak orally. But the startup has encountered difficulties in communicating with customers and distributing products. Everything is done through the company's website (https://www.tupan.net.br/). Revenues during 2021, up to the time of the interview, did not exceed U$ 2,000/year. The prize of US$ 3,000 received in Texas was the only external contribution of financial resources in 2019. The COVID19 pandemic had a strong impact on the business takeoff as well. Confinement has not made urban displacement an immediate necessity. Therefore, no matter how much the products were advertised, users did not feel an immediate need to purchase them. Students continued their courses, making of the startup a secondary activity. They will likely have to become employees of other companies for still some time. Despite knowing that accessibility products are products of a niche market, only after the end of the pandemic it will be possible to assess the real impact of the product on the market.

Asked about what kind of support has made a difference in the development of the startup in the first moments, they highlighted the following items:

1 – Having participated in the University Incubator

For them, being incubated means much more than only receiving a physical space and working in a coworking space. It would be relevant to receive guidance on the market, on setting up a business plan, and to have on access to the use of laboratories with inputs. This incubation includes contact with other startups to receive feedback and learn from the experience of other entrepreneurs in a similar situation (smart money). A great difficulty for them, as they say it, it is having to “pave all the way alone”. They are just good engineers unprepared for the “jungle of the market”.

2 - Venture Capital

Not being connected to investors who provided venture capital and smart money was a limiting factor in the development of the business. Receiving some financial support in the company's first year would have allowed for a smoother take-off. This could have been boosted by opportunities due to the high media exposure they had in Brazil after the victory in the national and international editions of the event. This financial support could have come from: (a) funding grants to participants with the purpose of allowing the transition from an educational project to a startup; (b) resources for inputs necessary for the manufacture and assembly of the product; (c) working capital for day-to-day, sporadic expenses.

3 - Mentorship

In the same way that the IFTP provided mentors for the development of the idea and the prototype, there is a need for systematic and regular mentoring on entrepreneurship in the incubation process. This would have avoided predictable errors by reducing the time spent in the trial-and-error process. Guidance in the Business Plan was also a highlight as, while the tools are easy to understand, reflection on their content is not automatic for university students.

4 – New posture of undergraduate programs for entrepreneurship

It's not about having just one discipline of entrepreneurship. It is about presenting the possibilities to the student from the very first moment of the program. The members of the Tupan team only considered the entrepreneurial possibility after the event. During ~~your~~ training, only technical perspectives are considered. This characteristic makes the search for formal employment the only way to go. Faced with the prospect of running a business, arising from an innovation, the professional in training feels weakened and even discouraged. We can say that developing entrepreneurial thinking is a new and important skill, which goes beyond what are considered soft skills.

5 – Local entrepreneurial ecosystem

One of the most important actions raised by the group is the need to bring the university closer to the local entrepreneurial ecosystem. Innovation ecosystems are knowledge networks (Calon, 1996) where there is exchange of information and learning (Braga & Guttmann, 2019). Collaboration in creative work and in the development of ideas builds a collective intelligence involving different stakeholders from the university and external to it (Braga & Schettini, 2020). The practice of networking facilitates the first steps of startups because it aggregates experiences from other companies at different stages of maturity. The discovery of complementarities can boost the business.

Conclusion

The Tupan case can teach us several learning points in relation to the role played by universities in terms of the entrepreneurial training of engineers. Both CEFET/RJ and Texas A&M University have their own innovation sparking events. CEFET/RJ has

EXPIN[48] and TAMU has Aggies, both of which are very similar in format. The IFTP is an international event spearheaded by Texas A&M that brings together several institutions. The main role of these events is the training of students in innovation and entrepreneurship. Nothing prevents real cases of innovation from emerging from these events and gaining market share through entrepreneurial students. Universities must be prepared for the "bottom-up innovation" because it comes from the student base and not from cutting-edge research carried out in their laboratories. It is essential to build support structures that support these students during their take-off, even before they acquire maturity for flight.

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APPLICATION OF INNOVATIVE SOFTWARE TO THE SUBJECT PROJECT I OF THE DEGREE IN ENGINEERING IN INDUSTRIAL TECHNOLOGIES (GETI)

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Keywords: *Innovative software, Project, Manufacturing, Statistics.*

ABSTRACT

In this work the results about the use of innovative software in the subject Project I is presented. The subject is given in the Degree in Engineering in Industrial Technologies (GETI) in the School of Industrial Engineering of Barcelona (ETSEIB) of Universitat Politècnica de Catalunya (UPC). In Project I, small groups of 12 students or less are defined, with the purpose of developing a collaborative project along one semester. The project discussed in this work was prepared by two different departments: Mechanical Engineering and Statistics and Operative Investigation. It deals with the measurement of shaft diameters with a micrometre, in order to evaluate the measuring system employed. Traditionally, many activities of the subject were recorded in handwritten reports. The present academic year, within the frame of the project EQUIPA'T (equip yourself), innovative software was applied to the subject. As for the methodology, first the teachers attended a training course. Then, the application of innovative software to the subject was planned. Finally, it was implemented. Google forms was used in the first and last classes to gather information to prepare subgroups of students and to evaluate the subject respectively, Edpuzzle was employed to add questions to videos about two lessons of the manufacturing area: metrology and

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turning, and Trello was used to manage the design of a 3D printed support by different teams of students. In subsequent years, the application of new software is expected.

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1 INTRODUCTION

1.1 Description of the subject Project I

The subject Project I is given in the second year of the Degree in Engineering in Industrial Technologies (GETI) of the School of Industrial Engineering of Barcelona (ETSEIB) of Universitat Politècnica de Catalunya (UPC). It is a mandatory subject, although the students are divided into small groups with 12 students or less, with a specific theme for the project. The Department of Mechanical Engineering, in collaboration with the Statistics and Operative Investigation Department, offers the following subject:

Are we measuring correctly the parts that we manufacture? In this project, the measuring system for shaft diameters (consisting of using a micrometre and a support) is evaluated. An R&R (Repeatability and Reproducibility) study is used for this purpose.

1.2 Background of the research

In the past, several authors have dealt with innovative software in the engineering area. For example, in the US, in 2011, a new software was developed and presented in order to teach Digital Signal Processing [1]. Other authors have applied existing software to improve teaching in the Engineering area, for example Labviews for data acquisition [2].

On the other hand, some technical universities develop group-environment courses in order to help the students developing employability skills such as team-work, communication skills, problem-solving, organizing, etc. [3,4]. In this sense, the Barcelona School of Industrial Engineering (ETSEIB) implemented the subject Project I with the new GETI degree in 2010. The students are divided into smaller teams of 3 or 4 components, and the subject is evaluated by means of three successive presentations (with a written report and an oral presentation). Some results about the evaluation of the subject were presented in the CIDUI2014 conference [5], and lead to the publication of a journal paper [6].

In year 2017 an important innovation was added to the project about the evaluation of the measuring system. It consists of the design and manufacture of a 3D printed support that helps to fix the micrometer and the shafts when measuring (Figure 1). An example of a support was presented in the CNIM2021 conference [7]. 3D printed supports are commonly employed in industry to fix parts, both in machines and in measuring instruments.

Fig. 1. Example of a 3D printed support used to measure the shaft diameters

As for the development of the subject, along the semester, five sessions are directly related to the Manufacturing area. Session 2 consists of explaining the turning process, to the students. Session 3 corresponds to the measuring systems, both conventional and advanced, as well as the concept of tolerance interval. In session 4, the design methodology for machines is introduced. In session 5, the students design a support that will be used in session 9 to measure the diameter of the parts.

The main pedagogical approach that the teachers use in this subject is the Project Based Learning, with the final objective to perform an R&R study of the measurement system.

1.3 Objective of the research

The main objective of this work is to present the results about the application of innovative software to the subject Project I of the GETI. The purpose of applying the new software is to increase the involvement of students in the subject, and encouraging them to participate in the different activities, but mainly in the of design and manufacture of the 3D printed support.

2 METHODOLOGY

This research is included in a project called EQUIPA'T (equip yourself), in which two different schools of UPC (ESEIAAT-Terrassa School of Industrial, Aeronautics and Audiovisual Engineeing and ETSEIB-Barcelona School of Industrial Engineering) are involved, as well as different departments: Projects, Mechanical Engineering, etc. The main theme of the project is the application of innovative software to the subjects involving collaborative work.

The general methodology of the EQUIPA'T project is summarized in Figure 2.

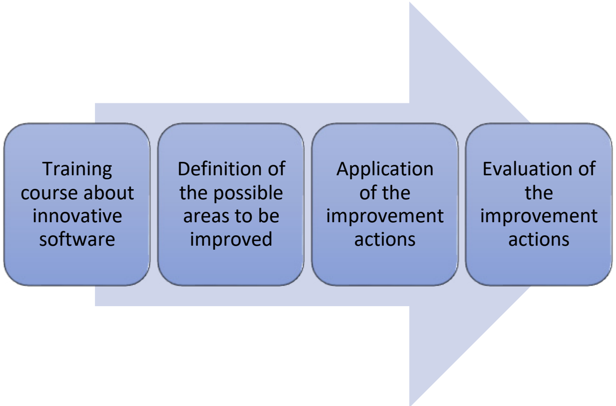

Fig. 2. General methodology of the EQUIPA'T project

The specific methodology that was used to implement the improvements to the subject Project I is explained in sections 2.1, 2.2, 2.3 and 2.4.

2.1 Initial questionnaire

During the first class, a Googleforms questionnaire was used about the different subjects that had previously been taken by the different students. It stated the following question:

Please mark what is your situation about the following subjects: 1- Statistics, 2- Statistical techniques for quality, 3- Manufacturing workshop

And the possible answers for each subject are:

1- I did not attend it, 2- I am attending it now., 3- I attended it in the past

The results of the questionnaire, which are explained in section 3.1, were used to define different subgroups among the students of each class. The idea is that in each subgroup there be, at least, one student with previous knowledge in Statistics, which will help the rest of the students in this area.

2.2 Edited videos

In order to encourage discussion in sessions 2 and 3 (about turning processes and metrology respectively), it was decided to use Edpuzzle to add questions to the videos to be presented in class. In a first step, most appropriate videos were selected among the possible ones. One video about turning operations and another video about tolerance intervals were used, which had been previously edited by other authors. The videos were shortened and more questions were added, according to the objectives and requirements of the subject Project I. The results are presented in section 3.2.

2.3 Management of the design process

The design process of the support is a quite long activity. It starts with the definition of the necessity of the technological object to be manufactured, as well as its main requirements. Then, conceptual design is carried out with the definition of the main moduli of the device. Later, the materialisation design is performed, in which different alternatives for each modulus are stated. Finally, the detail design is carried out, and the final drawings are obtained [8]. In order to keep track of the development of the design process, the Trello software was used. It allows preparing lists of tasks in different columns: - *Pending, - In progress, - Finished*. It also allows adding drawings, pictures and comments to each task during the development of the design activity.

The results of the application of Trello to the design process of the support are presented in section 3.3.

2.4 Final questionnaire

In the final class, a Googleforms questionnaire was used in which the students were asked about 3 positive aspects of the subject and 3 aspects to be improved. The results can be found in section 3.4.

3 RESULTS

3.1 Initial questionnaire

The results about the initial questionnaire that was carried out during the first class are presented in Figure 3.

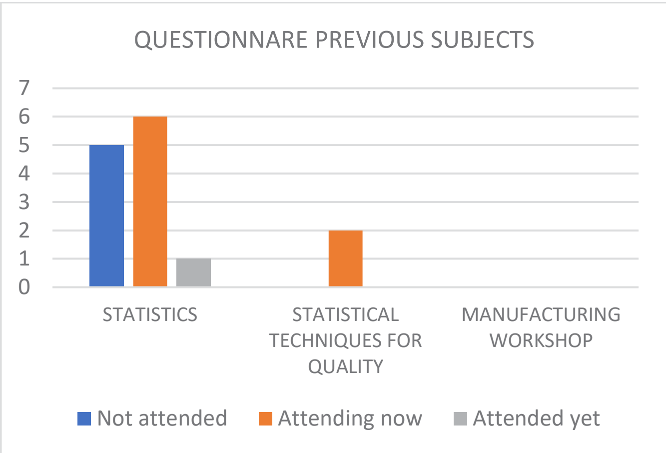

Fig. 3. Results about the subjects that the students previously attended.

Figure 3 shows that 11 students out of 12 had had previously attended Statistics or were attending it, while only 1 student had not attended the subject. In addition, 2 students were attending Statistical Techniques for Quality, and no student had previous knowledge about Manufacturing Workshop. Three different subgroups were defined in which, at least, two components had previous knowledge about Statistics.

It is expected to use the Googleforms questionnaire in the first class again the next academic years, because it helps to balance the subgroups regarding the knowledge of the students on Statistics.

3.2 Edited videos

Edpuzzle software allows the possibility to edit videos in a way that several comments and questions can be added [9,10]. In this work, two different videos were edited, for the machining (Figure 4) and for the metrology class (Figure 5) respectively. In both videos, several subsequent questions appear to be answered by the class group.

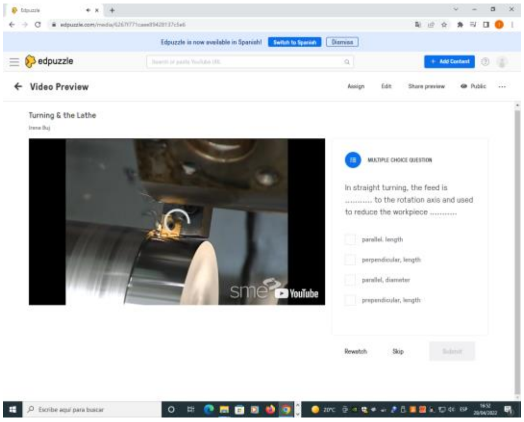

Fig.4. Screenshot of a video about turning

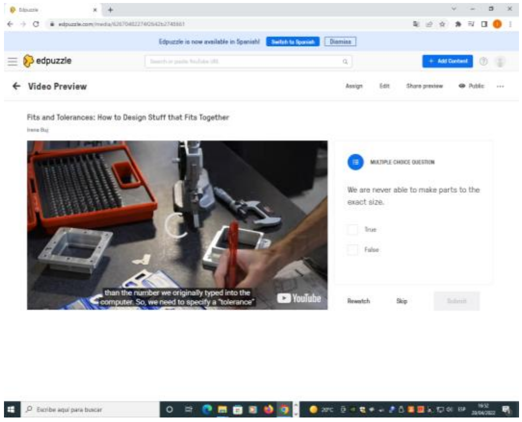

Fig. 5. Screenshot of a video about metrology

The selected video for Session 2 about machining processes is “Turning & the lathe”. In it, different turning processes are described, for example straight turning. In addition, the concept of rough and finish machining is explained.

The selected video for Session 3 about metrology is “Fits and tolerances: how to design stuff that fits together “. The concepts of nominal dimensions and tolerances are explained, as well as the three kinds of fits: clearance, transition and interference.

Both videos led to a discussion in class. For example, regarding the turning operation, the chamfering operation was commented. Its main aim is to avoid sharp edges that could hurt the person that machines or transports the part. In another example, the video about metrology helped to find some real examples for the different kind of fits that are used in mechanical design.

The next year, it is expected to add another video about 3D printing. Another possible improvement is that the students answer the questions individually, in order to analyze the results and to compare them to the final marks.

3.3 Tracking of the design process

The application of Trello led to uneven results: while some groups just used it as a list of tasks (Figure 6), other groups took great advantage of its possibilities, adding schemes, pictures and comments to the list of tasks (Figure 7).

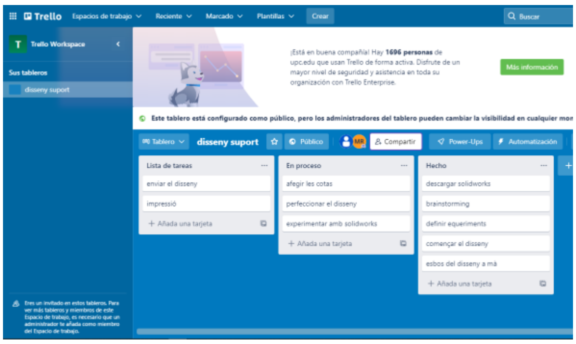

Fig. 6. Screenshot of Trello with three sets of lists

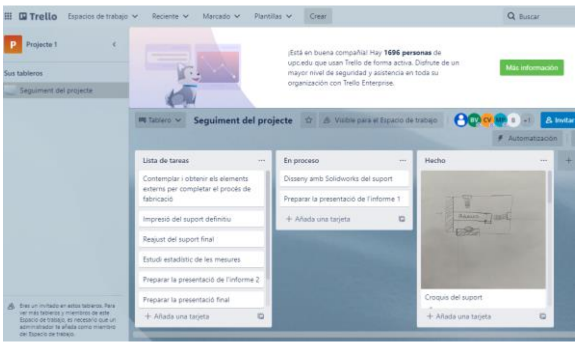

Fig. 7. Screenshot of Trello with lists and schematics

In addition, the use of Trello favoured the use of other software. For example, the Measure app of the mobile phone was used to measure the dimensions of the micrometre from an image (Figure 8).

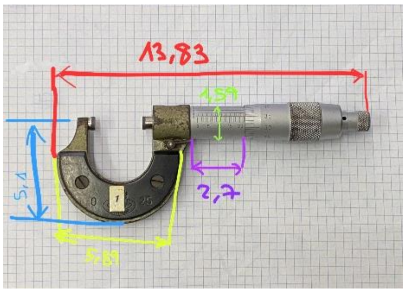

Fig. 8. Measurement of the micrometer from an image

Next year it is expected to replace the conventional written report that was used to evaluate session 5 of the subject with a Trello file, in order to avoid duplication of information.

3.4 Final questionnaire

The results of the final questionnaire are as follows (Figures 9 and 10). The most positive aspects of the subject are team work, followed by oral presentations, to learn 3D Printing and to learn Statistics. The main aspects to be improved are that there are too many presentations, the fact that all the teams deal with the same subject and the fact that there are too few laboratory classes at the workshop.

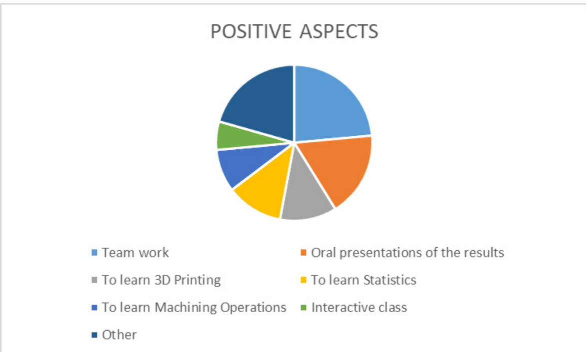

Fig. 9. Positive aspects of the subject

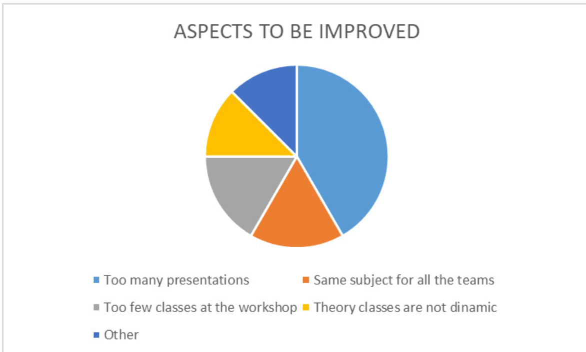

Fig. 10. Aspects to be improved

4 SUMMARY AND ACKNOWLEDGMENTS

In this work the results of the application of innovative software to the subject Project I are presented. In the first session, a Googleforms questionnaire was used to ask the students which subjects they have previously taken. In the second and third sessions, Eddpuzzle was used to add questions to a video, which were answered by the students globally in class. In the fourth and fifth class, the tool Trello was used, which allows to perform a list of tasks that are pending, in process and finished respectively. In the last class, the students were asked about the subject with another questionnaire. From the teacher's standpoint, all the innovative tools allowed to enhance the discussion of the subject with the students in class.

In subsequent academic years, it is expected to use the three tools again, with a special focus on the possibilities of Trello, which could completely substitute the use of conventional reports along the design process of the measuring supports. The students mainly appreciate team work and the possibility to present their achievements.

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IMPLEMENTING A SUITE OF SKILLS MODULES IN A FIRST-YEAR ENGINEERING PROJECT-BASED SUBJECT

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Keywords: *Skills, project-based, first-year*

ABSTRACT

Students commencing engineering at university often have no prior experience of engineering, what the profession entails and the distinctions between disciplines. Consequently, tertiary institutions often offer common first-year engineering subjects that aim to give students an experience of the engineering profession and method, while providing exposure to different disciplines through applied project-based learning. The difficulty with this approach is that there is a wide variance in terms of students' knowledge, skills, past experiences, and expectations. In a team context, these discrepancies could lead to conflict and poor educational outcomes. Furthermore, if the project is of reasonable length, students might be locked into a discipline-focused project that they realise does not suit them as a potential major.

To this end, a suite of self-enrolled skills modules was developed to support student skills development in a first-year, project-based engineering subject under two categories – *technical*, focusing on skills that had direct applicability to the project-work and *general*, focusing on skills related to assessment. The modules aimed to (1) improve individuals' skills in a team context; (2) give students an opportunity to learn skills unrelated to their chosen project in a low-stakes context; and (3) promote interaction and peer-learning outside of their project team and class, building a wider sense of cohort.

This paper discusses the creation of the modules and evaluates their outcomes in achieving their goals based on numerous data gathered throughout the semester and student feedback. Initial results have been positive and suggest future directions for development.

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1 INTRODUCTION

In a major review of the knowledge, skills and attributes that will be required of graduate professional engineers in the future, the "development of technical and professional skills supporting collaborative, inter-disciplinary teamwork" has been identified as becoming a more important part of the engineering education of the future [1]. In light of this, many tertiary institutions in Australia have moved to offer large-scale, first-year programmes that teach more general engineering subjects, with the aim to give students an experience of the engineering profession and begin the early development of professional skills such as problem-solving techniques and communication skills, rather than necessarily teach discipline-specific knowledge. Students commencing engineering at university often have no prior experience of engineering, what the profession entails and the distinctions between disciplines and offering general engineering subjects in this fashion can help them more broadly understand what engineering is about before committing to a particular discipline. This approach gives students some flexibility to choose or change a previously nominated engineering discipline after completion of the first year of study, without having to go back and complete discipline-specific first year subjects. This is seen as beneficial to students, especially where a broad range of engineering specialisations are offered and making a choice could become difficult.

The issue with this flexible approach is that there are several inherent concerns with pooling all engineering students into a common first-year subject, particularly one employing project-based learning [2] to help develop professional skills. Firstly, in recent years there has been a marked increase in the number of students entering the university system in Australia [1, 3]. In particular, the increase in intake means that those attending university are now coming from a wider range of backgrounds and, as a consequence, there is a greater variation in their prior knowledge and experiences [4]. The widening variance in terms of students' knowledge, skills and past experiences, even within specific discipline areas, could lead to conflict in a team context and poor project outcomes [5] Secondly, students who are certain about the discipline of engineering that they would like to pursue may become bored or even disillusioned if forced to complete tasks or projects in a first-year, general engineering subject that do not align with their skills and interests. These factors could easily lead to reduced educational outcomes and a negative experience of engineering, which can have dire consequences in terms of student retention.

To address these concerns, a suite of self-enrolled skills modules was developed to support student skills development in a first-year, project-based engineering subject. The modules were broadly classified under one of two categories – *technical*, focusing on skills that have direct applicability to the project-work and *general*, focusing on professional skills more related to assessment. The modules comprised a mix of self-paced online and self-signed up workshops aimed to (1) improve individuals' skills in a team context; (2) give students an opportunity to learn skills unrelated to their chosen project in a low-stakes context; and (3) promote interaction and peer-learning outside of their project team and class, building a wider sense of cohort.

This paper provides a background to the specific university setting and details the development and implementation of the skills modules within the context of a first-year project-based engineering subject. The relationship of the modules to each project and the assessment tasks is outlined, along with a description of the methods of delivery employed. An evaluation of the modules is performed, using numerous data gathered throughout the semester such as number of enrolments, attendance and completion rates, popularity of times when they were taken and student feedback with specific reference to the three aims mentioned above.

2 BACKGROUND

At the University of Melbourne, students must complete a three-year Bachelor of Science degree, majoring in one of the six ‘Engineering Systems’ majors, before choosing to apply for entry into a postgraduate Master of Engineering degree. In their first year of study, they complete the science subjects underpinning the engineering topics that they will encounter in later years of the degree – namely, mathematics, physical sciences such as physics, and possibly computing. In this context, students’ first introduction to engineering is via a general first-year engineering subject – one designed for all students, irrespective of (future) discipline and intended to teach some basic discipline knowledge, introduce and develop both technical and professional skills, and provide an authentic initial experience of engineering.

The general first-year engineering subject, titled Engineering Modelling and Design, was designed from scratch as a new project-based subject, with a backbone of cohort-wide lectures supporting three independent, team projects that are delivered via smaller interactive workshop classes. The lectures were designed to be independent of choice of project and focused on the engineering profession, problem-solving methods and project management. The weekly workshop classes were three-hours in duration and consisted of one-hour of interactive teaching related to a technical part of the project and two hours of team-based project work, completing a series of incremental tasks that would build towards the final project outcome. Students complete only one out of the three possible projects over the 12-week semester in a team of three. At the beginning of the semester, each student nominated the project that they would like to complete over the semester via selecting the corresponding workshop classes in the timetable system.

3 MODULES DEVELOPMENT

The three projects were the core elements of the subject and ranged from programming an autonomous robot to designing, building and testing a speaker, to simulating and mitigating the effects of a coastal flooding event. Once the scopes, goals and content of the projects were determined, the teaching team identified any potential gaps that might exist in terms of students’ prior knowledge or skills with respect to the technical and professional skills requirements for completing each project. This process was completed through a study of the first-year students' backgrounds, observation of the current content of high school curricula and knowledge of what is covered in complementary subjects at the first-year level. These gaps were deemed sufficiently large if it was thought that they might not be able to be overcome by the students over the course of the semester without additional learning activities and support early on.

3.1 Technical skills modules

Six *technical* skills modules were developed that covered a range of discipline skills in engineering, namely Basic MATLAB/Simulink, Arduino, Robot Control in Simulink, CAD & 3D Printing, Circuit Theory and QGIS. Students would find some of these technical skills modules closely aligned with their selected project, however they were not forced to take any one particular module. Indeed, students were encouraged to take the opportunity to develop skills in areas outside of their selected project field through taking additional modules. These modules were delivered in the format of self-sign-up small-group workshop classes. During the 1.5hr facilitated workshop sessions for these modules, students would first progress through a set of guided activities to familiarise themselves with any required hardware or software. They would then be required to complete a set of specific tasks on their own in order to be certified as having completed the module.

3.2 General skills modules

Four *general* skills modules – Teamwork, Report Writing, Video Production and Prototyping – were developed. The Teamwork module was offered as self-enrolled workshops where a demonstrator would facilitate a series of team activities, including team discussion and role play. The other three modules were offered as self-paced online modules developed in H5P, comprising guided activities (that could take up to 4-5 hours) that build towards the submission of a piece of assessment. In all the four general modules, the Padlet App was utilised as a sharing and discussion platform within the activities, promoting student engagement within the cohort.

In total, there were ten skills modules available across the two categories, shown in Figure 1, along with their alignment to either project stream or assessment task. As part of the subject assessment, students were required to complete at least one General Skills module and at least one Technical Skills module to qualify for 10% of the subject mark on a pass/fail basis. The completion of a particular module was based on two components: a preparation activity and either workshop participation or submission of a piece of work. This grading scheme was chosen in order to provide a low-risk environment for students to learn additional skills, either due to the project requirements or out of interest. Under this model, even though students were 'locked' into a project at the start of semester, they would be able to explore some of the skills from the other projects in a low-risk manner.

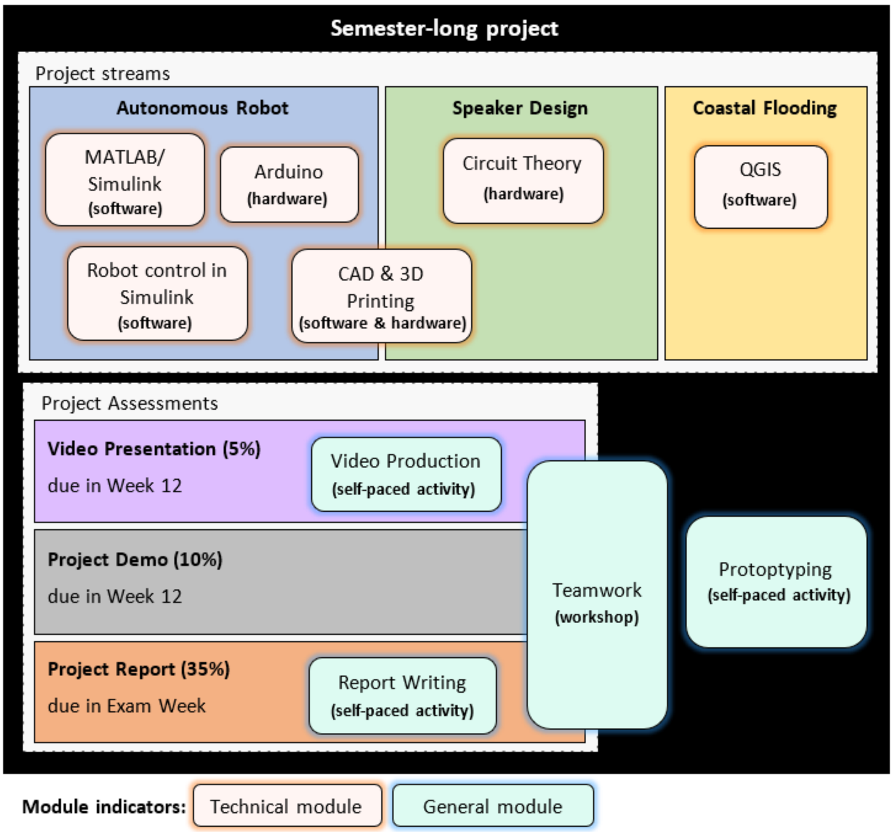

Fig. 1. Alignment of Skills Modules with project streams and assessments

4 IMPLEMENTATION AND EVALUATION

The modules were introduced in Semester 2 2021, with a cohort of 370 students supported by 5 demonstrators. The skills modules that were supported by self-paced online activities could be completed at any time, while the workshop-based ones required students to sign up via the student Learning Management System (LMS). Enrolments were continuously monitored such that workshops could be added or removed according to demand and slots for a particular module were rotated around the week to cater for different availabilities of students.

The distribution of students completing each of the skills modules is shown in Figure 2, split according to project. It was evident that students largely preferred the technical modules most relevant to their project. Based on this data, students' perception of the technical skills modules is perhaps not to use them to explore different skills, as we might anticipate, but instead, to view them in terms of applicability to their chosen project. The Report Writing module was the most favoured general skills module, with a significantly higher completion rate compared to both the Video Production and Prototyping modules, and just ahead of Teamwork. This could be attributed to the high weighting of the report assessment in the subject (35%), and the perception of the importance of teamwork in delivering a successful project outcome. The spread of students across the three project streams for the completion of the general skills modules was relatively balanced, as we would expect since the development of professional skills does not discriminate between the different project streams.

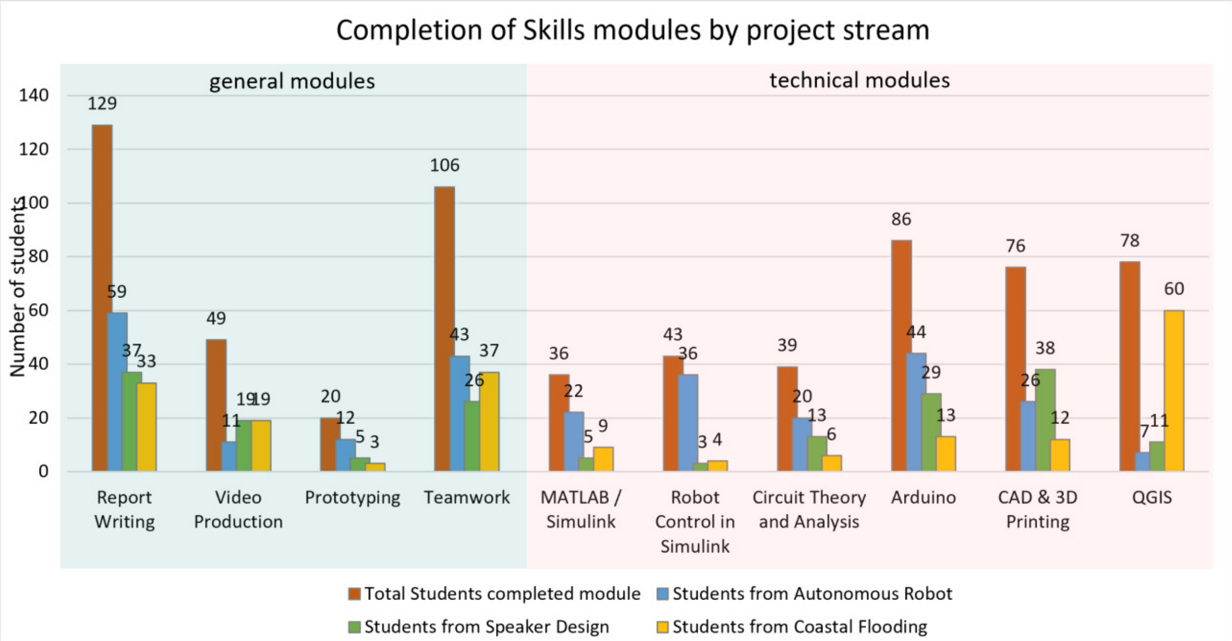

Fig. 2. Completion of all skills modules by project stream

Table 1 provides a summary of the completion of different combinations of the general and technical skills modules across the cohort.

Table 1. Breakdown of the number of skills modules completed

Number of modules completed		Total number of students
General module	**Technical module**	
0	0	36
0	1	28
0	2	5
1	0	13
1	1	265
1	2	17
1	> 2	3
2	1	3
	Total	370

A majority of students (71.4%) completed the minimum requirement of one General Module and one Technical module, suggesting that most are completing only the minimum requirement to achieve the skills module component mark. A total of 22.4% did not manage to meet the minimum requirement: 9.7% did not complete either of the modules, 9.2% completed only one technical module and 3.5% completed only one general module. Only 6.2% of the cohort attempted to take on more modules than the minimum requirement.

Figure 3 shows the uptake of the skills modules that comprised of facilitated workshop sessions. Workshop attendance for the 6 technical modules and the Teamwork module appeared to be lower in Weeks 2 and 3, likely due to students adjusting to the concept of the Skills Modules at the beginning of semester.

Interestingly, there was no strong correlation between the uptake of most of the technical modules in relation to the demands of the respective project(s) at any particular timeframe during the semester, suggesting that students tend to take up the technical modules at their convenience or availability rather than during their times of need in the projects. There was however a clear ramp-up in workshop uptakes towards the end of semester as students rushed to complete the skills modules requirements by Week 11 - the week when the last of the skills modules workshop sessions were offered.

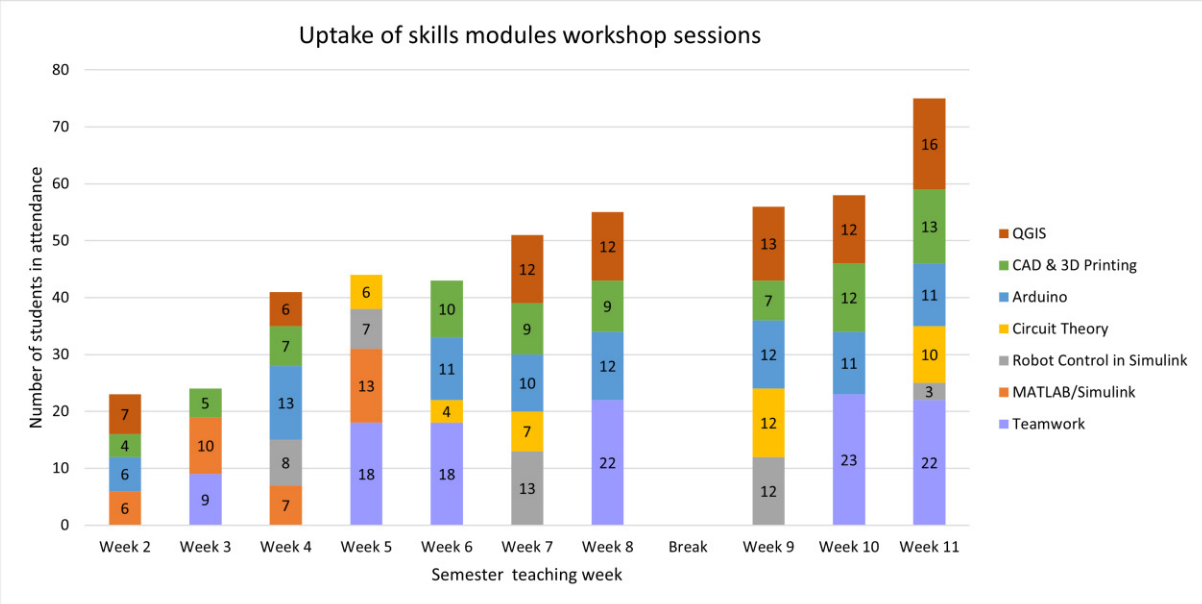

Fig. 3. Uptake of skills modules workshop sessions

A similar ramp-up trend was observed for the submissions of the self-paced online general modules, shown in Figure 4**.**

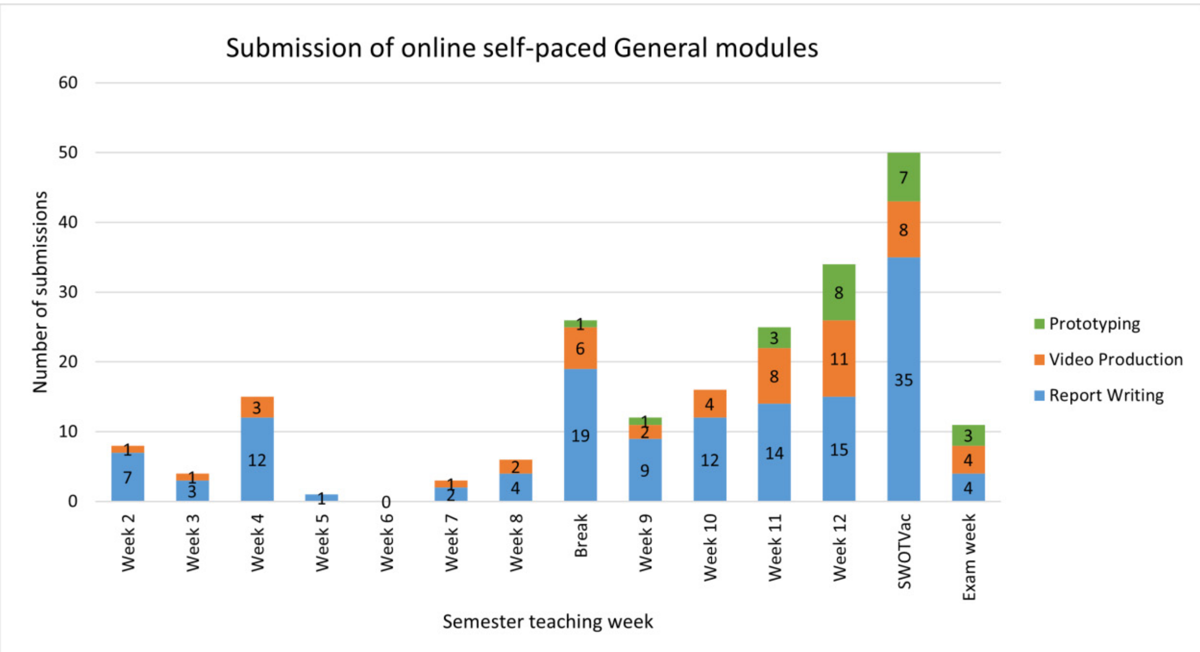

Fig. 4. Submission of online task for the general skills modules

There was a significant increase in submissions during the end-of-semester SWOTvac week, particularly for the Report Writing module, attributed to the project report deadline on the first day of the exam week. The prototyping module, introduced in Week 8, being the only self-paced module that did not offer a skill that was related to the subject assessments, showed interest peaking in Week 12, implying that these students believed their project assessments were under control and had the flexibility to try something different. Approximately 9% of students managed to complete their general modules before Week 5 when the overall subject workload was not yet too demanding and the subtle spike in submissions observed during the mid-semester break week saw about 8.6% of students use this period to complete a module.

Student feedback showed that students found the general modules' materials and skills useful when applied to team assessments within the subject, however they had difficulty justifying the application of the skills to another subject as the nature of assessments were different. It was encouraging that students were particularly positive about Padlet being an effective tool for information sharing that promotes peer-learning outside of their project team and class. This was especially significant as the online self-paced had no direct interactions with peers.

For the technical skills workshop sessions, it was more difficult to achieve a balanced level of satisfaction. Students appreciated the guided activities that introduced a particular technical area facilitated by a demonstrator when a topic was new to them. However, students who have prior knowledge or experience from their project were disappointed that the workshop activities to be too basic and they are not challenged. As this is the first time the skills modules are being offered, there was only one set of activities for each technical area, with limited coverage. Despite the challenges in bridging the gap between student expectations and actual experience, students agreed that the technical modules have provided them the knowledge and application of a relevant engineering skill.

5 CONCLUSION

The skills modules were instrumental components in the subject's project-based framework that offered flexibility in terms of choice and timing in a low-risk setting. With the first-time implementation of these modules, it was found that the majority of students did not complete more than the minimum requirement of modules and, for the technical modules, largely chose them according to the perceived relevance to their project area. This is not necessarily a failure in terms of the stated goals of the skills modules but could represent the fact that most students are largely decided on which discipline of engineering they would like to pursue and accordingly pick a project aligned with that discipline and completed the most closely aligned skills module. The suite of skills modules received overall favourable student feedback and will continue to be developed into the future, including providing students with better guidance around their utility and purpose.

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TO BE fAIr: ETHICAL AND FAIR APPLICATION OF ARTIFICIAL INTELLIGENCE IN VIRTUAL LABORATORIES

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ABSTRACT

In 1984, the film "The Terminator" predicted that a hostile Artificial Intelligence (AI) will threaten to extinguish humankind by 2029. Even though the real present is quite far from this post-apocalyptic scenario where AI rebels against its creator, a growing concern about the lack of ethical considerations in the use of AI is rapidly spreading, leading to the current "ethics crisis". The lack of clear regulations is even more alarming considering that AI is becoming an integral part of new educational platforms. This follows the wave of digital transformation mainly induced by the Fourth Industrial Revolution, with advances in digitalization strategies, and the COVID-19 crisis, which forced education institutions worldwide to switch to e-learning. The appeal of AI is its potential to answer the needs of both educators and learners. For example, it can provide help grading assignments, enable tutoring opportunities, develop smart content, personalize and ultimately boost on-line learning. Although the "AI revolution" has great potential to improve and boost digital education, there are no clear regulations in place to ensure an ethical and fair use of AI. Therefore, this work aims to provide a comprehensive overview of the current concerns regarding fairness, accountability, transparency and ethics in AI applied to education, with specific focus on virtual laboratories. The main aspects that this work aims to discuss, and provide possible suggestions for, are: (i) ethical concerns, fairness, bias, equity, and inclusion; (ii) data transparency and digital rights, including data availability, collection, and protection; and, (iii) collaborative approach between disciplines.

1 INTRODUCTION

1.1 Virtual Laboratories and the introduction of Artificial Intelligence

Recent years have seen an increased focus on sustainable development, which is defined by UNESCO as a *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*[2]. One of the 17 core objectives presented in the SDG initiative is to improve the quality of education. Some of the proposed goals are to help countries in implementing innovative and context-appropriate solutions. This aims to provide education remotely, leveraging hi-tech, low-tech, and no-tech approaches, as well as to seek equitable solutions and universal access. In these times of educational disruption[3], where, according to UNESCO, never before have so many students been out of school, drastic changes in education have been accelerated, resulting in significant advances in adopting digitalization strategies [1, 2]. In this scenario, virtual laboratories (VL) offer a solution to provide inclusive learning opportunities [1].

[2] UNESCO Sustainable Development Goals, https://www.un.org/sustainabledevelopment/education/ (accessed April 29, 2022).

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In the field of Chemical and Biochemical Engineering, for example, educational process computer-aided tools are becoming widespread and are proving their relevance. Simulators, such as ASPEN Hysys[4] or SuperPro[5], were already fundamental tools in the teaching of Process Systems Engineering (PSE), but recent events have contributed to expanding their application.

Differentiated and individualized learning has been a priority for educators across domains for years [3]. Educators are also aware that one of the most effective ways of learning is to receive immediate and continuous feedback [4, 5]. This prevents small errors and misunderstandings from propagating. Educational tools, thanks to the recent advances in AI methods, are trying to replicate the same process. This is done by using algorithms to understand the level and preparation of the students and adapting the learnings and exercises accordingly [6]. It follows that Artificial intelligence (AI) is becoming an integral part of new educational platforms, since AI has the potential to answer the needs of both educators and learners by providing help in grading the assignments, enabling tutoring opportunities, developing smart content, or/and personalizing the learning. For example, Lu et al. (2021) introduced RadarMath [6], an intelligent tutoring system to support intelligent and personalized learning for math education. Another solution is provided by Carnegie Learning, developing 'Mika'[6], a tool that uses cognitive science and AI methods to create personalized lesson plans and tutoring that adjusts based on student's performance, and it also provides real-time feedback [7].

1.2 Ethical concerns

As reported in the EU guidelines on ethics in artificial intelligence document[7], the core principle of the EU guidelines is that the EU must develop a 'human-centric' approach to AI that is respectful of European values and principles.

> *"The human-centric approach to AI strives to ensure that human values are central to the way in which AI systems are developed, deployed, used and monitored, by ensuring respect for fundamental rights, including those set out in the Treaties of the European Union and Charter of Fundamental Rights of the European Union, all of which are united by reference to a common foundation rooted in respect for human dignity, in which the human being enjoys a unique and inalienable moral status."*

Studies [8] researching the awareness of ethical issues in e-learning systems focus on how to prevent students from behaving unethically (e.g., copying assignments from their classmates) or assessing their knowledge of what ethical behavior is. Preventing

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this kind of behavior is imperative and should not be overlooked in designing an educational on-line tool, since these platforms might be used for grading assignments; therefore, preventing unethical behavior from the students' perspective is a very crucial issue. However, this work aims to focus on safeguarding students and their digital rights through the investigation of ethical behavior in virtual laboratories.

The focus on ethics and fairness in Artificial Intelligence (AI) has gained traction in recent years, as demonstrated by the establishment of various Conferences focusing on ethics in AI. Among those, the ACM Conference on Fairness, Accountability, and Transparency (ACM FAccT)[8] had its first event dating back to 2018, and the AAAI/ACM Conference on Artificial Intelligence, Ethics and Society[9] will have its fifth edition in 2022.

This recent trend sprang due to the fact that, although AI has proved to be beneficial in many aspects, standing out for the accuracy of predictions and the ability to solve complex problems, it can pose risks to the right of personal data protection and privacy, as well as discrimination, as highlighted by EU guidelines on ethics in artificial intelligence document[10], published in 2019. The EU ethics guidelines provide a good overview of the possible ethical concerns surrounding AI and the principles that should be followed to ensure its ethical applications. On the other hand, these guidelines are non-binding, although concerns over the lack of regulatory oversight to support their implementation have been raised.

On 24 November 2021, the Recommendation on the Ethics of Artificial Intelligence[11] was adopted by UNESCO's General Conference. This work builds on the preliminary study on the ethics of artificial intelligence[12] of UNESCO's World Commission on the Ethics of Scientific Knowledge and Technology (COMEST)[13]. This study emphasizes that currently, no global instrument covers all the fields that guide the development and application of AI in a human-centered approach.

We believe that assessing possible ethical issues regarding how data is collected, stored, and used in modelling when designing a virtual environment is fundamental. Data is currently considered a very valuable resource, which could provide extensive knowledge about a person's habits, preferences, and skills, and could therefore be used, if not regulated, for economic gains outside its primary scope. Therefore, this study aims to build on the current knowledge on ethical applications of AI in

[8] ACM Conference on Fairness, Accountability, and Transparency (ACM FAccT) https://facctconference.org/index.html (accessed April 29, 2022).

[9] AAAI/ACM Conference on Artificial Intelligence, Ethics, and Society. https://www.aies-conference.com/2022/ (accessed April 29, 2022).

[10] EU guidelines on ethics in artificial intelligence: Context and implementation (2019). https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/640163/EPRS_BRI(2019)640163_EN.pdf (accessed April 29, 2022).

[11] Recommendation on the ethics of artificial intelligence. https://en.unesco.org/artificial-intelligence/ethics#recommendation (accessed April 29, 2022).

[12] Preliminary study on the Ethics of Artificial Intelligence (2019). https://unesdoc.unesco.org/ark:/48223/pf0000367823 (accessed April 29, 2022).

[13] World Commission on the Ethics of Scientific Knowledge and Technology (COMEST). https://en.unesco.org/themes/ethics-science-and-technology/comest (accessed April 29, 2022).

educational platforms and provide cause for reflection on the multiple possible ethical concerns that introducing data-driven solutions to a virtual laboratory might raise. Our objective is that, by highlighting these aspects, more researchers and practitioners working on Engineering Education might contribute with other reflections and resources in the future, to ensure a more ethical and safe virtual experience for learners, where every aspect of the "digital contract" is transparent.

2 BACKGROUND

This work aims to assess the impact that introducing AI can have on Virtual laboratories from an ethical perspective. In order to do that, we focus on the following clusters of aspects to ensure ethical and fair treatment of data: (i) fairness and bias; (ii) equity and inclusion; (iii) data transparency and digital rights; and (iv) collaborative approach between disciplines.

2.1 Fairness and bias

Fairness in AI refers to the attempt to correct algorithm bias in algorithmic decision making models. These models, if trained on biased data, can fail in a multitude of scenarios. This problem is particularly relevant when the outcome can affect people's lives, leading to cases of sexual hiring, racial bias in the justice system, face recognition issues, predicting car robberies, used by the police in Belgium, or profiling unemployed people, as used in Poland[14].

Virtual Laboratories should refrain from using biased data for their predictions and employ effort and resources in investigating this problem.

We provide a possible scenario to clarify this concept. Assume that we created an on-line platform to teach bioprocesses to students. The platform contains a section where the students can practice their knowledge through practical exercises that become increasingly more difficult. The recommendation of exercises is powered by a data-driven model. All students start with a few default exercises, necessary to assess their preparation and confidence. Afterward, the model needs to predict the appropriate exercises to recommend to the students. These exercises have a dual objective: to maximize both their learning curve and engagement, since if the exercises recommended are too easy, the students might get bored and not visit the platform anymore. In order to maximize the likelihood of recommending the most appropriate exercise, we train the model on personal information about the learners, such as gender (which, per se, already entails problematic assumptions), age, education, and country of origin. Furthermore, let's assume that the platform is relatively new and therefore we do not have much data, but from the few examples we gathered, it seems that learners that selected "male" as their gender, perform worse than others. If we

[14] EU guidelines on ethics in artificial intelligence: Context and implementation (2019). https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/640163/EPRS_BRI(2019)640163_EN.pdf (accessed April 29, 2022).

feed this information to train the model, the model will be biased and will learn that new students that selected “male” as their gender, would be less trained on the material, and therefore should be recommended easier exercises.

This example shows that it is very important to assess the fairness of the data available before using it to make predictions, which will be inherently biased otherwise. Multiple metrics have been proposed to assess a model’s fairness, distinguished into procedural fairness, which focuses on the decision process, outcome fairness, a consequential approach focusing on the end result, and dynamic fairness, i.e., integrating formal fairness metrics with ethical principles.

2.2 Equity and inclusion

A well-designed VL should enhance culturally inclusive learning [9]. When designing a virtual laboratory, it is important to reflect on how inclusive the content is. If a VL is accessible worldwide, the cultural diversity of the users should be taken into account. For example, some common sayings or metaphors might be difficult to understand or offend the users’ sensibility.

Moreover, a good e-learning platform should account for individual learners’ differences and cater to their learning abilities. This could become an issue of inclusion since it would be unjust to either make the material more accessible for slower learning students or too challenging to benefit the quickest ones.

2.3 Data transparency and digital rights

Before collecting and storing data in virtual applications, it is essential to establish a clear scope and purpose for data collection and analysis. Virtual laboratories should aim to create a feeling of trust in the user, by being clear and transparent on the nature and extent of the data gathered, and what kind and how much of their data is being stored and used [9]. The data collection needs to follow the Principles of GDPR[15]. Moreover, users should be ensured that their data is secure and there will be no breaches in computer ethics. This is particularly important since it often happens that websites are hacked and data accessed. Therefore, gaining the students’ formal consent on how the data is stored and used is very important.

This “transparency contract” also covers AI applications. The user should be informed about what data is fed into data-driven models to improve their experience on the platform and they should have power over their preferences, such as deciding whether to stop allowing their personal data to be used for training models.

[15] General Data Protection Regulation GDPR. https://gdpr-info.eu/pdf (accessed April 29, 2022).

2.4 Collaborative approach

We believe that engineers working on the design and implementation of virtual laboratories should be acquainted with ethical principles and that ethics should be taught in computer science degrees. However, since these issues with ethics would likely require the cooperation of stakeholders of varying expertise in business, law and other disciplines, regulations must be established and enforced at a higher level [10]. The ethics crisis does not only affect engineers and, therefore, should not be solved only by technical people but as a collaborative effort among different disciplines.

As argued by [10], solutions and guidelines to address the ethics crisis cannot be siloed, i.e., each discipline working on a solution without taking into account the point of view of others. This can be exemplified by analyzing the lack of joint outputs and cross-citations among different fields, for example, between articles in computer science journals and articles in the humanistic social science field. Echoing [10], we argue that the best way to address this issue, which should be perceived as a transversal problem that involves theories and methods across several disciplines, is through a collaborative effort between disciplines.

In summary, this study aims to address ethical concerns due to the introduction of AI in virtual laboratories. We aim to build on established knowledge and inspire researchers to contribute to the discussion. In our analysis, we focus on different aspects, such as the evaluation of fairness and bias, equity and inclusion, the necessity for data transparency and privacy protection, and the need for a collaborative effort across different disciplines to establish clear regulations.

3 RECOMMENDED FRAMEWORK AND FUTURE DIRECTIONS

We recommend following these four checkmarks in order to assess the ethical application of AI to virtual laboratories: (i) clarify scope and purpose; (ii) ensure transparency; (iii) protect users' privacy; (iv) help students – the ultimate goal.

(i) Defining a clear scope and purpose for data collection and analysis allows for setting ethical boundaries. Before starting to collect users' data, it is important to be clear on the scope and purpose of the collected data. It is important to reflect on whether all the data points collected are necessary, and establish a plan for exactly how the data will be used. If the scope changes, a new assessment will be necessary.

(ii) Once the data is collected and safely stored, it is important to assess its quality and fairness, before using it to train data-driven models. Assessment of fairness can be performed through various fairness metrics, defined as formal criteria to score fairness. This will build control into the design of the implemented algorithms. Establish guidelines on how to assess whether the data contains bias and remove the biased content from the data. Also, investigate the transparency and understanding of the algorithm: what the prediction is based on, the features that lead the model to that specific prediction, and consider probing the model to understand what the model knows about the user. Moreover, consider the whole process in a holistic way, rather than analyzing small pieces of the process as a silo.

(iii) Regarding transparency and consent, learners should be aware of how and why their data is being collected and used. This process should be clearly described and shared with the users. Consent must be established before data is collected. Also, consider and clearly communicate whether the students can decide to revise their selected preferences on data sharing at a later stage.

In order to protect the students' personal data, access to the data should be restricted to only the necessary fields, and not all stakeholders working on the VL need access to all data. For example, access to credit card information, passwords, and similar field should be restricted. The available information should also be assessed carefully when selecting the parameters to be used in training a data-driven model.

Finally, we aim to highlight that educational platforms should have the purpose to help students. The ultimate goal of a virtual laboratory is to help people learn, so the solutions implemented should be directed towards this goal. We also argue that platforms should provide the possibility for students to freely share their ethical concerns, ask questions, and in return receive transparent elucidations on their requests.

4 SUMMARY

This study aims to address possible ethical concerns arising from the introduction of Artificial Intelligence in virtual laboratories. Building on established knowledge and regulations, we provide a checklist of aspects to consider when evaluating how to ethically incorporate AI models into an on-line educational platform. Specifically, we focus on fairness and bias, equity and inclusion, the necessity for data transparency, and privacy protection. Moreover, we address the need for a collaborative effort across different disciplines in establishing clear regulations, with the final goal of safeguarding students and their digital rights.

Our objective is to spur researchers and practitioners working on Engineering Education to contribute with reflections and resources to ensure a more ethical and safe virtual experience for learners, where every aspect of the "digital contract" is transparent.

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LIFE IN THE AI ERA
First result of the Erasmus+ HEDY project

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ABSTRACT

HEDY - Life in the AI era is a 2-year Erasmus+ project started in November 2021 targeting higher education audience. Its goal is to offer a comprehensive and shared view of how Artificial Intelligence (AI) is affecting our lives and reshaping our socioeconomic, cultural, and human environments and to define which topics related to AI are of interest to different university studies and how they should be addressed.

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Four specific free and accessible sources of information will be produced to reach these goals, the first of which is the Booklet, the subject of this paper. The Booklet is an essay defining the HEDY position on life in the AI era and its aim is to identify the challenges, opportunities and expected impact of AI on four different areas: business, governance, skills & competencies, and people & lifestyle. In this paper, we summarise the content of the Booklet. In particular, we describe our methodology to build our rationales based on collecting information from two sources: i) Literature survey, and ii) Focus groups. These two sources provide a unique contribution on AI panorama by combining state of the art research with first-hand opinions and debated questions, concerns, and ideas of interacting individuals. The main finding is that there is the necessity to train citizens in AI by providing teachings, courses and trainings in schools and higher education institutes to facilitate the use and adoption of AI for young people and future generations.

1 INTRODUCTION

The digital is invading our world, with technology being used in all dimensions of life, from education to work, health or governance. Knowledge and skills development is now a lifelong process, demanding growing digital literacy. Assuming that AI will transform the labour market, it is relevant to imagine the education system in a world where work is not a central factor in life or where jobs, as we knew them, do not exist. What would be the role of education? How could we organize it? What would be its aims and what needs would it address? How do we ensure that every citizen develops the necessary skills to remain included in an increasingly digital society? And how achieving fairness rather than amplifying inequalities?

This is the leitmotiv of HEDY – Life in the AI era [1], which is a 2-year Erasmus+ project started in November 2021. HEDY project stands for being a *free and accessible source of information* regarding the AI. The purpose is to provide teaching and course materials to incorporate the possible positive future applications, the challenges, the opportunities, and the possible impact of AI into university studies. Four specific results will be produced, being the Booklet the first of them.

The scope of the Booklet is to organise the AI features, identify challenges, opportunities, risks associated with certain uses, and expected impacts on different ambits of our society. At the time of writing this paper, we have delivered the first version of the Booklet for internal and external review. We consider therefore appropriate to present a summary of the content of the Booklet in this work.

The rest of the paper is organised as follow. In Section 2, we describe the objectives of the HEDY project as well as more details about the Booklet. In Section 3, we present the methodology we adopted to build our rationales. Section 4 discusses the main findings and highlights the key ideas. Section 5 concludes the paper.

2 THE HEDY PROJECT AND THE BOOKLET

HEDY – Life in the AI era provides tribute, in its own title, to Hedy Lamarr [2], an Austrian actress and inventor (1914-2000), co-creator of wireless communications technology and currently still used in mobile networks, Bluetooth devices and Wi-Fi. HEDY's goal is to offer a comprehensive and shared view of how AI is affecting our lives and reshaping our socioeconomic, cultural, and human environments by promoting critical reflection, self-based learning and debate on these issues. The main (but not exclusive) target group of this project is higher education audience.

Four specific objectives will be produced to reach this goal:

1) A **Booklet** – an essay defining the HEDY position on life in the AI era and the rationales for that position;
2) A **Toolkit** – a collection of influential AI audio-visual related tools, including films and expert talks with the ability to have a more immediate impact to the audience;
3) A **Massive Open Online Course** (MOOC) – a course to spread out the awareness of main developments in AI and promote extensive knowledge, critical reflection and debate on AI and its key impact on society;
4) A **Guideline** – a concise and easy-to-read documentation for the best use of the assets produced and for the creation of a solid foundation to ensure the usability of the HEDY results by a wider community of practice network.

The Booklet is the subject of this project. As stated above, its scope is to identify the challenges and the risks associated with the use of AI and the expected impacts on four different ambits of our society: **business**, **governance**, **skills & competences**, and **people & lifestyle**. Besides describing the current applications and expected impacts of AI for each ambit, we also aim at identifying the 5/6 more concerning issues about AI. Nonetheless, we are not trying to provide general solutions of these concerns; on the contrary the idea is to offer an engaging way to stimulate reflection and debate on knowledge society topics, discuss the ethical effects of these emerging digital technologies and provide paradigmatic examples.

Currently, the first version of the Booklet is under the internal review process. After that, the Booklet will be presented in a so-called Multiplier Event to a group of at least 40 selected participants. During this event, the Booklet will go through the external review process. After implementing the feedbacks received from both processes, the Booklet will be published in the project website [1]. It will be freely accessible and available in 7 different languages: English, Portuguese, Bulgarian, German, Spanish, Catalan and Hungarian. The expected publication date is July 31th, 2022.

3 METHODOLOGY

3.1 Introduction

We collected information from two different sources to build our rationales: 1) Literature survey, and 2) Focus groups. Clearly, the first source consisted of collecting the current state of knowledge about the applications and impacts of AI. The second source consisted of gathering information by interviewing people through focus groups with expert and non-experts in AI in 5 different European countries. Due to the space limit, here we can provide only a summary of our methodology while all details will be added in the extended version of the Booklet soon available in the project website [1].

3.2 Literature survey

Our first source of information came from the available literature on AI in general and on the four ambits described above in particular. The aim was to acquire an in-depth grasp of the subject and to understand current knowledge. This allowed us to: i) identify relevant theories, methods, and opinions in the existing state of the art and report them in the Booklet; and ii) organise and guide the participants through the focus groups with these bases already learned so to obtain the complementary information we needed.

Hence, we searched, read and evaluated more than 250 documents, between research papers, magazine articles, expert blogs, companies' reports, agencies' guidelines, etc. to get the proper knowledge on the challenges and opportunities of AI and the current applications and expected impacts in both short and long terms.

3.3 Focus groups

During February 2022, we prepared and conducted two different focus groups in each of the project partners' countries: one focus group with only experts in AI and one focus group with only non-experts in AI. The project defines the term *expert* as a person with a university degree, working for at least 5 years in the area of AI, digital society, human-robotic interaction or Industry 4.0, and at least 3 published scientific or professional articles. The number of participants for each group was set to a minimum of 5. In one case, the focus group was not possible to be organised due to conflicting schedules/COVID restriction; we substituted the focus group for a questionnaire. The questionnaire was created with similar questions used in the focus group. In summary, nine focus groups and one questionnaire were organised and the results analysed following the directives available in [3]. More details are listed below:

1) Two focus groups in Budapest (Hungary) about AI challenges and opportunities
    - 8 experts (7 males, 1 female) aged 28-61 years old;
    - 5 non-experts (2 males, 3 females), aged 20-28 years old, university students enrolled in a Master's degree
2) Two focus groups in Münster (Germany) about AI in business
    - 7 experts (7 males) aged 26-50 years old;
    - 7 non-experts (3 males, 4 females), aged 22-30 years old, university students enrolled in a Master's degree
3) Two focus groups in Barcelona (Spain) about AI in governance
    - 9 experts (7 males, 2 females) aged 35-70 years;
    - 10 non-experts (7 males, 3 females), aged 22-70 years old, from civil society with no previous knowledge on AI.
4) Mixed approach in Lisbon (Portugal) about AI in skills & competencies
    - 9 experts (6 males, 3 females) aged 26-67 through an online questionnaire;
    - 5 non-experts (3 males, 2 females) aged 23-55 master students or recent graduates through a focus group.
5) Two focus groups in Varna (Bulgaria) about AI in people & lifestyle
    - 6 experts (4 males, 2 females) aged 29-59 years;

- 15 non-experts (4 males, 11 females), aged 20-24 years old, students enrolled in a university degree.

4 DISCUSSION

AI came to stay in our daily lives. This is an obvious conclusion and we need to deal with it. So, how can we do that? In this paper we have reviewed many literature sources and talked directly with experts and non-experts in AI to have a better understanding of the problem, the concerns, and the opportunities AI can bring to the humanity and its impacts to our society. In this section, rather than presenting the literature survey and focus groups results separately, we prefer to discuss them together. In this way, we can reflect and contrast people's (both experts and non-experts) first-hand opinions with state-of-the-art research and vice versa. Thus, we are now able to provide a set of key ideas.

There is a clear indication that AI is conceived in two different ways:

a) **Restrictive view**: AI as one more technology and therefore needs to be treated like any other technology.

An expert said: *"AI is technology and a technology is not for everything, it is for what it is".*

b) **Disruptive view**: AI as a differential technology, which marks a before and after in human society and the relationship with technologies.

An expert said *"It simply came to stay. He has come to change society and, moreover, we will not be able to go back".*

These two ways of conceiving AI appear alternately throughout our two-fold sources. While seemingly restrictive and disruptive views may be understood as contradictory, they are in fact complementary views that make it possible to grasp the complexity of opinions, concerns and proposals around the use of AI systems.

From a restrictive point of view, AI tends to be seen as a chance: it can create new, very qualify and remunerated jobs, open new market and business opportunities, make life easier and heathy, the bureaucracy faster, etc. [4][5]. The common idea is that AI is useful in decision-making processes [6]. The challenges that may be raised by these processes are considered restricted and possibly overcome by drawing a clear border between when AI may be employed and when it cannot. In this sense, AI is thought to be particularly effective for data management and analysis, as well as information assistance for decision making and assessment, but not for automated decision making [7]. In this sense, it is thought that decisions that have a direct impact on people must be decided by people.

An expert said: *"In the end they are algorithms and we should not let them decide for us".*

In contrast, from a disruptive view of AI, the argument is that in contemporary societies any area already integrates or will integrate soon AI. It is thought that, while we do not want AI to participate in many aspects of our daily lives, it is vital to analyse the costs and benefits, based on assessing what would happen if AI systems made incorrect decisions [8]. This may affect several areas of our environment and is in these specific areas that the risks of using AI systems need to be assessed. The justice, the people's privacy (i.e., freedom), the algorithms themselves (aka, the bias of the data), the biomedicine, the finance are only few examples of the areas identified [9].

A shared concern, which is mostly associated with a restrictive view of AI, and which appears both explicitly and implicitly throughout all sources, has to do with the relationship of AI systems with science fiction imaginaries or with the idea that AI can solve all problems of any kind.

> An expert said: *"I think I know the difference between science and fantasy, but it is the interaction between these two fields that has led to the development of both".*

> A non-expert said*: "It is important to see and read how science fiction artists think, and be inspired to develop real-world solutions supported by AI to help humanity evolve".*

Numerous applications have been developed in the field of AI and can be applied in many fields [5], but there is a significant gap between current functionalities and technical capabilities and the narrative of what AI could do in the future [10]. This type of narrative around AI, which does not correspond to current developments, is considered to have two types of negative effects: i) The difficulty of articulating a proven public debate on accountability when using forms of AI in decision-making processes; ii) The emergence of a series of catastrophic imaginaries that generate reluctance towards AI between public opinion and citizens [11].

Regarding the specific ambits analysed, we can summarise that:

- In **business**: AI is seen as a great potential especially when it comes to saving time, facilitating tasks and bringing innovative solutions, especially in field such as medicine, biomedicine and finance. Risk is related to finding a balance between the economic interests of companies and the non-violation of citizens' rights in matters related to privacy and individual freedom [12].
- In **governance**: there is a global agreement on a fundamental set of five AI principles that are functionally algorithm-agnostic, technology-agnostic and sector-agnostic to provide a trade-off between company's strategies and objectives, legal requirements, and ethics: accountability, transparency, fairness, safety, and human control [13].
- In **skills & competences**: the need for physical, basic cognitive and manual skills will be reduced due to the taking over through AI while digital competencies, critical thinking, teamwork, communication, technological as well as social and emotional skills will be more demanded. Education systems' priorities need a shift to reflect this to better develop students' abilities. Major risk is related to "less developed" countries which are in danger of being left behind even more [14].
- In **people & lifestyle**: AI should contribute to make person's life more productive, efficient, secure and easier. We may have personalised monitoring and diagnostic

capabilities, an increased free time, the possibility to develop our natural interests and talents, a better and faster infrastructure, etc. Major risk is related to the fact that AI can be biased and perpetuate or even increase the gender, racial, and ethnic disparity and inequity [15].

It is worth to mentioning also one of the most important topics not addressed in our survey and focus groups. That is the impact of AI to our environment and how it can help with the current crisis due to the climate change. On the one hand, AI is a major energy consumer given the complexity of training and inferencing on big data, above the fact that all ICT ecosystem is already one of the major contributors to greenhouse gas emissions [16]. On the other hand, AI has also been presented as the solution of the climate change due to its multipurpose capabilities, which include tracking and cutting emissions, allowing creative economic models to aid the environment, and enhancing climate resilience. For instance, a study commissioned by Microsoft [17] concluded that using AI for environmental applications has the potential to boost global GDP by 3.1 – 4.4% while also reducing global GHG emissions by around 1.5 – 4.0% by 2030 relative in business, up to 2.2% in energy and up to 1.7% in transport.

Many considers that human social and intellectual capacities like creativity, empathy, innovation, teamwork, etc. are irreplaceable by AI (see for instance [18]). In short term, the vision is that we will face the emerge of more artists as a response to the lack of those works replaced by an AI. Nonetheless, this vision seems too optimistic: AI is already able to compose symphonies, paint pictures, write poems, songs, and stories as well as play games. Some countries like Australia already accepted that an AI machine can be registered as an inventor in a patent. In the future, it is likely that these capabilities will be even more explored.

Finally, a common opinion is also that AI should not replace human capability and human freedom to make decisions should be prevented from being influence by AI-driven tools.

> A non-expert said: *“I only believe in AI when it gives the same result as human intelligence”.*

In particular, ethics is a recurrent problem raised in all our sources. Even the experts we have interviewed consider that they do not have enough knowledge to be able to decide on ethical and social issues, a knowledge that should be integrated in an interdisciplinary way.

> A non-expert said: *“An investigation to recognize a person from the iris was funded through tax haven funds, to identify women with burkas and whether or not they were with their husbands. I was very surprised […]. How to do it? Getting here, yes? Getting here, right? What’s the limit?”.*

In order to avoid this type of narrative and its negative effects, actions related to information and citizen participation are needed:

- **Information**: Ensuring that the media reports ethically and honestly when talking about AI systems, which allows for a clear distinction between speculative futuristic visions and current developments and possibilities. Develop a pedagogical task that allows the public to know how AI works and what applications are being developed.

- **Participation**: Involve the public in the establishment of priorities for the development of AI, in the service of needs. This is considered to be the added value of the European AI development strategy, compared to other strategies that may be more technologically advanced or in terms of implementation, such as China or the United States. It is considered that the European strategy can incorporate as an added value to its AI the integration of citizens in the establishment of priority areas in which to develop or apply it.

5 SUMMARY AND ACKNOWLEDGMENTS

In conclusion, AI is a technology that in its design and development is so far removed from everyday life that experts believe that the population is not trained enough to make decisions about how to use AI. Although, at the same time, it is considered necessary for citizens to make decisions and decide on the course of AI. For this reason, we point out the necessity to train citizens in the operation, potential and possible effects of AI. We need therefore to provide teachings, courses and trainings in schools and higher education institutes to facilitate the use and adoption of AI for young people and future generations. This is indeed the main goal of the HEDY project. Throughout the next two years, in addition to the Booklet, HEDY will provide a MOOC with exactly the aim of reaching higher education audience and show them the capability of AI, the opportunity our society has in this moment to change our environment to a better one but also the risks we are facing from different point of views. This material will be complemented with the Rootkit: a set of supporting multimedia tools with the ability to have a more immediate and visual impact to the audience. The final contribution will be an easy-to read Guideline to ensure the usability and sustainability of the HEDY results, and promote a wide and solid community of practice network.

Finally, it is worth mentioning the limitations of our analysis. On the one hand, it is a qualitative analysis therefore general conclusions are more difficult to elaborate compared to a quantitative one. On the other hand, there is the limitation of the heterogeneity of the focus groups since most of the experts were academics and the non-experts were students. However, our two-fold approach allows us to contrast people's opinions with the available literature and vice versa, so we believe our findings are valuable and other similar work is likely to reach the same conclusions.

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PROGRAMMING 1 and SUSTAINABILITY

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ABSTRACT

Computer programming is an essential skill for today's engineers, and sustainability plays a role of growing interest in any of the design phases of an engineering project. The fundamentals of sustainability, with basic concepts such as "carbon intensity", must be covered in any engineering curriculum.

We propose a basic computer programming course in which the lab sessions incorporate exercises related to the computation of environmental impacts. For instance, an exercise might request the computation of the carbon footprint of the lab

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sessions during a whole year. Lab sessions use an automatic evaluation server, so called Jutge.org that assesses about the correctness of the programs submitted by the students. New exercises concerning sustainability topics are included in the Jutge.org course.

The course involves the effort of a multidisciplinary team. First, lecturers on basic programming are required. An expert on automatic evaluation of computer programs is essential to prepare the statements and the test sets of the proposed exercises. Finally, the advice of economists and sustainability experts is crucial to guarantee judicious conclusions are drawn from each exercise. Forming a team with this profile is a challenging task.

Our Computer Science (CS) department lectures basic programming courses to more than 1700 students/year. The success of this approach could bring a substantial social impact in our ecosystem.

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1 TEACHING PROGRAMMING AND SUSTAINABILITY

Sustainability principles are playing an increasingly important role in our society.

Nowadays, the environmental impact of any major business, social or policy initiative is always examined. In the task of promoting sustainable behaviours, universities must play a prominent role and teaching sustainable development must be part of the curricula. For students motivated in the subject, books on sustainability like Bill Gates' [1] or William Nordhaus' [2, 3] can be recommended.

Basic programming courses are common in science and engineering majors. Introducing fundamental concepts of sustainability in programming assignments is a way of disseminating this knowledge to many students. While keeping traditional learning goals, we propose a first computer-programming course that considers, besides standard lab exercises, assignments concerning the computation of environmental costs.

This approach is close to the one described in [4], where the pedagogical results of a programming course that introduces a list of sustainability-themed assignments are reported. The novelty of our course is to integrate this type of assignments in an automatic evaluation server, so called Jutge.org [5], which assesses about the correctness of submitted programs.

The exercise statements in Jutge.org have to be short, clear and self-contained. More importantly, they also need to be easily understandable without prior knowledge on sustainability. New sustainability lab exercises need to be carefully designed, involving the effort of a multidisciplinary team. First, lecturers on basic programming are essential to assess the suitability and understandability of the new proposals. Second, a Jutge.org expert is required to incorporate the new exercises and test cases to the evaluation platform. Third, experts on ecology, sustainability and economics are required. A multidisciplinary team with combined expertise contributes to design meaningful assignments with convincing outcomes. Our CS department lectures basic programming courses to more than 1700 students/year. In the long run, the approach we propose can have a significant impact on the environmental awareness of students.

2 THE JUTGE.ORG APPROACH

For fifteen years, our CS department is using Jutge.org [5], an automatic evaluation platform, in several programming courses. Jutge.org has an extraordinary amount of exercises organized in lists and courses. Each programming exercise consists of a statement and several test cases. Public tests shown in the problem statement improve global readability and help students to find a correct solution. Additional private tests, not visible to the user, are included to evaluate the submitted programs.

From our experience, we think Jutge.org provides an invaluable help to student progress. The immediate feedback about submissions allows student self-learning at any time and place. During lab sessions, instructors can focus on aspects Jutge.org cannot assess, like program readability, coding style, and basic principles of algorithm efficiency. Beyond immediate feedback, the use of the evaluation platform is a way to develop an active learning approach.

3 BASIC PROGRAMMING COURSES

Courses taught by the department consider specific School circumstances, but lab sessions are always an unavoidable course part.

3.1 At Computer Science School

The first programming course is a very basic course. As a typed approach is considered, C++ is used. Sequential decomposition and case analysis are first introduced. After that, item sequences are considered to deal with loops. Emphasis is placed on sequential treatment schemes: treat-all and searching. Later, procedures and functions are shown. Vectors and Tuples (Structs) are also taught. No more data structures are introduced.

The schedule is 2 hours/week of theory lectures on fundamental programming concepts and 3 hours/week guided lab.

3.2 At Engineering School

As the introductory course will be the only general programming course for most students, more programming features are taught but in a less depth way. Python is the programming language and lists and dictionaries are the main data structures. The schedule is 2 hours/week of theory lectures on fundamental programming concepts and 2 hours/week guided lab.

3.3 School influence on jutge.org courses

Specific School requirements translate to specific Jutge.org exercises. This should be considered when we deal with sustainability topics.

4 SUSTAINABILITY CONTENT IN PROGRAMMING EXERCISES

A computer program processes a data set to obtain new results. Two crucial points when proposing a new exercise are to provide right input data and to formalize, unambiguously, the questions the program has to answer. Regarding these points, a number of issues arise when writing new exercises with sustainability content. Some of these difficulties are described below.

The main problem faced by the team is: programming exercises designers are not experts on sustainability. They follow suggestions about possible exercises of the team's experts; they ask questions and get answers. The dialog is fruitful, but it takes time, sometimes a lot of time. Following two aspects of such difficulties.

4.1 About input data

Lack of intuitive meaning of big numbers and data reliability are the main concerns about program input data.

Lack of intuitive meaning of numbers. *What does 51 gigatons of Co2 per year mean?* [1] That is $51 * 10^9$ tonsCo2/year. As Bill Gates points out, *this number means nothing intuitively for most of the people*. In order to get some insight, let us compute the ratio per capita. The world population is $7.93 * 10^9$. Therefore, the number of tons per capita is 51/7.93 = 6.43 tonsCo2/human. It seems that 6.43 tonsCo2/human looks both, more understandable and very impressive!

Data depends on the source. At https://www.worldometers.info/co2-emissions/ we found the ratio per capita 4.79 tonsCo2/human. At least it seems to be of the same order of magnitude. Another example, looking for the Co2 emitted by a query on the Web, we found 0.2 gCo2/query for a Google search (look at https://searchengineland.com/calculating-the-carbon-footprint-of-a-google-search-16105) but we also found 0.09 gCo2/query (look at https://www.altavia-group.com/en/green-web-needs-to-happen/). As 0.2/0.09 = 2.2, there is a degree of uncertainty about data.

Even working with uncertain data and unintuitive numbers, the topic is so important, that makes sense to introduce sustainability concepts in basic programming courses.

4.2 Issues working with rough numbers

Imagine that you would like to prepare a lab exercise on the number of trees needed to absorb the annual CO2 emissions. After asking an expert, you assume that one tree absorbs an annual average of 24 kgCo2. As a first idea, you will work with rough numbers. From Bill Gates book [1] you assume an annual emission of 51 billion tons Co2 = $51 * 10^{12}$ kgCo2/year.

From https://www.gotreequotes.com/how-many-trees-in-world/ we find that the number of trees in the world is $3.04 * 10^{12}$.

As $51 < 24 * 3.04$ you may conclude, that trees will absorb all Co2 emissions and thus, there is no problem. This reasoning is quite incomplete and shows a lack of knowledge about the carbon cycle. Computer scientists without expert's advice can make big mistakes. A way to avoid this type of mistakes consists on working with an interdisciplinary team. Having members with depth knowledge in ecology and sustainability is fundamental.

5 SUSTAINABILITY IS A HUMAN PROBLEM

As we are in an Engineering University, we are familiar with units like kgCo2/kWh.

It could be tempting to think that all sustainability problems can be solved through good engineering improvements. From our point of view this is a big mistake. Of course engineering is fundamental to improve the situation [1] but according to Nordhaus [2, 3], the problem is motivated by human society. Therefore we have to consider human aspects. Most relevant ones are described as global goals in the United Nations collection SDGs.

Sustainable Development Goals (SDG, https://sdg-tracker.org/*)* are a list of seventeen goals designed to be a plan for a better and sustainable future. A straightforward way to encode SDGs as a data structure is by a dictionary, a resource available in Python as basic structure:

dic_SDG = {"Goal 1": "End poverty in all its forms everywhere",

"Goal 2": "End hunger, achieve food security and improved nutrition and promote sustainable agriculture", … ,

"Goal 17": "Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development"}

Taking *dic_SDG* as data structure, we can design exercises to introduce SDG to our students. In Engineering Schools dictionaries appears in the program and there is no problem. As in CS school dictionaries are not in the basic course but we can develop exercises through the targets of the goals.

Do not forget economic aspects. The economic activity (figure 1 on pag 10 of [2] and figure 5 -1 of [3]) is at the core of the problem. Some exercises, need to face this. According to Brundtland Commission [6] a sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs". We need to compare today consumption with tomorrow consumption. This implies to discount the future to valuate into the present. This is an old problem (chapter 11 of Keynes [7]). Having an economist in the team is also fundamental.

Biodiversity. Topics like biodiversity (chapter 11 on [2]) are even more challenging.

6 PROGRAMMING EXERCISES

6.1 On the mechanics of designing an exercise

It all started with a meeting between a CS member and a sustainability expert. This meeting was fundamental in two aspects. First, it provided to CS members team with a list of links to start working. Second, the expert strongly emphasized the need to give a concrete meaning to the big numbers. After that, the team start planning exercises for Jutge.org.

The development of exercises for the Jutge.org takes much more time than expected. Even if some of the CS members has an informal knowledge on sustainability [1, 2, 3]; this knowledge was too general to be transformed into exercises. They go through the links over and over, talk and talk with sustainability experts, reread the books and slowly tentative ideas for exercises appears. As Tony Hoare point out years ago over ambition was the problem for CS members. Following we give an example.

6.2 Example of Jutge.org Exercise: Co2 to Trees

Statement. Co2 is one of the most important greenhouse gases. Trees extract CO2 from the air and convert it into oxygen and plant material through photosynthesis. Browsing the web, we got the following data.

First, the annual average kWh_consumption, denoting the household energy consumption (due to electricity):

- France: 4760 kWh
- Germany: 3149 kWh
- Ireland: 4200 kWh
- Spain: 3487 kWh

Second, considering how electricity is produced we get different conversion_factors:

- France: 0.059 kgCo2/kWh
- Germany: 0.181 kgCo2/kWh
- Ireland: 0.292 kgCo2/kWh
- Spain: 0.209 kgCo2/kWh

Finally, from https://www.encon.be/en/calculation-co2-offsetting-trees let us assume that the average annual CO2 offsetting_rate is 24 kgCO2/tree.

For a given country, we ask to compute the number of trees by household needed to absorb the Co2 generated in a year. Write this number with 2 decimal places.

Input. The input is formed by a non-negative integer *n* followed by a sequence of *n* triples. Each triple consists on a country name (string), a household energy consumption (double) and a Co2 conversion factor (double).

Output. For each country in the input sequence, a line with the number of trees by household to offset its Co2 emissions. Follow the format in the example below.

Public test cases.

Input

```
4
France 4760 0.059
Germany 3149 0.181
Ireland 4200 0.292
Spain 3487 0.209
```

Output

```
France: 11.70
Germany: 23.75
Ireland: 51.10
Spain: 30.37
```

6.3 List of Programming Exercises.

Following the list of currently available exercises in the Jutge.org

a	Co2 emissions by activity
b	Co2 to Trees
c	Carbon intensity of electricity generation
d	Life expectancy
e	Income inequality
f	Carbon emission reduction

Most of the proposed exercises, a, b, c and f are related to the carbon emissions. The exercises d and e are inspired in SDGs. Currently some topics are missing on the list. Exercises based on economy are missing. Should appear exercises based on Carbon Tax or Green Premium. In addition, exercises that relates the present versus the future should appear. We could do that through the idea of present value. Some of the missing exercises are under construction. Others will need much more reflection and time.

7 POSSIBLE COURSE ORGANIZATIONS

Jutge.org offers facilities to create new courses and also to update the list of exercises on existing courses. This offers different possibilities.

7.1 First year programming course.

We plan to update the introductory programming courses of our Department with sustainability exercises. In fact, we start doing that. In the first Control, of CS students, it appears one exercise of the list. Doing that we expect to catch the feeling of the CS students about this kind of exercises.

7.2 Transversal first year sustainability course.

This is a very ambitious project because it is difficult in our University to offer new courses. This course should offer the possibilities to our students to get basic knowledge about sustainability. It should consider, both, engineering aspects but also human aspects. The course could be seen as a guide for self-study and active research. As basic readings along the course, we consider Bill Gates book [1] and or William Nordhaus book [3].

Several topics could be considered in this course with the corresponding links.

- *Co2 and trees:* Encon: from emissions to trees.

  https://www.encon.be/en/calculation-co2-offsetting-trees
- On ways to produce electricity.

  ourworldindata.org: primary energy versus consumed energy.

  https://ourworldindata.org/energy-substitution-method

  electricityMap: conversion of kWh into Co2.

  https://app.electricitymap.org/zone/ES?solar=false&remote=true&wind=false
- SDG

  https://sdg-tracker.org/
- Co2 and streaming videos.

  idea: carbon footprint of streaming videos.

  https://www.iea.org/commentaries/the-carbon-footprint-of-streaming-video-fact-checking-the-headlines

Programming possibilities: To have a guide on programming exercises you can take any one (or both) of the following choices:

- Jutge.org

  https://jutge.org/
- Jeffrey Stone projects: 9 topics each one with a self-contained video.

  https://sites.psu.edu/sustainabilitycis/active-projects-cpp/

8 SUMMARY AND ACKNOWLEDGMENTS

We have introduced our efforts to deal with sustainability in first-year programming courses.

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Learning path for Construction 4.0 based on tinkering and STEAM

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ABSTRACT

This article describes the outcomes of a completed study of practice in civil engineering education. The study is aimed at infusing Construction 4.0 content to a Bachelor degree on Civil Engineering. A set of STEAM-rich activities are created in the form of an individual learning path. These activities are conceived with a threefold perspective: i) Construction 4.0-related, ii) STEAM vision by-design and iii) hardware-software independent (open-source, accessible, affordable). Cornerstone and capstone projects as well as a set of workshops represent some demonstrators of these activities. All these demonstrators are knitted together in a single path in that is pegged to the traditional curriculum The STEAM perspective provides completeness to the whole development. During the last two years, design, development and implementation of several demonstrators have been completed. Some results related to the application of some activities are already available. In the years to come, it is expected that an improved systematic deployment of such activities will allow assessing the evolution between tools, pedagogies and the needs of the sector. In this paper, the description of the activities together with the discussion on the potential of tinkering on Construction 4.0-based curriculum is addressed.

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1 INTRODUCTION

The process of digitization of the Architecture, Engineering and Construction (AEC) sector is relentless. In other sectors, this has represented a major change between players. AEC will certainly experience a significant disruption as well. The built environment sector is reaching maturity for leapfrogging to more efficient production, business models and overall, value chains. Both the natural as well as the built environments provide endless possibilities for digitization when it comes to linking physical assets and virtual models. A balanced path to digitization of a sector implies coordination between stakeholders. Academia where new generations of civil engineers are formed is called to be present and active in such scenario.

Technological advances in AEC are presently disrupting the sector. When applied in a coordinated and systematic way, these advances are much more powerful in efficiency. The coordination between the construction realm and its virtual counterpart is generating a framework in which a tripod of three themes can be identified

- Industrial production (prefabrication, digital fabrication, additive manufacturing, offsite manufacture and robotic assembly).
- Cyber-physical systems (autonomous systems, digital twins, smart infrastructure).
- Digital technologies (BIM, extended realities, interoperability, cloud computing, blockchain, AI, computer vision, etc.).

In AEC, proposals for infusing automation and robotics within the curricula have been discussed for some decades [1]. On the other hand, the adoption of BIM in civil engineering curricula is a matter of survey, debate and systematic scrutiny [2]. When it comes to cyber-physical systems in AEC classrooms, developments are also identified [3-4]. Within «de las MATES al STEAM », an educational project developed between 2019-2021 at the School of Civil Engineering at the Universitat Politècnica de Catalunya in Barcelona, Construction 4.0 and STEAM were put together. The initial conundrums at the onset of this development were : How prepared are existing civil engineering curricula for this disruption?. How is digital and automated fabrication being infused in AEC classrooms? Are AEC students prepared enough for understanding cyber-physical systems conceived for the natural or built environments ? What is the level of maturity of BIM-based curricula in AEC. An extensive academic literature review allowed identifying academic practices worldwide as well as gaps within curricula [5-8].

This paper shows the key takeaways of “de las MATES al STEAM”. The project resulted on the design of set of activities for embedding Construction 4.0 concepts within a civil engineering curriculum. The development of these activities was conceived by-design using a STEAM, tinkering perspective. Findings related to the attractiveness of this perspective in AEC students are also described. The activities are knitted together in the form of an individual learning path that reinforce concepts of traditional curricula in civil engineering with the use of Construction 4.0 open, accessible and affordable technologies.

2 LEARNING PATHS

Standard degrees are necessarily complemented with personal learning paths. This need is embedded into the DNA of intrinsically motivated learners. Civil Engineering Schools may or not have a vast array choice of optional courses. A complementary personal learning path is a learner-centered approach that emphasizes learner-specific goals and objectives, as well as preferences that a learner elects on their own. Students comprehend their personal learning pathways through several ways such as: (i) the identification of optional courses through preference of topics that are the most relevant to student’s current or future professional activity, (ii) use of accountable side-courses, workshops, capstones, hackathons or (iii) development of internships and academic exchanges.

3 LEARNING PATH IN THE PROJECT “DE LAS MATES AL STEAM”

The proposed learning path for the infusion of Construction 4.0 activities within a standard curriculum is illustrated in Fig. 1. By-design, the path is conceived for including the depicted tripod of themes of Construction 4.0 with a STEAM approach. Dissecting this illustration, one identifies several bullet points:

- In the 1st academic year, cornerstone projects related to coding are proposed. These projects are conceived for the sake of introduction to visual and geometrical programming, which are fundamental for subsequent developments. The programming content of the projects is also aligned with the actual syllabus of regular courses of Calculus, Algebra and Geometry. Pilot implementations within formal courses have already been taken place at the School in the last three years. The principal STEAM components of such projects are Maths (M) and Arts (A).
- In 2nd and 3rd year, the activities consist of a set of workshops. Different themes of Construction 4.0 such as Automation and Robotics, Digital Fabrication, BIM or IoT represent fertile topics for the generation of workshops

that can be updated year by year. The principal STEAM components of such projects are Science (S), Technology (T) and Engineering (E). These workshops are self-contained but if students are acquainted with the content of the cornerstone projects, their learning curve as well as their achievements are boosted. These workshops are conceived for 1 ECTS. If this credit needs to be recognized to the students by the system, the minimum number of hours of these activities with proper compeletion is 12.

- In 4th year, a capstone project allows closing the loop by integrating all (S)(T)(E)(A)(M) components in a single activity. Ideally, this represents a fertile ground for more ambitious projects with a multidisciplinary perspective. Its application may range between individual final project for the Bachelor degree to more multidisciplinary projects in which students from electronics, computer sciences and civil engineering may converge. The former option has already been experienced at the School whereas the latter requires more coordination between educational centers at University levels.

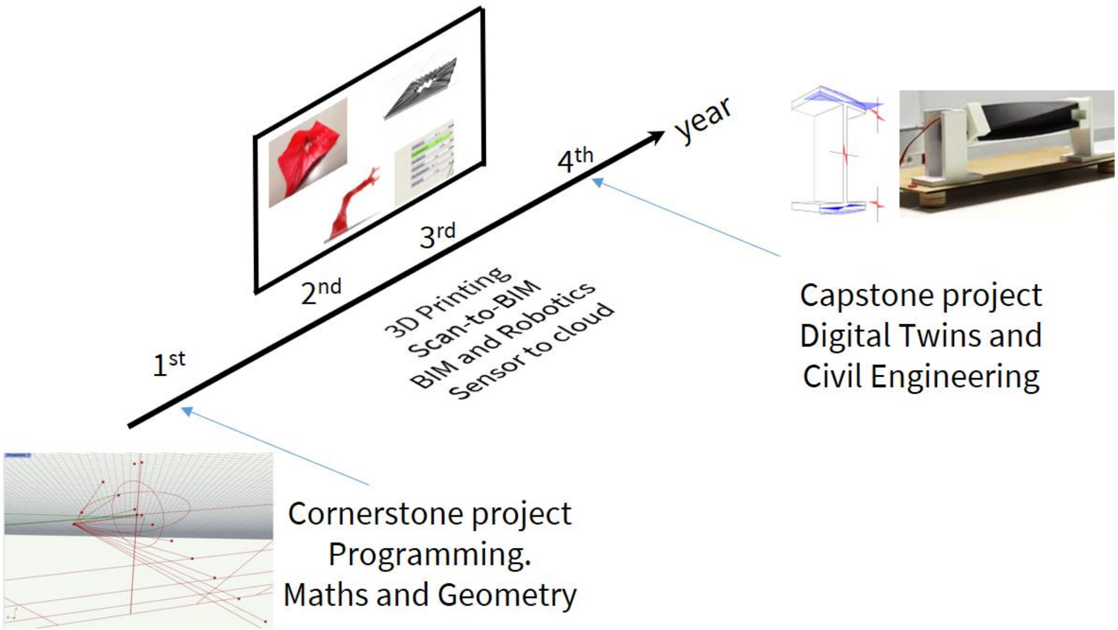


Fig. 1. Schematic view of the proposed set of activitis within the civil engineering timeline

4 LEVEL OF IMPLEMENTATION OF ACTIVITIES IN RECENT YEARS

In the last years, many of those activities have been implemented at both Bachelor and Master levels. In the following, a brief description of these implementations together with results obtained so far.

- Cornerstone projects: The cornerstone projects are established as activities related to Calculus and Computational Geometry for 1st year students. These activities are conceived for the sake of exposing our civil engineering students to the development of computational applications using basic concepts of mathematics and geometry. One of the already implemented projects (2020, 2021, 2022 editions) is related to the development of visual applications using functions and derivatives. An introductory programming challenge is optionally proposed to students. For different editions, students have or not received a reward on the total grade of the courses if the challenges is achieved. The application of the programming activity in the 1st Edition (2020) coincided with the global lock down and the participation peaked 98%. In subsequent years participation has lowered to 50%. Applied introductory programming are always useful and necessary for civil engineering students due to their uneven prior acquaintance with coding skills. The project is aimed at reinforcing concepts of differentiation throughout a hands-on coding activity. The formal Calculus syllabus (M) including derivatives is illustrated by students by designing a beautiful visual application (A).The challenge of the activity is: For a given implicit function, an interactive visual application must be developed. Details on the developments the can be found in [9] and an illustration of the developments is presented in Fig. 2.

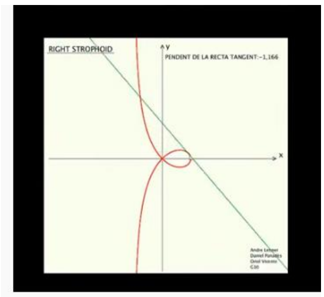
- Workshops:

    - ***Sensor-to-cloud***, a workshop already implemented within formal courses at the School, represents a journey from physical-to-virtual. AEC classrooms are filled with countless attempts of understanding both natural and built environment. Practically every single magnitude studied in AEC is prone to be measured with sensors. Acquiring basic skills on measurement is thus, very relevant. This activity has been implemented in varying forms by the educator since 2015, when electronic prototyping platforms such as Arduino were first used in the School. The activity has already reached maturity and present editions are developed in 12 hours (1ECTS). All participants are provided with sensors, microcontrollers (open, accessible and affordable) and an account to a cloud-based IoT platform developed at the School. The development of this activity has evolved rapidly and different cloud technologies have been tested [10] in the classroom.
    - ***3D printing*** (prepared) represents a journey from a virtual space to the materialization of an object. The workshop may provide not only a better understanding of the virtual space but also, it sets some realisms to the boundaries provided by 3D printers. This workshop is prepared yet it has not yet been implemented. The duration of the activity is 12 hours (1 ECTS).
    - ***Scan-to-BIM*** (1st attempt done) represents a journey from physical magnitudes to a BIM-compatible space. The workshop shows one of the most promising technologies for the built environment, which is laser scanning. The workshop provided a real time illustration of how points are measured with sensors (lasers, accelerometers in this case) and virtualized with computational geometry tools. In AEC, the use of

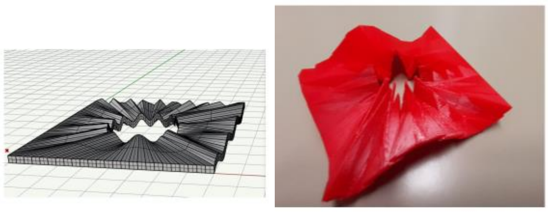
"as-built" entities in BIM software presumes an understanding of these principles. In 2022, the 1st Edition of the workshop was implemented. A short 2 hours experience in which students played with spheres, scanned the spheres and subsequenty, identified the spheres in a parametric-generative modelling tool.

- **BIM-to-Robotics** (under preparation) represents a journey from virtual to physical within a BIM-compatible space. The workshop introduces the potential of automation in construction with accessible and affordable equipment. It illustrates to AEC students what has been more traditionally present in other engineering branches, instrumentation and control of machines.

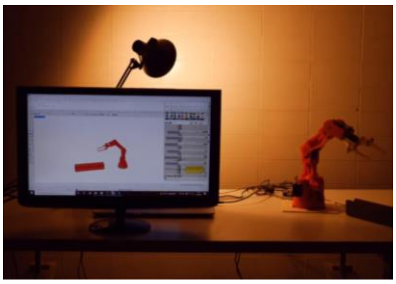
- Capstone projects: Construction of a digital twins of an asset represents a comprehensive activity that encompasses all previous developments. It represents an information construct in which both the development as well as its systematic usage are didactic. The flow of information goes from physical-to-virtual and vice versa. Sensors are needed, Virtual spaces are needed and a seamless communication between both realms is required. Digital twins also represent a promising conception in the built environment called to help in a better understanding and management of the assets at design, construction and maintenance stages. Five individual final projects at Bachelor levels have been successfully implemented since 2016. Ideas for expanding these projects to diverse teams (electronics, computer sciences, civil engineering) require further coordination between Schools. A sample of applications are found in [11,12]



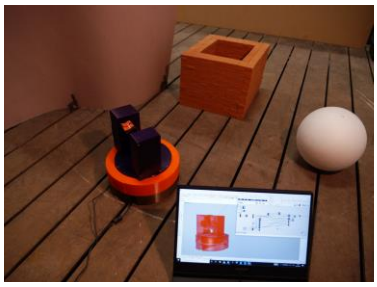
1st Year. Cornerstone Project. Calculus and Interactive Coding



2nd Year. 3D Printing and Maths



3rd Year. BIM and Robotics



4th Year. Capstone Project. Digital Twins

Fig. 2. Developments for some of the depicted activities

5 DISCUSSION AND FUTURE IMPLEMENTATIONS

Developments and findings of the recently finished educational project “de las MATES al STEAM” are depicted. The project The following key takeaways are worth pointing out:

- The market-driven driving forces for digitization of the sector are erecting a frame labelled as Construction 4.0. Digital Industrial Production (from virtual to physical), cyber-physical systems (from physical to virtual) and an established framework for digital technologies (BIM) represent the tripod of this definition.

- It is observed that Civil Engineering students are lacking specific knowledge for their proper inclusion in the Construction 4.0-related job market. This aspect is being addressed by educators and schools at a rather slow pace. Civil engineering schools are unevenly integrating Construction 4.0 activities in existing curricula. This lack of content is identified in many aspects such as the use of sensors and measurements, the use of BIM-enabled computational tools and the real time connection between the physical and the virtual realms. In addition, coding and computational geometry tools are required skills for Construction 4.0 related activities.

- Following the identified tripod, a Construction 4.0 learning path for standard degrees on Civil Engineering has been proposed. Cornerstone projects, workshops and Capstone projects were conceived with the intention of filling the Construction 4.0 identified gaps. All activities were knitted together using a (S)(T)(E)(A)(M) educational approach. Cornerstone projects are intended to foster motivation at early stages of the degree. Maths (M) and Arts (A) are blended together in hands-on activities. Subsequently, the set of workshops are intended to provide necessary knowledge on different engineering (E) technologies (T) with a critical scientific approach (S). These workshops are not limited to those proposed herein. Thus, the capstone projects result on integrators of all aspects dealt with along the degree. A (S)(T)(E)(A)(M) development of digital twins for civil engineering represents an accessible, affordable and scalable vehicle for infusing Construction 4.0 in civil engineering classrooms.

ACKNOWLEDGMENTS

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SIMULATING AN ENGINEERING WORKPLACE: A NEW APPROACH TO PROTOTYPE-BASED TEAM PROJECT

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ABSTRACT

This paper documents the remote management of a first-year foundations of engineering course with special focus on students' learning by completing a prototype-based project in an online course. The COVID-19 pandemic brought on unprecedented challenges to the teaching and learning communities around the world. Educators made purposeful changes in their teaching approaches, shifting rapidly from in-person to online mode of instruction. This study documents a project-based course that adopted an asynchronous mode of instruction as a part of the general engineering curriculum at a large Southeast university in the United States during the pandemic. This asynchronous course – through implementing necessary changes and adaptations – simulated the experience of a cross-border engineering workplace. The course content focuses on engineering design and problem-solving, physical prototyping, simulated data collection and analysis, contemporary software tools, and professional practices and expectations (e.g., communication, teamwork, and ethics). Learning activities are designed to introduce students to the types of work that engineers do daily and to challenge students' knowledge and abilities as they explore the different elements of engineering by completing an aesthetic wind turbine project.

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Our paper reports on the development of the course site as informed by recent national developments in scholarship and practice for online teaching and learning. The principles of course design alignment as well as instructor presence and learner interaction as suggested by these national standards are discussed. Further, the study records strategies adapted to enable students to complete a successful prototype-based project working in geographically distributed and virtual, international teams.

1 INTRODUCTION

The COVID-19 pandemic presented innumerable challenges for multiple fields, including the education sector. As a result of the implementation of social distancing and isolation measures to mitigate the spread of the contagion, educational institutions in the US, including schools and universities [1] [2], faced sudden nationwide closure for months from March 2020. Classes were abruptly shifted from being conducted in person to being conducted online via video-conferencing applications [3]. Active methodologies for optimal student learning [4], which conventionally focus on direct teacher-student interaction in a classroom, were no longer sufficient [1]. Lecture-based instruction was able to continue, however, coursework requirements became an issue – in particular for engineering courses that typically required hands-on, practical components such as labs and the completion of prototype-based course projects.

It is important to note that most engineering students were not used to online education, thus capturing their attention and encouraging their participation could represent a significant challenge. Some factors that contributed to this were the lack of motivation for online learning and academic stress related to it, for example speaking up in class became more stressful [5]. Although teachers adapted well to the sudden transition from teaching in person to teaching through online video conferencing software [6], students struggled with finding uninterrupted time or a quiet place to attend classes at home [7]. Another hurdle was the prevalence of digital inequalities among students [8], such as limited internet or technological resources as theorised by Beaunoyer et al. from a few factors that determine the efficiency of using technology. The primary factors were the quality of available hardware and software to access the tech resources, help provided by peers, and personal experience [8]. Interestingly, student satisfaction with the new learning methodologies differed from the suppositions initially made. In a study [9] it was established that not only did student satisfaction remain high when adapting to remote learning, but this was also reflected in the higher grades, indicating an overall improvement in the learning outcomes [9].

This paper records the ways in which a course instructor at a large, Southeastern university tackled the unprecedented changes brought about by the COVID-19 pandemic. It contains a detailed description of the modifications to the course format and deliverables, and the methods of student communication and collaboration from different geographical locations. It concludes with an account of how student participation in remote teams resulted in successful achievement of the course goals, including the prototype project, while inculcating ethical awareness. The asynchronous course simulated a global engineering workplace by replicating the typical experience of engineering projects whose success relies heavily on both individual and team-based efforts within the context in which team members are separated by both time and space – through implementing various adaptations. The theoretical framework used in this study mainly integrates active learning [4] and project-based learning (PBL) approaches. Simulating an engineering workplace in an asynchronous setting is challenging for a multitude of reasons. For instance, one of the abilities the students are expected to demonstrate is innovation, which tends to be inadvertently suppressed by students reluctant to venture beyond their earned expertise or skill set [10]. The PBL approach overcomes this by assigning projects that often revolve around solving a real-world problem through consistent and focused teamwork [10], so that students experience a learning curve addressing areas inside as well as outside of their major. Active learning has been established as a highly effective mode of instruction in both modern classroom and online synchronous/asynchronous settings [10]. This paper discusses a course in an asynchronous setting that allowed students to access the course materials at a relatively relaxed pace but still used active learning principles. Through group projects, the course ensured active student-student and student-content interactions.

2 METHODOLOGY

2.1 Overview of Course Designs

Foundations of Engineering is the second course in a two-course sequence taught to first-year general engineering students at a large Southeast university. This project-based course serves as an introduction to engineering for students through various skill development tasks. According to the curriculum, this is accomplished by engaging students in coursework that focuses on engineering design, problem-solving, physical prototyping, simulated data collection and analysis, contemporary software, as well as project management skills and standard professional practices in communication, teamwork, and ethics. Students are to design and build a 'backyard' wind turbine that operates as a kinetic sculpture kit that can be sold to homeowners, as an aesthetically-pleasing lawn ornament that generates some electricity. They are expected to be able to demonstrate competencies in using various engineering skills and tools to solve design problems. Students are reminded to implement engineering design processes while evaluating the potential ethical implications of their proposed solutions.

Using SolidWorks as a tool for computer-aided design (CAD), students learn to create physical analogs of virtual geometric solids in preparation for their project drawings. They first individually learn to design simple solids with step-by-step instructions and video tutorials provided. Their learning is then tested through SolidWorks assignments asking students to design the flange, tool block, and shaft.

Students are also introduced to the concept of stakeholders with different objectives. One of the course goals is to train students to not only develop engineering expertise but also interpersonal skills that will enable them to communicate engineering decisions to technical managers in an effective manner. To facilitate the acculturation of learning and working in a project-based environment, students are introduced to various aspects of day-to-day engineering tasks as they familiarise themselves with the different elements of the engineering design process.

2.2 Project Management and Professional Skill Development

Even though the course had to switch to remote instruction for this particular cohort, expectations on course outcomes were upheld. Students were expected to be able to define the project specifications as communicated to them through the Client's Project Description Letter. They were also to know the project timeline, to become familiar with project management tools, and to understand the uses of Comprehensive Assessment of Team Member Effectiveness (CATME). When discussing project management, the importance of early planning in relation to cost and influence was emphasised, highlighting the need to complete the project and deliverables in an efficient manner. Teamwork and issues with roles, responsibilities, and communication were thoroughly explored along with task management and the use of project scheduling tools such as Gantt Chart. Students were also briefed on details on project deliverables with milestones and important due dates throughout the semester.

Students were first given a Project and Team Start-up Package assignment to complete that contained: (a) the context and background of the design problem, (b) statement of given specifications, (c) major stakeholders, (d) questions that they may have about the project, (e) an initial project schedule, (f) identification of the major roles of team members, and (g) a team contract (agreement among team members). This assignment provided them with crucial guidance on resource management and planning throughout all major phases of the conception and design of a modified solution. Students were instructed to develop the scope for what needed to be done, identify all necessary tasks, and define the milestones and deadlines that would allow them to track their progress towards completion.

An essential first step was for students to demonstrate their comprehension of the design problem and their awareness of its technical implications to the project client. After identifying specifications, describing major and minor tasks, and providing the background in their project plan, students were asked to specify: (1) the stakeholders, (2) project management logistics (team roles and team contract documents, software tools being used for remote communication, file repository, and task management), and (3) individual questions for the client from each team member. Within team contracts, students were prompted to identify team goals and strategy, schedule and location of team meetings, team reporting and communication details.

With the help of first-quarter project and team status update reports (similar process was in place for the third quarter), the importance of periodic reports was emphasised - ensuring adequate project progress on time, within scope, and under budget. All teams were expected to have completed the design and construction of a first set of prototypes before the report was due. Hence, the main purpose of this report was for the teams to discuss the progress they had made and to present summaries of their early designs. In addition, the students were also required to reflect on what they had accomplished to date, examine their plans going forward, and make the necessary corrections to keep the project on track.

2.3 Decision Matrix and Prototyping

Students were encouraged to engage in individual design ideation and freely generate ideas and sketches (Figure 1) for the wind turbine's design. Then, they had to use the qualitative approach for the evaluation of alternative designs of fellow team members (Figure 2). This approach involved the use of decision matrices in the identification of the relative importance of the features/criteria through a set of systematic comparisons by using a pairwise comparison chart, followed by the assigning of weightage to features based upon the rank order of importance, scoring their alternative designs, and eventually narrowing down one final design to prototype (Figure 3). Using the specifications list as their guide, students were first instructed to submit five decision criteria for testing their team's wind turbine designs. Once a final design was selected, teams were instructed to build the model wind turbine with accessible materials and test it with a fan or hair dryer to observe whether a pattern was created when it spun (Figure 4). MATLAB was used to calculate the power and the torque generated by the specific wind turbine. As a team, students then virtually tested their prototype using Computational Fluid Dynamics (CFD), which analyses fluid flows using numerical solution methods. A video of their working turbine model was required to be submitted for grading.

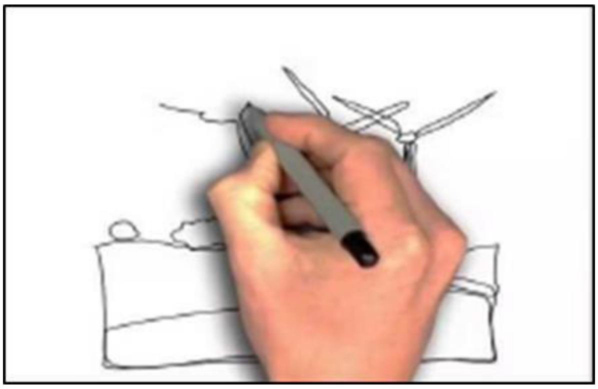

Figure 1. Freehand sketching of a student's online design ideation

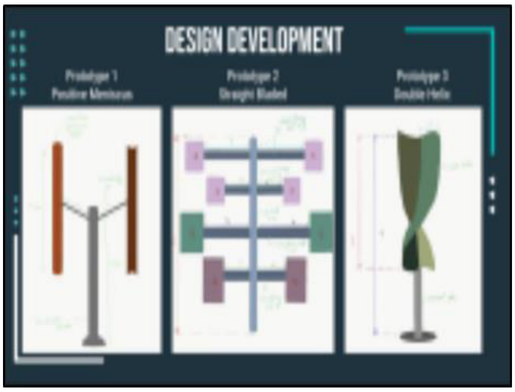

Figure 2. Design development with competing alternatives

Figure 3. An example showing the use of Decision Matrix

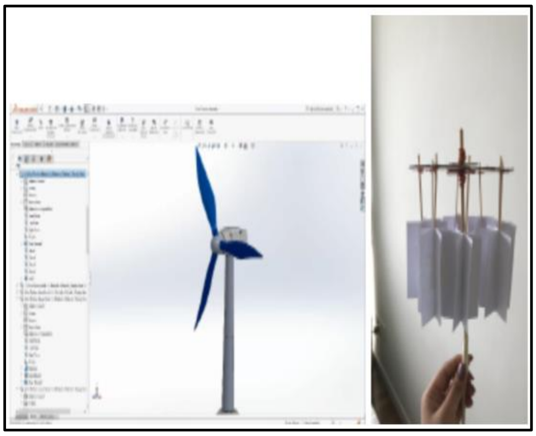

Figure 4. Virtual and physical prototyping examples

3 IMPLEMENTATION AND ADAPTATION

A cohort of 61 students was divided into 11 virtual teams of 5 students and 1 team of 6. Considering the asynchronous mode of instruction, the Canvas (a learning platform available for use by the university) site setup of the course was informed by recent developments in scholarship and practice for online teaching and learning (https://www.qualitymatters.org/rubric) with a particular emphasis on the purposeful planning of the online space alongside its structure and delivery. Table 1 summarises the primary changes and adaptations that occurred in the online format.

3.1 Highlights of Course Organization

First, an introductory video was included on Canvas to depict the instructor's passion for teaching. Adhering to the guidelines of quality assurance and management of online courses, the course homepage was strategically formatted for easy accessibility. The Modules page was also set up to contain one module per week, making it easy for students to find resources and lectures. The weekly class activity, learning materials, and weekly objectives were all linked thematically. In addition, the grading criteria were made clear for the graded discussion board.

Table 1. Summary of the primary differences between the two formats of the course.

Regular In-person	Post-COVID-19 Asynchronous Online
Mandatory **attendance** of class sessions and active in-class participation are expected.	Geographically dispersed students worked through course/project materials on Canvas in different time zones at their own convenience.
Team members are given class time to engage in **team-building activities** at the start.	Team-building exercises could not be executed due to the asynchronous nature of the course.
Team members regularly **meet in person** during scheduled class times to check in and to schedule group meetings outside of class.	Heavy reliance on online applications (e.g. Zoom and WhatsApp) for communication, and for completing project-related group tasks in general.
Materials typically required for team project prototyping are readily available throughout the course duration.	Students were expected to use their creativity in sourcing and securing suitable materials from their immediate surroundings.
Access to the well-equipped Frith **engineering design lab** on campus.	Students did not have access to special tools and lab equipment or lab assistants.
Live **CAD instruction sessions** are given to provide individualised help during class.	Students were given access to a set of pre-recorded CAD demo videos on CANVAS.
The use of **Computational Fluid Dynamics (CFD)** for testing prototypes is optional.	All teams used CFD as a means to virtually test their prototypes.
In-class **final project presentations** that showcase the teams' final physical prototypes.	Recorded online presentations were the only feasible option.

3.2 Feedback on Outcomes: Support, Accessibility, and Usability

All in all, feedback collected from students as part of the course surveys per IRB guidelines was overwhelmingly positive, such as "*the Sunday night email containing links with helpful resources helped a lot and the instructor was always welcoming and approachable*," giving much needed confirmations that students were able to benefit amply from this course delivery format.

The requirements for learner interaction were clearly stated on the discussion board. The instructor sent weekly emails that introduced the topics for that week, which allowed a more personalised approach generally uncommon with asynchronous teaching. This helped establish rapport with students, who lauded the instructor for being "*really friendly and understanding…helps the students in both course materials and mental health*." There were other comments and positive feedback from this cohort of students directed at how the instructor was handling the course, such as the instructor was "*always available for students, and … responds to emails very quickly*", "*helped me learn how to clearly use SolidWorks…was very helpful whenever I had any questions*", "*very helpful during her office hours and also a great person to talk to… understands the situations us students go through, and helps us accordingly*", and "*always provided instructions clearly and used recordings to explain content*.". Another student shared in the end-of-semester teaching evaluations that "*(instructor) is one of the best instructors I've had so far in my university. She always delivers the course material very clearly and effectively. The course is always engaging and I've never felt bored at all. The assignment feedback makes me improve always, and the weekly announcements help me stay on track and not fall behind.*"

An evaluation of the course from a faculty who provided a teaching evaluation review states: "*The instructor provides thoughtful learning experiences and resources that support her students at every step. For example, the instructor introduces conflicts of interest in an effective way and provides scaffolding through examples and an* *exercise to help students practise what they learned. The instructor managed to effectively teach, not only virtually, but also in a fully asynchronous mode*."

Navigating the entire course through the modules on Canvas was easy. Each week's resources could be located both on the overview page and the specific resources page. The PowerPoint files with audio were made easily accessible (yellow matter on Canvas). A testimonial from a student supports the above criteria of the course quality management guidelines: "*I really liked the course. It was engaging and interesting. … we had to collaborate on the interesting topic of the wind turbine. I really liked the part when we had to come up with our individual designs. Each team assignment, we had the time to socialise and talk which was really fun too. Overall, this class helped me awaken my creative sign with a mix of my academic side.*"

Not being able to meet in person encouraged students to switch to alternative methods of communication for completing group tasks. Zoom, Discord, and WhatsApp turned out to be popular and effective applications for direct student communications. Tools like Canvas, Google Docs, and Google Drive were used for shared storage and editing assignments. A student testimonial (edited for brevity) reads: "*While the course may not be as fun in an asynchronous setting, the course was most definitely productive … functionalities like screen share, and posting links in the chat were very convenient and reliable ... This made us more efficient and made our work even more valuable as everyone did their best work in their own style*."

Positive feedback apropos to the connection of the taught course with an actual engineering workplace was recorded by a student whose testimonial (edited for conciseness) reads: *"Taking the class online has made learning harder .... However, real-world engineering problems often deal with incomplete information and uncertainty. I believe that the uncertainty pushed the students to work by themselves and not count on anyone. In this way, we learnt basic engineering skills. In fact, engineers usually do experimentations with software, models, or prototypes in order to deal with uncertainty. Experimentations are one the first steps in engineering design. In fact, each engineer has his own plan to solve problems..."*

4 DISCUSSION AND LIMITATIONS

This study covers the various aspects of an engineering course forced to abruptly transition online due to the Covid-19 pandemic. The paper also reports the technical details of the course as well as the course outcomes that were achieved through the inculcation of communication, teamwork, and understanding of ethics in students. The course format was asynchronous, i.e., the minimum attendance course policy was suspended, to accommodate international students who resided in different time zones. Further, to reduce workload for students, the weekly assignments had been reduced to biweekly. Prompt steps, as highlighted above, were taken by the course instructor to fulfil the remote pedagogy requirement after the pandemic began.

The essence of the course was delivered through simulating the experience of remotely-connected global engineering teams. While working asynchronously, completion of the course project – a final design analysis and critique of a physical prototype made from a CAD model – remained a primary course requirement. Ethics in the engineering workplace was also a required consideration in the final assessment; how well students complied with stakeholders' interests was evaluated. Special consideration was given to ensure that students were provided with an immersive experience of how engineers work, remotely, on a regular basis: following industrial standards, collaborating in teams, complying with the customer design requirements, and completing projects with ethical considerations. The widely distributed geographical locations of international students, collaborating in an organised way and coming up with creative ways to procure the required materials, was a significant challenge. Working remotely, each group needed to spend time planning the project, organising the work, identifying action items for each person, and following up to ensure the work was completed on time as well as accurately.

The unavailability of hardware lab equipment and wind turbine kits for international students led towards devising creative solutions driven by conceptual clarity. Students used whatever resources that were available to build the project from scratch, such as cardboard pieces, tapes, straws, canes, etc. For the final prototype submission, the constraints of the previous version were solved to build a better working model. Data for the torque generated by the wind turbine as proportional to the wind speed and other factors was recorded and analysed for proficiency calculations and error estimations. Where this project showed positive results for the instructor's implemented methodologies of online pedagogy, it also exemplified the students' (a) keenness to learn, (b) remarkable adaptability to remote learning, (c) versatility to handle responsibilities in remote teams, and (d) resourcefulness and ability to reproduce results comparable to an actual engineering workshop.

However, some of our findings may not be entirely generalizable; for example, the scope of this study does not necessarily extend to non-STEM project-based courses taught online during the pandemic that may require different skill sets. In addition, the personal quality and previous online teaching experience of the instructor, as well as the availability of additional support could potentially have significant impacts on students' experiences. Further, the course introduced here was at the undergraduate level; findings of current study may not be replicable at other levels of education such as high school and lower, or in different educational settings. Lastly, future research is needed to help us more fully understand the challenges and opportunities in this specifically under-explored modality of online prototype-based learning, while possibly looking to integrate the best practices of using information and communications technology (ICT) in e-learning of courses specifically involving PBL.

5 CONCLUSION

This study presents findings from a first-year engineering PBL course that was taught online asynchronously during university closures due to the COVID-19 pandemic. Through various adaptations, the course simulated the global engineering workplace by imitating the experience of engineering projects within the context in which team members are being separated by both time and space. The essence of this paper is to provide fruitful insights into the prompt steps taken by the instructor for effective implementation of online learning methodologies for the course. It also shed light on how students living in different parts of the world communicated with the instructor, learned through asynchronous instructions, collaborated in teams, made ethically informed decisions, and timely completed the course project according to the stakeholders' requirements. The outcomes from this course add to the various methodologies being used in online learning. Highly favourable student feedback represents additional affirmation that the sudden pivoting to online learning had been a much welcome success in this setting. This experience of conducting a PBL course remotely, with further adaptations, can serve as a useful template to help guide colleges of engineering in similar courses if such need arises in the future.

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FROM CREATIVITY TO VALUE CREATION

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ABSTRACT

In today's world, globally interconnected, volatile, and characterized by a sky-rocketing complexity, significant and unprecedented interdisciplinary is required among various stakeholders to create resilient and innovative value chains. Within this compelling context, we focus on the new role that university-industry collaboration plays on a large scale in bridging the gap between idea generation and value creation to economy and society. A new way to promote attitude towards entrepreneurial leadership at an early stage among students and teachers is experienced by linking curricular and extra-curricular teaching and contents, as well as by supporting voluntary learning "on demand" among students. Intertwined links are indeed possible within a nursery environment, so-called *Entreprenursery*, where students are encouraged to express their creativity, both by raising startup ideas and by solving companies' technical and scientific issues. Entrepreneurial students are thus supported in their innovative ideas

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through collaboration with teachers, experts, entrepreneurs. They are also stimulated to engage other students to be part of an interdisciplinary team. Cooperation in supporting cross-fertilization of creative ideas will be fed by competencies, an open-minded environment, and where diversity integration plays an important role. Only through different thinking is it possible to develop outstanding achievements. Coordination is guaranteed by a collaborative IT platform, which is also open to SMEs to facilitate them in involving entrepreneurial students. Within this new collaborative framework, all stakeholders will profit from reciprocal learning and creativity, increasing the entrepreneurial attitudes of students and teachers and thus accelerating the transfer of academic startup ideas into industrial applications and business opportunities.

1 INTRODUCTION

Since 2017 an experimental way to encourage creativity among students in engineering has been developed. Finally, a method has been put into place to implement entrepreneurship consciousness and attitude. Thanks to continuously ingoing feedback, a set of services has been developed to help entrepreneurial creativity to evolve and to enable innovation.

The main goal is to transfer knowledge gained by students at school and to apply it by working on their own entrepreneurial ideas. It is expected that the chances to set up and develop science-based companies will increase and science-based innovation will be encouraged. In promoting science-based entrepreneurial initiatives, connections between higher education institutions, the private sector, and society will be strengthened and accelerated also through the use of digital tools [1].

Within an innovative work structure, an ideal place was built, the so-called " Startup Garage " (the Garage), for which an associated metaphor of a sailing ship has been chosen. Students are Skippers driven by passion and leadership and are ready to explore new lands ─ ideas and new innovative approach on problems' solving. They will be able to involve the crew ─ mentors, experts, researchers, entrepreneurs ─ and be ready to get back on course by defying winds and bad weather, i.e. mistakes and difficulties. So the Garage is a safe haven to meet, interact, exchange ideas and create effective teams and it has fertile ground, where entrepreneurial creativity and productivity are fostered.

While the need for tangible resources, such as physical meeting spaces, laboratories and materials, is obvious, the essential role potentially played by intangible resources should not be ignored. This approach, aiming to put into practice the quadruple helix model [2], includes an entrepreneurial university culture, an informed and constantly updated sustainability-focused innovation program, access to innovative research projects and ideas produced by the university's academics, as well as involvement of internal and external faculty members and industry practitioners as program mentors [3]. In such a nourishing environment, the mentors are one of the key innovative aspects. There are no teacher-and-students or expert-and-novices binomials, but simply peers working together shoulder to shoulder towards the final entrepreneurial goal. In The Garage, the mentors are called Standby Mentors, since they are requested on demand when the students need to confront with a specialist to overcome an obstacle. However, they do not offer a solution, but share their knowledge openly. They show to the students how to find the way to the solution, leaving them even to make mistakes if that could be a useful path to the increased knowledge. Within this creative working framework, the 17 ONU Goals are pursued, thus representing a sort of compass for all Skippers. In this way the entrepreneurial creativity is harnessed for value generation.

Intangible resources are also made of a non-formal learning process providing three evolving steps to develop further startup ideas in their scientific and technological feasibility [2], as well as in searching for business opportunities. Once students have received a bachelor's or master's degree, they can stay in the Garage for a further six months, thus having more time to choose whatever they want to do with their startup ideas already developed along three previous steps. Actually, step validation makes startup ideas much closer to real feasibility.

Thereafter, the step out of the Garage is compulsory, but nonetheless favours either entrance into academic startup incubators or a professional career as entrepreneurial employee.

2 CREATIVITY

2.1 Students' creativity on the road

By collecting data during the five years of the testing approach to creativity, some interesting consolidated results develop. They will be used to drive creativity to the next implementations.

First of all, we can say that engineering students are ready to put entrepreneurial ideas into a processing and developing system, especially when they are enrolled in the Department of Innovative Technologies (DTI) as first-year students.

Table 1 shows the retained ideas ─ the startup ideas to be worked in the Garage after selection ─ and the number of members forming up teams of skippers around the ideas development. In the last 5 years, more than 10% of all students of the Garage's project have shown an entrepreneurial attitude (Tab. 2).

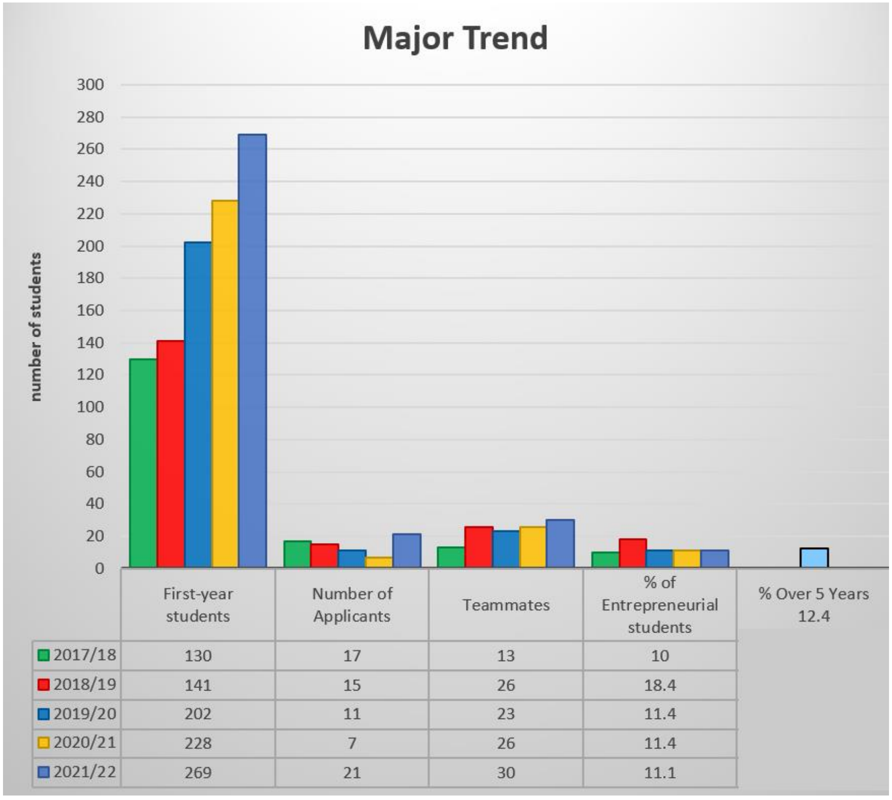
In order to scout creativity, students are informed and encouraged to submit ideas at the beginning of the academic year through a digital platform, called Pingel@p [4]. This application helps to facilitate both competence and need/issue sharing at all levels of the 4 quadruple helix model [2].

The collection of ideas takes place in this online platform and facilitates the homogeneous description of ideas according to a predefined structure, which is also captured and frozen out in smart contracts based on Blockchain technologies in order to guarantee intellectual property (IP) protection [2].

Every student enrolled in Bachelor and Master programs can submit her/his innovative idea which is then collected through a „Call for Ideas" event managed by an ICT system. The internally developed system enables the student's ideas to be matched with the best fitting Standby Mentor by automatically picking teachers, researchers, experts, company managers based on their expertise.

Table 1 — Garage's Data

Table 2 — Garage's Major Trend



	First-year students	Number of Applicants	Teammates	% of Entrepreneurial students
2017/18	130	17	13	10
2018/19	141	15	26	18.4
2019/20	202	11	23	11.4
2020/21	228	7	26	11.4
2021/22	269	21	30	11.1

After the submission of an idea, applicants are recognized as Idea Owners. Then, after a digital assessment process involving Standby Mentors, some of the brightest ideas are retained to be developed later according to the Startup Garage methodology.

In addition, a new tool for accelerating a potentially more valuable idea, has been integrated into the Pingel@p platform: the call-for-needs resolution. This tool aims to have a more open innovation cross-fertilization approach, where companies can describe some specific actual needs and share them in a nurtured way with other platform actors. In order to support the call-for-needs resolution process, regular “creActivity” events are organized by the Garage on a monthly base. These meetings with companies which concretely describe their needs or current impelling issues, take place in the Garage space and enable a first person contact and a live discussion between the different actors.

So cross-fertilization of fresh-minded Skippers with entrepreneurial spirit/attitude can accelerate the investigation of new solutions towards faster prototype development and market adoption, supported by a digital platform and nurtured in the Garage environment.

2.2 Creativity Spotlight

Pingel@p fulfils some essential requirements such as collection and evaluation of idea proposals, matching of students with suitable mentors, call-for-needs resolution from industry partners, as well as call–for-expertise to promote team-building among entrepreneurial students. In particular, the last two are in line with the theoretical model proposed in [3], where the Garage should comprise a number of fundamental components, including one to create positive collaboration and creative synergies, and another to generate productive interaction between entrepreneurial students and industry.

While today Pingel@p is a one-to-one match between a student’s idea and a mentor, we aim to build this connection multilaterally, enabling companies to promote young talents and creativity.

A virtual environment has also been thought to combine social and professional features in existing networking applications, such as Facebook, Instagram, LinkedIn. The goal is to create a virtual space for the Skippers to exchange opinions and resources, to encourage team building through cross-fertilization and gender inclusion. Moreover, we will create events in main city squares with activities managed by Skippers. They will promote interaction with the local community, stimulate general public thinking, and promote the university brand.

Actually, the lonely situation of the creative student, such as the need for help, can be overcome by exploiting the Pingel@p Webapp call-for-expertise [2] to look for students willing to help a single Skipper. This is a main goal, which will be pursued systematically very soon, because innovation for a sustainable future is a complex endeavour that cannot be accomplished by the solo-sailing of even the most talented and eager home garage-based entrepreneur [3].

2.3 Ongoing generation of creativity

An academic community of students interested in entrepreneurship has to build and connect to enable the visibility of startup ideas being processed in the Garage. Most active actors of this community will be referred to as Skippers hereafter, a new terminology for entrepreneurial students engaged in building up tight-knit teams working on startup ideas. All teammates should regard themselves as chief officers operating jointly in tune with their interests and competences to put sail to startup ideas by forming a cohesive and qualified crew. Actually, all people with good ideas can be Skippers, who are at one time at the helm or another time go onto the ideas' deck: a symbolically furnished corner built within the Garage.

Hereafter, an interconnected system ─ recalling quadruple helix model [2] ─ has been realized to support creativity aiming to transfer its value to the industry, as shown in Fig. 1 below.

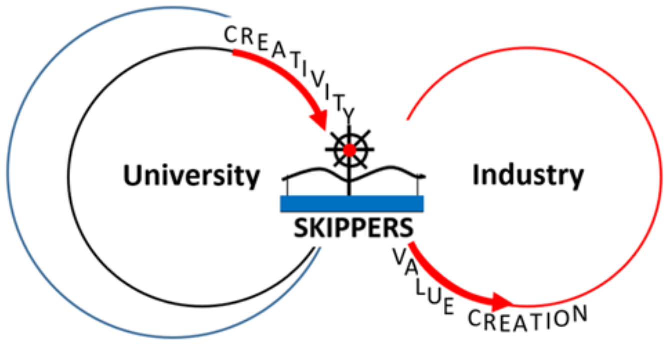


Fig. 1 ─ Creativity Interconnections

3 VALUE CREATION

3.1 Entreprenursery

Recently, an entreprenursery has been born focusing on entrepreneurial students and implementing the Garage's Concept&Method within a framework of a sharing creativity involving different stakeholders. Actually, the Garage should be seen as a nursery taking care of students' creativity and development in an entrepreneurial value dimension without being pressured by monetary constraints.

Relative to the general population, university students have an overall higher risk tolerance, as they are frequently unconstrained by overwhelming financial or family obligations that dampen risk-seeking behaviour [4]. It is essential to positively harness the risk-taking inclination through a structured process of "learning-to-fail" while limiting the scale and fallout of such failure.

As Charles Camarda, a NASA astronaut and Senior Advisor for Engineering Development stated, "You have to fail in order to be successful and there are smart ways to fail. So, I try to teach students how to fail smart, fast, small, cheap, early, and often" [5]. A cleverly designed entreprenursery would be the ideal environment for aspiring entrepreneurs to learn to fail with limited fallout.

Within a challenging, safely upgrading dimension, the entreprenursery project aims to expose entrepreneurial students to actual issues proposed by local companies: similar processes have to be formalized to support students in tackling such challenges and to create feasible and marketable solutions. Local companies have the opportunity to provide a call-for-needs-resolution (a business idea in need of development), through a predefined institutional gateway designed to give industry participants access to the Pingel@p platform. Skippers can adopt and investigate this idea, potentially proposing a solution and developing a prototype. Alternatively, firms can ‘tap’ the pool of existing ideas at various stages of development available on the Pingel@p platform, potentially offering funding or bringing them in-house (creative ideas transfer) for further business development. Likewise, companies can source entrepreneurial talent from among the students working on their startup idea in the Garage and offer them internships or employment opportunities alongside or upon completion of the university degrees. In this manner connections between company-student do not remain only in the classroom but they can go further in establishing entrepreneurial relationship. Indeed, companies will propagate opportunities for summer internships, creating strong cooperation between the academic world and local businesses [3]. Such early-stage interaction and team building contribute to the formation of extensive and heterogeneous professional networks, which, according to successful entrepreneurs themselves, are a fundamental prerequisite for entrepreneurial success [6].

A high priority is to ensure that no one is left behind. In building inter-multidisiplinary team, Startup Garage Management is highly aware of untapped potential of the gender diversity for entrepreneurship, but gender inequality, or the underrepresentation of women in top positions of business and industry as well as universities, remains an unresolved issue across Europe. Giving priority to diversity, equity, and inclusion in universities is often a strategic choice. This environment helps to build synergies, develop new ideas and investigate new fields. Often equality, equity, diversity and inclusion are used interchangeably, despite the fact that they may mean different things.

3.2 Entrepreneurial education

The continuous and fast evolution of new technologies and their adoption to innovate industrial processes, products, services and business models, requires an increasingly comprehensive vision of society‘s expectations and people‘s roles in managing market-reactive and human-oriented companies. As a consequence, education is a key factor to deal with the ongoing challenges for manufacturing companies from both the consumer-oriented and the worker-oriented perspectives. To deal with such a challenge new education and competence development methods [7] and instruments have gradually been introduced in the last decade within university education paths.

Nowadays, as a consequence of the disruptive, ongoing digitalization and industrial transformation processes, moving from the industry 4.0 to the industry 5.0 paradigms [8], a further relevant innovation in the overall education framework is of even increasing importance with specific reference to the complex “creativity to value” process chain management. According to the discussed novel open education framework, enterprises must share their practical and professional experience with students, so as to enable them to put their startup ideas and entrepreneurial skills into practice. In particular, companies should also involve students in facing production and product innovation problems, and ask them to suggest implementation proposals. Similarly, professionals and representatives from the society should inspire students to identify future needs and to propose potential solutions, based on their knowledge, skills, creativity and interdisciplinary teamwork. Such a virtuous and heterogeneously integrated approach sets the basis for a co-operative process and innovative transdisciplinary co-creation approach [9].

The proposed education paths and experiences will de facto enhance the student's entrepreneurial attitudes in facing real world challenges and increase their risk of failure acceptance and management capacities that constitute skills highly demanded today by industries, that have to compete within a more and more challenging and innovation-driven economy and society [10]. The aim is indeed to offer the academic system a synergistic framework that stimulates and transforms talented students into entrepreneurial employees, or to support them in turning business ideas into entrepreneurial projects. A system of intertwined connections is going to be put in place, in which the Startup Garage Management is much more extensiverly involved and engaged as is shown in Fig. 2 below.

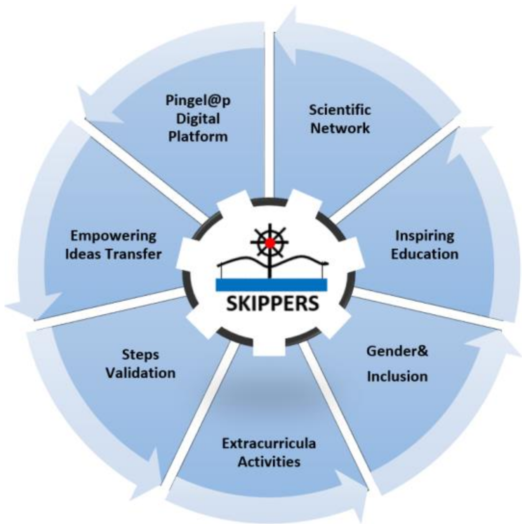


Fig. 2 – Garage's System

4. CONCLUSIONS AND FUTURE WORKS

The growing new centrality of humans within sustainable society, economy, and industry requires more and more to valorize soft and distinguishing skills like creativity, problem-solving and teamwork in strict correlation with entrepreneurial attitudes like business orientation, leadership, gender and cultural inclusivity, learning-to-fail, and resilience. The priority objective of the Garage is to let students express easily entrepreneurial ideas trying to optimize their skills without interfering or inhibiting their creativity. In this respect, it is however paramount to leverage the osmosis among industries, universities, and entrepreneurial students by means of the ICT applications, such as the Pingel@p, which acts as the driver to scale up the Entreprenursery concept. In this context, universities must embrace and face plainly the challenge and play their crucial role in sustain creativity as core value of the entrepreneurship. An impactful communication has to be put in place, making real such an important educational turnaround. The implementation of a new tool for accelerating potentially more valuable ideas, i.e. the call-for-needs-resolution, is underway to helps fresh minded skippers with entrepreneurial attitude to nurse their creativity towards new value creation.

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UNIVERSITY ACTIVITIES AND DEVELOPMENT COOPERATION IN THE AGRI-FOOD FIELD: KITEGA CC CASE

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ABSTRACT

The connection between the activities carried out by universities and cooperation projects for development is of great interest in achieving the Sustainable Development Goals and the 2030 Agenda.

This work shows the activities developed by the Universitat Politècnica de València (UPV) in terms of human development and international cooperation in the agri-food field. It starts from a description of the experiences and internships by the research staff, students, and technical staff of the UPV in a rural community of Uganda (Kitega), where it has been possible to connect two projects. The first one is related to improving agricultural systems, and the second one is on food conservation and processing techniques. Both intend to develop sustainable agri-food and are always based on actions that affect the needs of the most vulnerable groups.

Agricultural production in rural areas allows food to be obtained for self-consumption, while surplus production is offered for sale without any conservation or transformation system during its useful life. Poverty and lack of technical knowledge are essentially causing food unsafety and malnutrition. In addition, the narrow variety and low quality of the products sometimes do not allow to cover the nutritional needs of the families.

The conclusions obtained point to the importance of students, researchers, and staff from universities' participation in development cooperation projects to achieve a transition towards fairer societies in a sustainable and lasting environment.

1. INTRODUCTION

1.1. Cooperation for development and Research

Main world challenges (e.g., environmental protection, energy security, natural disaster mitigation, preventing and curing infectious diseases, ensuring food security) are increasingly the subject of policy-level deliberations, both nationally and internationally. It is recognized that international cooperation in science and technology is needed to deal with these issues. Cooperation between developed countries and developing countries is of special importance, because the first ones are often the ones most severely affected by global threats, and because they possess much of the expertise, data, and resources that are needed for finding effective solutions. [1].

In this context, universities play an important role as a source of knowledge and resources.

1.2. Cooperation Department at UPV

The Cooperation Department of UPV aims to support and encourage the participation of the university community in university cooperation activities for development.

Some of the programs offered and related to this paper are:

The Adsideo-Cooperation research program aims to promote the development of R&D projects in Development Studies, International Cooperation, and the application of Technology for Human Development.

The Meridies cooperation scholarships are intended for UPV students to carry out internships or Final Degree Projects in development cooperation programs and projects through universities, non-governmental development organizations, social entities, and any other international development cooperation system organization.

The staff Meridies cooperation program allows non-professors staff to stay in a short internship in an organization.

The development of one project or the participation of individuals from the university already positively impacts the community. Undoubtedly, when it is possible to connect more than one project and have more people involved, the results have even more impact. The university facilitates this connection through forums, expositions, meetings, and seminars in collaboration with NGOs.

In this paper, we will show an example of the participation of different people and the connection between two projects in the agri-food field.

1.3. Context

Uganda is a landlocked country in Eastern Africa located at the Equator. It has an area of over 240.00 km^2, and according to the latest Human Development Index Ranking from the United Nations Development dated 2019 [2], Uganda's data were:

- Position 159 (from a total of 189)
- HDI (value): 0.544
- Life expectancy at birth (years) 63.4
- Expected years of schooling (years) 11.4
- Gross national income (GNI) per capita: 2.123 $

1.4. Agriculture in Uganda

Agriculture accounts for 70% of employment, overwhelmingly on small farms; it occupies half of all land area and provides half of all exports and one-quarter of GDP in Uganda. It is considered a leading sector for future economic growth and economic inclusion in the current National Development Plan. Yet despite having excellent natural resources and climate conditions for the production of a wide variety of crops and livestock, the difference between aggregate output growth and the growth of all inputs and factors of production that produced it--in Ugandan agriculture has been negative for the last two decades [3].

The effects of climate change have not gone unnoticed, and the influence of foreign crops without knowledgeable technicians has resulted in an impoverishment of the soil. Dependence on seeds and uncontrolled use of plant protection products to combat pests and diseases have not helped its development.

1.5. Kitega Community Center (KCC)

Kitega Community Centre is located in Kitega, a rural village where the local economy is mainly agriculture-based. However, most of the population is unemployed, and the standard of living is low.

Kitega Community Centre Uganda is an NGO in Uganda founded in March 1999, to support children with disabilities, as a result of the stereotypes surrounding disability, the children were rejected and marginalised in the community.

In a bid to foster an inclusive community in which everyone is respected as valuable and contributing to the development of the community, the organisation launched a community development model to build capacity of local communities to address their own development challenges in Partnership with the Organisation. The community development model includes; Women empowerment, Legal Aid, Mobilising local farmers and training them, support to marginalised schools among others. Today, the centre is partnering with over 15 communities in Central Uganda.

Kitega has received international volunteers since 2009, and some have developed specific projects. Some of them have been under the frame of the Universitat Politècnica de València.

Kitega has an NGO partner in Spain who facilitates the connection with people and institutions.

1.6. Agri-business cooperation projects

The two Adsideo projects that successfully connected are: "Diagnosis of local production system in rural areas of Uganda. Proposals for a sustainable agriculture", which started in 2020, and "Evaluation of techniques for the conservation, transformation, and reuse of food in the community of Kitega (Uganda)" started in 2022.

The first project was proposed with an agroecological approach, characterized by minimal alteration of the ecosystem, by the nutrition of plants from organic sources and inorganic, the use of natural biodiversity, and oriented to the production of food, raw materials, and other ecosystem services, following the recommendations of the FAO in the Guide for those responsible for policies of sustainable intensification of production (FAO, 2014).

The approach for the second project has to do with the situation of farmers in Africa incurring the enormous loss of fresh horticultural agro-produces attributed to limitations in accessing modern food conservation technologies such as the use of electric dryers, freezing, canning, refrigeration, and cold-chain facilities [4]. Faced with this problem, several investigations highlight that the design of equipment for solar food drying is a practical and economical method that allows for the conservation of fresh horticultural products for extended periods [5, 6].

The local NGO, Kitega CC, has a relevant role in gathering farmers and local leaders, facilitating the network of contacts and the translation necessary to make communication possible.

2. METHODOLOGY

2.1. Diagnosis of local production system in rural areas of Uganda. Proposals for a sustainable agriculture

This project included the diagnosis of family farms to improve crop production from an agroecological point of view.

A group of farmers is involved with the help of Kitega staff, sharing their native knowledge, being part of the improvement process and decision making, and connected through the staff from KCC with the researchers from the university to discuss farming techniques.

The methodology used has been the field survey of farmers and interviews to study agronomic models, know the techniques they use, and the main difficulties they face.

The people who have contributed to the project through the Cooperation Department's support are:

- A staff person (Agronomy Engineer) specialized in training, who carried out an initial diagnosis on the knowledge of agriculture in farmers.

- A group of research professors (Agronomy Engineers and Biologists) to monitor crops and provide advice on crop pests and diseases.

- A group of students enrolled in the Master of Plant Health collaborated with the diagnosis from the university.

Fig. 1. Interview to the farmers for the initial diagnosis

Fig. 2. Farmers involved in the project and staff from KCC.

2.2. Evaluation of techniques for conservation, transformation, and reuse of food in the community of Kitega

As one of its objectives, this project has the design, construction, and commissioning of a solar drying system for the use of the community. The prototype is based on the design of a drying system successfully implemented in other countries such as Burkina Faso [8]. The choice of construction materials is adapted to the environment's limitations, and available materials have been sought with good resistance to climatic conditions.

Drying tests have been carried out by direct exposure to the sun and inside the dryer chamber to get drying curves and study dehydration kinetics for different local fruits and vegetables.

The fruits and vegetables are selected from surplus for consumption, extending the shelf life of these foods and avoiding the generation of waste. The process includes recommendations for good practices in food hygiene to obtain a safe food processing diagram.

The roles participating in this project are:

- A group of research professors (Agronomy Engineers and Ph.D. in Food Science and Technology).

- A student (Master in Food Processing) with a Meridies internship who has been in charge of the solar drying construction and first food measurement for three months.

Furthermore, it is planned for the following months:

- A student with a Meridies internship who will be in charge of exploring other ways of conservation.

- A person with a Meridies staff specialized in cooperative and entrepreneurship to encourage and motivate the community to commercialize the products.

3.3. RESULTS

3.1. Diagnosis of local production system in rural areas of Uganda. Proposals for a sustainable agriculture

A total of 20 farmers were interviewed to study their production systems, know the typology, understand their relationship with the environment, and find an approach that allowed improving agriculture from an agroecological perspective.

The answers showed that none of the farmers had specialized in agriculture training; they had learned only through practice. Extension services in the country are scarce, reaching a maximum of one visit a year when it happens. Some of them have heard of organic farming, which they associate with not using chemicals, but cannot explain more about it.

There is a low level of knowledge about the products they are using. None of them can identify labels or understand the scope of concentrations or solutions they are applying. That situation leaves the application of products entirely at the mercy of companies and sellers.

All farmers depend interviewed on rainwater for irrigation. In the context of climate change uncertainty, it is complicating traditional harvests as they have been doing until now when they were able to manage the seasonality. Their traditional agriculture labours, such as soil preparation, fallow, and sowing, have no dates anymore.

However, the way these family farms cultivate is more respectful and less invasive to nature than intensive agriculture. Nevertheless, that is mainly due to the lack of resources as a goal for sustainability.

During the project, several crops were monitored in an exhibition garden available at the KCC compound and in the family gardens; tomato, onion, pumpkin, pepper, eggplant, beet, and broccoli were cultivated with different results. A corn trial has also been carried out, with the varieties available in the area to determine its efficiency.

It can be pointed out that the most relevant result obtained in this project has been the built team of farmers, previously cultivating in isolation and now sharing knowledge and experiences. They have also shown great interest in food preservation techniques, aware of new business opportunities.

3.2. Evaluation of techniques for conservation, transformation, and reuse of food in the community of Kitega

The construction of the drying equipment was carried out in collaboration with local carpenters. The wooden structure was bought and built locally while the plastics were purchased in Spain.

Compared to the drying by direct sun exposure, the drying tests in the chamber of the built equipment offered dehydrated products with better characteristics and in more acceptable hygienic conditions than traditional drying.

The drying inside the equipment chamber was carried out at a temperature between 40 and 55 ºC without direct sun exposure, while in air-drying and by direct exposure the temperatures suffer a greater oscillation. Direct exposure to the sun also produced a greater deterioration in the products to be dried, in addition to the greater risk of suffering contamination and attack by insects.

Workshops were held mainly for women and young people, who showed great interest in this type of processing. It was insisted on establishing a clean working procedure, which includes the pre-treatment of the fruits and vegetables to be dehydrated, all of which allows for more stable and safe products.

Fig 3. Drying carrot testing

Fig 4. Drying banana testing

Fig 5. Drying banana testing

These results showed the importance of solar drying to promote food availability and security. Since the project seeks human development in the region, the actions impact the most vulnerable people and groups, especially young people and women who usually carry out daily agriculture and food preparation tasks.

The channels already established in terms of communication by KCC facilitated the development of face-to-face training talks, promoting the exchange of knowledge between local farmers and researchers.

Fig 6. Solar drying on construction

Fig 7. Workshop

4. SUMMARY AND ACKNOWLEGMENTS

In Uganda, as in many African countries, food insecurity amongst poor households remains a severe problem, contributing to poor health, problems with learning in school, and lack of socio-economic development. Family agriculture is in better conditions to optimize the better use of land. Besides, it has the most significant potential for increasing the overall base growth and creating sustainable wealth. Thus, all effort to improve them is not enough for the considerable benefit they offer. Encouraging these families to move to agroecological models would improve their lives.

The processing of agricultural surplus offers new business opportunities, which can be approached at family or community levels.

The support of the Universitat Politècnica de València in the two projects, grants, and internships given to the people who are participating, have made it possible to pass through the different phases of diagnosis, creation of teamwork, crop monitoring, surplus drying monitoring, workshops, meetings, and business opportunities analysis.

The researchers provide the knowledge and work methodology; the students contribute with time, data collection, knowledge, reports, and enthusiasm. The staff contributes with a professional approach. The excellent relationship and significant involvement of the KCC staff, together all around above, contribute to the project's success.

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Can Decolonising the Curriculum Provide an Enhanced Engineering Education?

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Conference Key Areas: *Ethics in Engineering Education, Curriculum Development*
Keywords: *Decolonising the curriculum, AI ethics, curriculum development, engineering education, cognitive load*

ABSTRACT

Decolonisation is defined and discussed. University College London has several initiatives to decolonise the curriculum and enhance diversity and inclusion. In 2022, a series of online flipped lectures were developed for the postgraduate software engineering module. The aim was to provide a range of perspectives on artificial intelligence (AI) ethics. Teaching was through the decolonisation lens, highlighting historical viewpoints and imbalances in power. Students could reflect on the ethics of AI systems and how these systems perpetuate colonial biases.

Students had previously indicated their interests in AI, environmental and social issues, including climate change. Before lectures, students completed questionnaires, providing an understanding of their prior knowledge of topics.

A qualitative analysis of the reading material using coding within ATLAS.ti provided insight to select schemas to scaffold students' knowledge. The suggested reading was then adapted to ensure a greater diversity of viewpoints. The analysis also indicates that adding these additional perspectives may not increase cognitive load.

Lectures include real-world perspectives from guest speakers from diverse backgrounds, reinforcing the importance of different opinions. Students greatly valued the different perspectives and opportunities to discuss ethical dilemmas. Students' answers, following ethics discussions, indicated an improved understanding of engineering concepts. This study suggests that incorporating a range of views can enhance the topics students want to learn. Providing different perspectives can also

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deliver a more balanced engineering pedagogy. Adopting a decolonisation approach that recognises the past but provides alternative narratives may strengthen opportunities for engagement with other universities: creating new scenarios in engineering education.

1 INTRODUCTION

> *Decolonization involves identifying colonial systems, structures and relationships, and working to challenge those systems. It is not "integration" or simply the token inclusion of the intellectual achievements of non-white cultures. Rather, it involves a paradigm shift from a culture of exclusion and denial to the making of space for other political philosophies and knowledge systems. It's a cultural shift to think more widely about why common knowledge is what it is, and in so doing adjusting cultural perceptions and power relations in real and significant ways.*
>
> Keele Manifesto for decolonising the curriculum [1].

Decolonising the curriculum is about overcoming the structural disadvantages and barriers in education and the lack of representation of black and minority ethnic groups. At its core, it is ensuring that what we teach and how we teach is 'more responsive to the problems of colonial racialised privilege and discrimination' [2].

Over the past few decades, there have been movements to decolonise universities to allow equal access and better educational outcomes for marginalised groups. There are efforts across UK universities by students and staff to dismantle the legacies of colonialism. Shortly following the Rhodes Must Fall campaign led by students and communities within South Africa to remove the Cecil Rhodes statue, several campaigns at University College London (UCL) have renamed buildings linked to racism. Not only to dismantle colonial statues but also to address the domination of structural inequalities and the idea that somehow the Global North is superior intellectually. In response to strong student interest, the SOAS was one of the first UK universities to commit to delivering a decolonising agenda. Their resulting toolkit [3] was one effort to provide suggestions to transform the legacies of colonisation. The toolkit suggestions were the starting point for developing the series of online lectures outlined within this paper.

The decolonisation projects at UCL are just one aspect of broader developments to enhance equality, diversity, and inclusion (EDI) to ensure that the university provides a welcoming environment for students from around the globe. The UCL Department of Computer Science has been recognised for its EDI initiatives. The department was awarded the Athena SWAN Silver award in 2015 and 2019 in recognition of advancing gender equality. When invited to deliver a series of lectures for the MSc software engineering professional practice module, the author was keen that this should support EDI initiatives and enhance the efforts to decolonise the curriculum.

The author had initially co-developed this module to include a range of guest speakers to provide a leading-edge and alternative perspective to the academic lectures. The speakers represent a diverse range of ethnicities and genders. Developing the new lectures was also an opportunity to tailor these lectures to students' interests in AI ethics. Students in the software engineering programme attend machine learning and software engineering modules and the professional practice module. The last module is focused on project management and ethics to provide students with the necessary knowledge to deliver their industry research projects. Machine learning is covered by theory and practical lab sessions, focusing on technical areas. Developing a series of new lectures provided an opportunity to align with the university's decolonisation initiatives.

This paper covers the development and open-ended approach (allowing for multiple answers) for the three AI lectures for the spring semester of 2022. These were designed as online flipped lectures with pre-lecture reading covering: research papers, reports, and textbook chapters. The emphasis was on discussions of the material before and during the lectures.

2 METHODOLOGY

2.1 Decolonising the reading lists

Reading lists have a role in decolonising our universities [3, 4]. The SOAS toolkit suggests providing a more comprehensive range of source materials, particularly from the Global South. A range of research papers and texts were considered, from geographic regions, particularly where they critiqued the subject matter or provided a different perspective. Where research papers had authors with more than one affiliation, the institution and country origin of their correspondence email was selected. The analysis included all authors for each research paper. The author's identification of gender and geographic/institution affiliation was confirmed by referencing publicly available web pages, the publication, and the journal itself or other research papers the author had published.

A more comprehensive representation of authors and countries [4] is one approach to decolonising the curriculum. The reading material was updated to include authors representing a more comprehensive range of countries, Fig.1.

Data collected 2020/21 via a departmental questionnaire indicated the highest number of students logged on from the UK and the second-highest number of students from China.

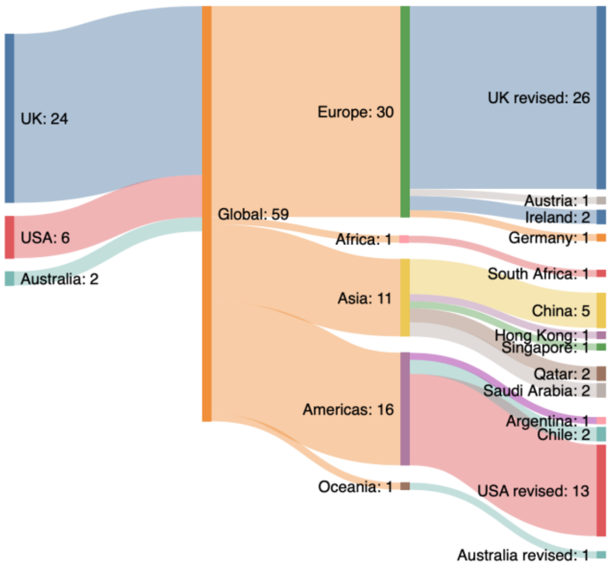

Figure 1. Geographic distribution of author locations for reading list and research papers cited. The left-hand side represents the initial documents selected for the lectures. The right-hand side indicates documents after analysis and review. The recommended reading now better reflects the many countries UCL computer science students are from during 2021/22.

UCL Postgraduate computer science students during the academic year 2021/22 registered from many countries, including Austria, Ireland, Germany, South Africa, China, Hong Kong, Singapore, Saudi Arabia, and the UK. An analysis of the reading list now shows a broader range of perspectives, including the Global South, Fig.1.

2.2 Use of questionnaires to understand student's prior knowledge

Questioning is a powerful tool to unlock learning and new ideas. Asking students what they already know does not create a defensive response. Students frame their replies as part of their perspective and view of the world. Understanding what students know can be used to tailor the lecture content, which avoids the repetition of well-understood concepts. Once each student had answered each question, more detailed information and resources were provided automatically according to their answers, ensuring that time during the flipped lecture was devoted to developing a deeper understanding of the topic.

Students had previously shown an interest in health and sustainability, including climate change, when answering questionnaires. Analysing questionnaires and incorporating data from online posts, Table 1., helped determine the three main AI topics delivered during 2022: AI and bias, AI emotion recognition software, and AI and sustainability.

Lecture topic	Year and Student Registrations	
	2019/20 N=39	***2020/21 N=42***
Sustainability	10	18
Inclusion and Diversity	18	20

Table 1. The two topics with the highest level of interest as indicated by online posts for lectures during the last two years. For 2021/22, 36 students registered for the module.

An analysis of student's answers to the questionnaires indicated the level of understanding of each topic. Students demonstrated a high level of understanding of most machine learning concepts. However, one question regarding receiver operator characteristic (ROC) curves was less understood. 66% of students (N=24) provided option (c) as the correct answer for this question.

What does the area under the curve (AUC) for a receiver operator characteristic (ROC) curve tell us?

(a) How well the model works at its optimum decision threshold
(b) Indicates which is the optimum decision threshold
(c) Provides a summary of how well the model works across a variety of thresholds

The information from the questionnaires provided an opportunity to adapt the lecture material accordingly, with a threshold example within cancer diagnosis. It was optional for students to retake the questionnaire. After class explanations, every student who retook the questionnaire selected the correct answer. The teaching highlights a research paper that indicates medical professionals often have difficulty interpreting threshold data [5]. This research suggests an alternative approach to independently examine the ROC curve's axes of sensitivity and specificity by encapsulating the data as one metric: net benefit to the patient.

2.3 Using computer-aided software to develop the schema

ATLAS.ti version 22 [6] was used for quantitative analysis of the reading list. Segments of the text of the intended reading list had codes attached (or tags) representing social phenomena, such as colonisation, bias, and perpetuation of bias. Analysis of the data within the software tool provided a way to integrate the data in numerous ways. The data querying also provided a visual impression of the interrelated concepts, helping formulate ideas to refine the schema. Visualising the codes, for example, as a heat map, also provided information to ensure there was adequate coverage of concepts.

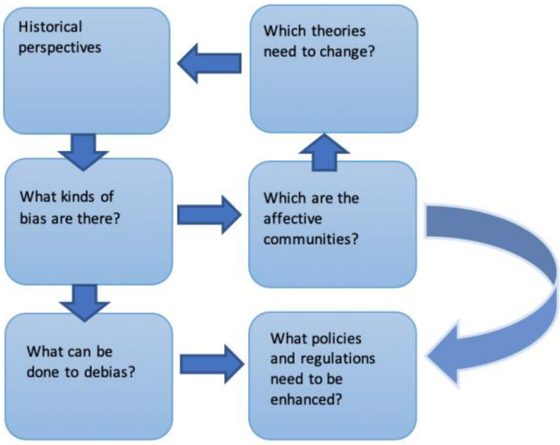

Figure 2. The schema developed for the lectures focuses on historical perspectives, the categories of bias, and which communities are affected. Discussions also encompassed techniques to debias and if underlying theories need to change.

Analysis of the selected documents helped refine the schema to emphasise adversely affected communities Fig.2. Discussions focused on what developers need to do and how regulations must adapt. It also helped students consider how communities can be empowered to have a voice in the deployment of AI systems.

Research indicates that providing appropriate schemas of related information can reduce cognitive load and improve learning [7]. Building on what one already knows with schemas helps retain information. Adopting appropriate schemas aids the rapid assimilation of new concepts and information. Although the reading list now has a broader range of references, the specific pages for suggested reading are limited to ensure an overall reduced cognitive load.

2.4 Flipped lecture examples

The focus during the first lecture was on machine learning: selecting data, bias, and how to debias. The pre-reading [8] includes Amazon's failed attempt to use AI to recruit staff, resulting in the AI system training on the predominantly male workforce data, perpetuating gender bias. Students readily identified solutions such as removing gender or words used by a specific gender. As students had mentioned an interest in health-related topics, lectures covered medical examples, including how medical data is often biased. The material also covered how a proxy of healthcare spending per person determines future healthcare spending for communities within the United States. Research shows that monetary spending per patient is less for black and ethnic minorities; this perpetuates inequality of healthcare provision for these communities. The students recognised that if the data is biased, this will exacerbate the problem. Historically clinical data has been collected predominantly from white non-Hispanic populations. Using AI algorithms with these records provides poorer identification of illness for other ethnicities. Discussions covered approaches to mitigating these situations, such as oversampling. An outline of how synthetic data could compensate for the lack of data for ethnic minorities and help reduce the bias in clinical data was also introduced [9].

Several students had previously outlined their interest in advanced AI techniques. Therefore, the background reading and slides included the use of adversarial techniques [10], illustrating how using AI, new data sets for under-surface ice profiles can be created to determine ice melt and better understand climate change. The students recognised the importance of these measurements and the threat to global communities at risk of sea level rises, often in the Global South.

The class pre-reading also includes using AI systems to identify cancers during surgery [8]. These critical decisions with a high risk have a human-in-the-loop approach. In this case, the surgeon makes an informed decision based on the AI system prediction combined with their expert knowledge. Students appreciated that the EU recommends this approach as oversight for many AI systems that affect individuals and society.

3 DISCUSSION

Although there are numerous papers covering AI ethics, there is a paucity of research papers on how AI ethics should be taught [11]. Also, the canon of AI ethics does not necessarily prioritise students' interests; students' environmental and climate change concerns are often a sub-category of AI ethics [12]. Students have recognised the importance of alternative perspectives and have suggested alternative sources during their discussions. Accepting the value of students' suggestions is one step toward co-creating the curriculum.

Tailoring content can have a positive impact on cognitive load. Linking knowledge to well-understood schemas can decrease the cognitive load. These schemas then act as a scaffold to learning new information. The questionnaires also provide a chance to learn from smaller units of information. Students can steadily build their knowledge via the automated feedback within the questionnaires. Ensuring well-understood concepts are not repeated during class allows for more challenging problems to be discussed. Evidence from answers to questionnaires suggests that considering ethical and moral dilemmas can improve technical understanding.

Providing questionnaires in quiz form with an assessment also provides students with an indication of their progress. Detailed explanations after each choice also help students prepare for the lecture, provide time to assimilate this knowledge into a schema, and embed information into long-term memory.

The discussions helped students appreciate the relevance of ethics; how we can balance choices. The discussion regarding interpreting the ROC curve highlighted the need to lower the threshold to improve cancer diagnosis. However, it raised potential resource problems associated with the increased number and ratio of false positives. The discussion also raised further questions, such as the availability of medical testing and whether tests should be free of charge, a particularly relevant societal issue in the UK. The discussions also reinforced that persons affected by AI should be empowered to participate in its regulation, a key recommendation of the Ada Lovelace Institute's Policy Briefing 2022 [13] to strengthen the EU AI Act.

4 CONCLUSIONS

The interests and knowledge of students should be considered when designing modules. Incorporating the perspectives of countries where students come from acknowledges the importance of their communities. Ensuring all students see themselves and their cultural backgrounds reflected in the curriculum helps ensure all students feel welcomed and engaged.

These preliminary studies have indicated that decolonising the curriculum can support the development of engineering skills. However, these studies have focused on AI ethics and bias, and future research is required to confirm the validity and efficacy of this approach for other teaching contexts and other engineering fields.

Diversification of the reading list has an essential contribution to the decolonisation process. Encouraging students to suggest additional research which critiques the reading or has a different perspective is one way to co-develop and decolonise the curricula. Decolonisation provides an opportunity for staff and students to collaborate. This approach may be one starting point for comparative studies across universities.

Viewing the curriculum through the decolonisation lens helps us consider that not all students have equal chances in education. Considering perspectives from around the world, examining the histories that have led to injustices, and sharing our decolonisation practices, we can hopefully break down some of the barriers in engineering education.

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CHEATING IN ENGINEERING EDUCATION: MODERN METHODS AND POTENTIAL COUNTER MEASURES

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ABSTRACT

Engineers must engender trust in order to collaborate successfully to produce solutions that the world needs. As part of building this confidence, students with an accredited degree must meet learning outcomes i.e. demonstrate skills to an acceptable standard. Cheating during such assessments reduces professional integrity and future work quality. Through careful assessment practice and encouraging a professional culture with ethics, we may minimise student's opportunity and motivation to take short-cuts. With this in mind, it is useful to understand which technical and professional skills are most affected. Cheating is evolving, with more collaborative online opportunities. Previous research suggests a majority of student's admit to dishonesty at least once, and that there are several motivations, including individual, demographic, institutional, and societal. We describe today's engineering education environment in terms of how it affords cheating behaviours and their methods, including the popularity of online services such as Chegg. By analysing potential cheating methods against a current agreed inventory of contemporary engineering skills, we highlight where educators might focus efforts to reduce bad learning practices. We also consider how the covid pandemic with more online and remote studying amplifies the situation.

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1 INTRODUCTION

Prior to employment, a young engineer's development relies heavily on meeting learning outcomes through university programmes. Accreditation bodies set these objectives at national or multinational levels, and higher education institutions (HEIs) provide the environment to teach the skills. Universities and the accreditation bodies foster mutual trust in the teaching and evidencing student achievement through rigorous assessment.

HEIs use a variety of assessment methods, either to assess individual teaching blocks, or synoptic assessment for a series of modules. While accreditors don't determine the testing and evidencing regime, they observe, probe and draw on their experience of visiting other places to satisfy themselves that the quality of education is comparable. They will look at programme structure, teaching materials, and various assessments including examination scripts, coursework, and laboratory reports.

Graduate employers trust HEIs to award degrees which are fit for purpose. University ranking, reputation, and the accreditor's seal of approval increases industry's confidence. This is particularly so for a vocational degree like engineering, where the question becomes whether the graduate, with the correct blend of emerging technical and professional skills, will fit into the company and contribute to its commercial success.

In this paper we reflect on the challenge for HEIs to maintain confidence in student achievement, which in turn, preserves the confidence of accreditors and potential employers that engineering graduates are not only well taught and that the assessments accurately demonstrate competency level, but that no cheating has taken place which might inflate grades. The sudden move to online assessment during the COVID19 pandemic has undoubtedly increased the potential for academic dishonesty, and the question we face is how to detect and deal with it rigorously, fairly, and with compassion.

We reflect on issues related to students cheating - which existed prior to the pandemic - but have been accentuated due to the increasing reliance upon online teaching resources and assessment. We base our commentary on experiences over the past three years both at our home institution and through discussions with other institutions that have observed similarities in the approach of some students to dishonestly enhance their performance, thus potentially deceiving future employers that their learning outcomes are truly reflective of their achievements.

2 BACKGROUND

2.1 Academic dishonesty

Academic dishonesty is endemic, as evidenced by the longitudinal studies on American and Canadian college students by Bowers then McCabe [1] [2] spanning over half a century; e.g. in one study between 2002-2010, 59,907 of 90,145 students anonymously self-reported one or more of nine identified cheating behaviours which we'll refer to by their numbers in later sections: 1) Copying sentences from material without quoting / citing sources. 2) Adding unused citations to the bibliography. 3) Plaigiarizing published works. 4) Getting questions and answers before taking exams. 5) Copying another student's work. 6) Unpermitted collaboration with other students. 7) Submitting another students work as their own. 8) Giving answers to other students in exams. 9) Using unpermitted notes.

The motivation to take short-cuts includes wider societal norms and behaviours, and more localised peer, family and classroom expectations. A framework proposed by Murdoch [3] on motivational factors for cheating identifies 3 questions that students may ask themselves. Table 1 lists these questions, together with examples of influences we've identified from the literature and our own practice (column 2).

Table 1. Motivations for cheating (adapted from [3])

Motivational question	**Examples of influences which encourage cheating**
What's my purpose ?	Low grade expectations, unfavourable peer comparison, inconsistent faculty approach to cheating, extrinsic goals overriding subject mastery.
Can I do this?	Underconfidence, limited available effort, inadequate learning level reached, unclear assessment standards.
What are the costs?	Low personal morals, unfollowed or ignored codes of academic practice, poor faculty monitoring and detection of cheating, perceived classroom injustices.

The multitude of influences suggest that efforts that we make to contain academic dishonesty must utilise a several strategies. Typically, most faculty rightly claim to adopt a consistent approach to cheating through clear assessment standards and requiring students to agree to codes of academic practice. These approaches however, may not inhibit all influences.

2.2 New engineering skills

The challenge to teach new skills in engineering degrees can motivate academic dishonesty because our understanding of what is required is still evolving. The SEFI engineering skills special interest group surveyed 25 2021 conference delegates about 8 typical barriers faced by educators when teaching emerging technical and professional skills (Figure 1). Responses revealed that an overloaded curriculum (row 4 and 8) and lack of time and resource were common hinderances, despite industry demand being strong (row 5).

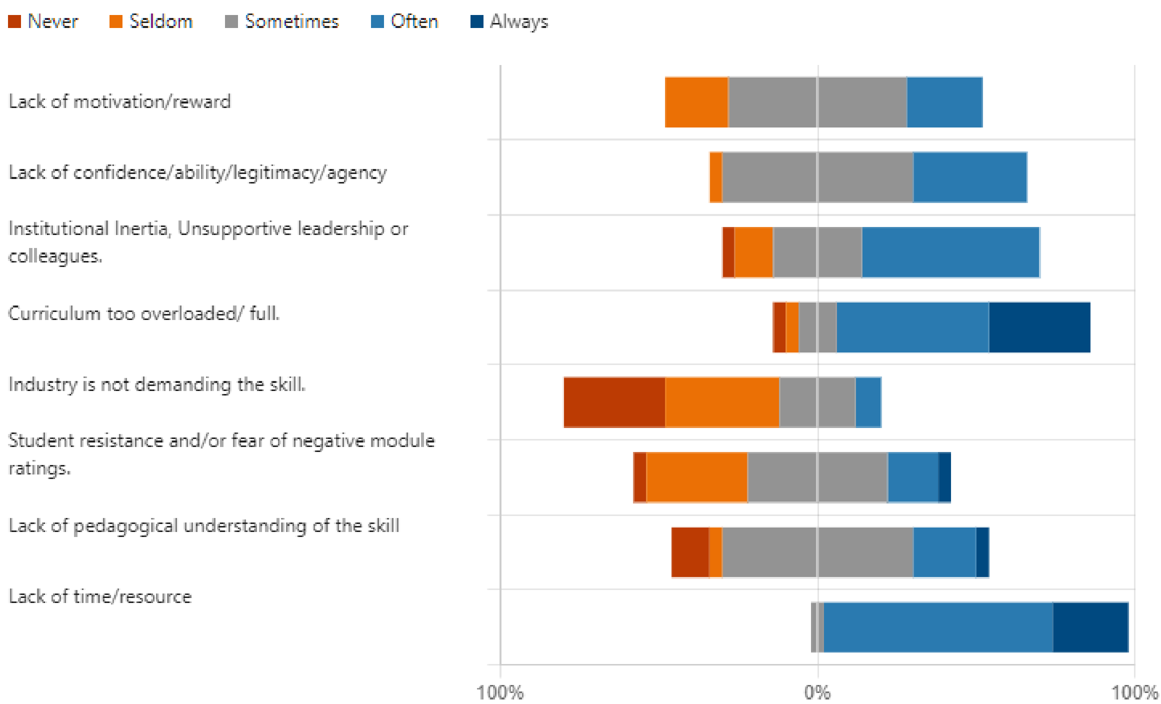

Fig. 1. Responses of the SEFI 2021 Engineering skills SIG survey to the question “I have come across the following hindrances in teaching new design, technical or professional skills:” (n=25)

Although the sample size from this survey is too small to draw meaningful conclusions, many of the hinderances identified can be related to the influences which motivate cheating in table 1. e.g. An educator's lack of pedagogical understanding in teaching the skill results in an inadequate learning level reached and unclear assessment standards, which influences students to answer affirmatively to “Can I do this?”. Thus, educators must be aware that, as we evolve the curriculum, our barriers to teaching skills effectively may inadvertently motivate cheating.

3 THE CURRENT ENVIRONMENT

3.1 Academic integrity process (honour code)

The methodology relies on our experience of operating a ‘academic integrity process’ at our home institution in which engineering is but one discipline and therefore being able to compare the concerns faced with other scientific but also non-scientific disciplines. We consider how each of the nine cheating behaviours in section 2.1 manifests in modern practice in sections 3.2, 3.3 and 3.4, and outline our process for detection and resolution in 3.5.

The issue of academic integrity is introduced to students by a presentation and they’re pointed towards online resources which set out its importance and the consequences of falling short. The materials explain what is acceptable assessment practice. This is part of an “honour code” [2] which is a learning agreement between student and university.

3.2 Plagiarism detection in coursework (behaviours 1,3 and 7)

Universities have moved to online submission of most coursework to allow checking for copying through similarity checking software such as Turnitin [4]. Students upload their submissions and Turnitin checks its extensive database to identify matches that contain either a fully copied piece of work from another author at one end, heavily copied and unattributed or badly attributed material in the middle of the scale, to badly referenced material which can be improved through better referencing practice. Turnitin is helpful in investigations into plagiarism when students would have to explain why the similarities have occurred. However, what it cannot reliably identify is work translated from other languages, or copying of text or table via their inclusion as images that are not textually searcheable.

3.3 Online resources that facilitate cheating (behaviours 2,4,6 and 7)

The internet affords the academic community many helpful resources such as substantive reports and research studies, but information can be weak and not peer-reviewed. Students in particular will use public search engines such as google to help them in their learning. The challenge HEIs face is in how to point students to good external assets on a particular topic. For engineering, some online materials use different methods to solve problems and explain concepts, which may enhance overall understanding or clarify misunderstandings from the in-house teaching.

However, a recent issue that became a challenge with wider use of online assessment is using sites that invite students to upload questions that others can answer that the student then uses substantially as ‘their’ answer. A platform rapidly gaining popularity reported by many institutions is ‘Chegg’ [5] . This file-sharing platform offers services to students which range from access to notes to providing expert advice on ‘homework’. Subscribers can upload questions and receive answers with the term ‘homework’ used rather than examination. Chegg allows HEIs to request the email and the IP address used by subscribers. At this stage the laws of countries where students are using this and similar services do not judge the sites to be illegal.

3.4 COVID19 pandemic and closed-book examinations (cheating behaviours 5, 8 and 9)

The procedures for dealing with closed-book examinations and those for online examinations are different and present different challenges. The pandemic resulted in a sudden move to only online examinations or only continuos assessment through coursework which in many cases universities and academics judge as appropriate to replace closed book examinations. Most universities also introduced emergency regulations to help arrive at fair outcomes in terms of actual module marks and overall GPA or degree classifications. They have produced challenges in themselves, however this is not the subject of this paper.

3.5 Code of Practice on Academic Integrity – detection of cheating.

Our home university operates what is referred to as a Code of practice on academic integrity (including plagiarism and conduct in examinations and class tests), which like other codes of practice is reviewed on an annual basis. It sets out the responsibilities of the principle academic units, the responsibilities of the students and the processes for investigations into different aspects on academic integrity. It describes categories of plagiarism, how investigations are to be conducted when a student is suspected of breaching academic integrity and the sanctions available to the principle academic unit to impose. Very serious cases are referred up to college misconduct committees and the students have a right of appeal which can reach senate and the external body for student affairs if a student pursues an appeal all the way through the university processes but is still dissatisfied with the outcome.

The sanctions available range from a revise and resubmit to the recording of a mark of zero and no further opportunity to resubmit, which depending on the weighting of the component under investigation, could result in failure of the whole programme. An example of this is a taught master's level project, which counts for one third of the credits for the 12-month degree programme. Should a student be awarded a mark of zero after an investigation and not be allowed to resubmit, the student could not achieve enough credits to be awarded the master's degree and would therefore leave the university either with no degree or a diploma or certificate depending on the number of credits achieved.

There are three levels of plagiarism or cheating which the code asks Academic Integrity Officers (AIOs) to judge in any investigation. They are: poor academic practice,. moderate plagiarism (or cheating), and serious plagiarism (or cheating). The level at which the student is studying is a factor as it is expected that a first year student's understanding of plagiarism and cheating is less thasn that of a more senior student.

Following a referral to the AIO from an assessor raising concern related a student's piece of work, the AIO decides whether the concerns merit an investigation and if so, calls the student to a meeting where they have an opportunity to respond. The AIO in consultation with a memebr of the module team determines the plagiarism level and then decides upon a sanction based on the options provided by the code of practice. Most cases under poor academic practice relate to inadequate referencing or to a misunderstanding of how to write a report following extensive reading in which it is not clear which parts relate to the literature read, and which parts are the student's own writing.

4 REFLECTION

4.1 Plagiarism detection in coursework (behaviours 1,3 and 7)

Plagiarism continues to be challenging in relation to student research and report writing skills. Making the judgement about what is synthesising and reporting other authors' findings rather than the student's own writing does not come easy to students. It is a skill that requires time for development. It is particularly difficult for students whose first language and culture are different to the university. What has become clear over several years is that the concept of plagiarism is considered differently in different countries. Students often argue that in their home countries they are encouraged to identify ‘the best resources’ and to include text from them without following appropriate referencing practice to distinguish between their words and those of an original author.

Attempts to encourage correct referencing at the start of programmes and then to reinforce the importance of avoiding plagiarism continue as students progress through their degree programmes. However, the issue of English language competence adds a further challenge to students attempting to read widely, to synthesise correctly and to then refence accurately. Experience by many academics who use Turnitin indicates that a substantial proportion of students use it at the draft stage of report to paraphrase sentences and paragraphs to reduce the similarity with the source they’ve copied. The skill being developed by students becomes beating the similarity algorithm, rather than developing the skills to write and reference correctly.

4.2 Online resources that facilitate cheating (behaviours 2,4,6 and 7)

This does seem to be an increasing threat to the integrity of the assessment system, which the COVID19 pandemic extenuated but will also apply to online assessment going forward. It’s important to start with an acknowledgement that if it were not for online examinations, the progression and completion of university degree programmes during the pandemic would have been extremely difficult, especially with many students studying remotely.

By their nature online examinations were typically open-book, which for many engineering academics was not the norm and therefore may have risked pedagogical frialty. Extra time to complete the exams was given to allow for uploading the answers and to help students overcome internet difficulties. Students taking the examinations in different time zones meaning some would start and finish before others within a designated window. Even with this flexibility some students failed to upload their answers as specified, and emailed them afterwards claiming they uploaded the wrong version, raising suspicions as to whether they had obtained external help with the final versions. The decision on whether to accept a later emailed answer version was left with individual lecturers resulting in potential arguments and disputes.

There was also the potential that students used social media apps such as WhatsApp and telephones to obtain the examination paper from another student who logged on and stared the examination early in the time window available and therefore to gain unauthorised extra time to complete the examination.

For both coursework and online examinations the potential to use platforms such as Chegg to upload questions and purchase answers was encountered. It is in theory possible to post questions at the start of an online examination, to start answering the questions but then amend answers if external answers were offered in time. Sometimes these answers were shared with others. Furthermore, students could simply Google a question to see if similar questions have been solved.

While in the early days of these potential incidents occurring, students may have used an email address and IP address that could be identified with them as it was used by them in other communications with the university. But there's evidence that they are now much more careful with this once learning that Chegg responds to queries from universities for information on individuals uploading their questions.

4.3 COVID Pandemic and Closed-book examinations (cheating behaviours 5, 8 and 9)

The challenge in closed book examinations generally revolves around potential cheating through bringing unauthorised resources into the examination rooms, hiding them, and using them when possible. In previous years, this has included the dishonest use of programmable calculators but has in recent years moved towards the use of mobile telephones to store additional materials, such as lecture notes and tutorial questions and answers. Investigation procedures are now long established and if a cheating offence is identified and evidence is collected, the procedures available can deal with the dishonesty in a now established way. The pandemic is gradually easing and the issues with closed-book examinations being compromised by remote exams is seen as less worrysome. However, universities that beleive in developing new online assessments are striving to find a way to keep the integrity of the assessment even when online.

4.4 Further reflections on staff resource

The impact on staff resources of this growing development of academic dishonesty shouldn no be underestimated. More time is required for staff to identify and evidence suspicions of cheating and for the processes employed to continue to be fair and robust. This is particularly the case with 'homework' platforms such as Chegg where the identification of cheating and evidencing it is not always straight forward. The system relies on the module team to identify plagiarism and cheating and to spend time evidencing and challenging the students identified as not displaying the honesty required. A possible reaction to the challenges presented could be to move back to assessment by closed book examinations only, particularly in the latter years of programmes when the recent trend has been to use more diverse ways of assessing the development of skills and attributes.

5 SUMMARY AND ACKNOWLEDGMENTS

We've reflected on the current challenges of academic dishonesty in an engineering faculty through reference to nine cheating behaviours and their modern guises. By considering student motivation for taking short-cuts and the underlying factors, we consider that the barriers educators face when teaching emerging skills may be encouraging students to take the wrong path.

We require multiple strategies to reduce academic dishonesty because there are many influences. While faculty work hard to dampen the third motivating question "What are the costs?", to make progress we need to develop strategies that counter the preceding questions: "What's my purpose?" and "Can I do this?". This means going far beyond a consistent approach to cheating, clear assessment standards and agreeing a code of academic practice, towards upskilling educators to teach and assess emerging skills without hinderance while compassionately addressing students' beliefs and goals.

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EFFORTS TO IMPROVE ATTRACTIVENESS OF LOWER LEVEL ENGINEERING EDUCATION (CONCEPT)

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ABSTRACT

There are nine study programmes awarding the degree bachelor in engineering (högskoleingenjör) at the University of Gävle. Some of these have only a few applicants, even though the graduates are appreciated by a relatively large regional primary and secondary sector industry.

A major revision of the programmes is planned. One objective is to increase the attractiveness of the programmes. In the revised programmes, students are proposed to study most courses together during the first year of study, even if they belong to different engineering specializations. This is intended to improve the study environment. Students in programmes with low numbers of applicants will become part of a richer and livelier student collective. However, the attractiveness could further be problematized by asking to whom higher education is attractive. A special focus will be on increasing the admission of students from groups in society that have been underrepresented in higher education. More specifically this may be linked to individual factors such as the educational level of parents, family income,

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immigrational background and geography. There may also be societal explanations in traditions of gendered professions. Engineering programmes, and especially some of the specializations at the university, are dominated by male students.

This study focuses on how universities can take action to further increase the attractiveness of the engineering programmes, with a special regard to groups that are known to be underrepresented among the students.

1 INTRODUCTION

1.1 The growth of technological education in Sweden

In Sweden, the question of who or which groups in society are given the opportunity to take part in higher education, has a long tradition. For example, a governmental report 1965:11 stated that the number of students in tertiary level education at the three existing institutes of technology should increase from the 2001 admitted students in 1964 [1]. According to Statistics Sweden (SCB), there were 12051 admitted students in 2018, of which 4195 were students for a bachelor degree in engineering. The development of the proportion of the population has increased steadily. In 2020, 44.6% of the population between 18 and 64 had a degree in higher education [2]. It is above the OECD average (38.6%) but lower than countries such as Canada, Japan, and South Korea which are above 50% [2]. At the same time, there is also an objective to broaden participation in higher education. This has also a long history but the development has intensified in recent decades. Not least, the amendment to the Higher Education Act 2005 has clearly stated this change [3]. It stipulates that higher education institutions "actively promote and broaden recruitment to higher education". This is also connected with more general formulations in, for example, the global goals for sustainable development. This type of issue is also raised in the Bologna reform for a consolidated education platform within the EU. The London Communication 2007, for example, states that “the student body entering, participating in and completing higher education at all levels should reflect the diversity of our populations” [4]. In the bill text (Prop. 2001/02: 15), several measures are proposed that the higher education institutions should take to affect the new law. There are ideas about establishing local action plans, increasing the number of preparatory educations (so called “basical years”, complimentary courses to secondary education programmes), increasing the number of distance education, enabling lifelong learning, and more. The purpose is stated as "to increase diversity and reduce social bias in recruitment" (Prop. 2001/02: 15). However, similar objectives already existed in the major higher education reform in 1977. In the new Higher Education Act of 1977, the objective was “to promote social equalization and increase access to higher education” [5]. An important part of the reform was to transfer several different post-secondary educations to the higher education sector. Among them are teacher and nursing educations that came to be those that included the large educational cohorts. However, the technical education took on a different design. The technical education remained in the upper secondary school, having a duration of four years and leading to a high school engineering degree. As a complement, a two-year technical post-secondary education was developed that would lead to a university degree in engineering. These educations were placed in several newly established smaller colleges outside the traditional university cities (Prop. 2001/02: 15).

In summary, there are two parallel objectives for universities regarding admission to engineering programs. One is an increased number of students in total and the other is that these students should have a more heterogeneous background.

1.2 Previous studies of attractiveness in a national context

Programmes in engineering are known to attract mainly male students. The Rose project investigated attitudes to learning science and technology in several countries [6]. The results show that there is a big difference between boys and girls. In Sweden, almost 60% of boys express that they want to work with technology, but less than 20 % of girls. The situation is similar in other wealthy countries. This corresponds well with national statistics presented by Royal Swedish Academy of Engineering Sciences [7]. In 2016, only 25% of the admitted students at bachelor of engineering programmes on a national level were women. In certain specializations, e.g chemical engineering, there are more than 50% women, but others have far fewer, e.g. specializations in electrical, mechanical, and computer science engineering, which all had less than 10% female students on a national level. In 2022 a thorough examination of broadening participation was published by the Swedish Higher Education Authority [4]. This study continues to pin-point at the lack of equality in recruiting students. The report also broadens the scope of attractiveness by addressing oblique recruitment of more social issues such as immigrant background, parental education level and geography.

1.3 Engineering education at University of Gävle

University of Gävle offers programmes on the level of bachelor in engineering. There are presently nine such programmes. The programs are often developed in close relation with industry and are given in Swedish. The level of internationalization in the programs are therefore low. The main rationale for the supply of programmes is to provide regional business and industry with qualified competence. However, many of the programmes have only few applicants, implying difficulties for the education as well as recruiting problems for the companies that employ the graduates.

In Swedish, the name of the degree is *högskoleingenjör*. This is a first cycle degree (undergraduate) awarded to students after three years of dedicated engineering studies. The programs normally extend over three academic years, i.e. 180 credit points (cr) according to the ECTS (European Credit Transfer System).

Our engineering programs aiming at the degree of högskoleingenjör correspond to what in Anglo-American countries sometimes is called bachelor of engineering in <major> (B.E. in <major M>) and sometimes bachelor of science in engineering (B.Sc.E. in <major M>).

The framework is regulated by the Swedish Higher Education Ordinance (1993:100), Annex 2 – System of Qualifications [8]. However, the scope or specialization of the studies is to be decided locally at each university. At the University of Gävle, the major field of studies of these programmes comprises a minimum of 90 cr, including a 15 cr degree project. Depending on the field of studies, the curricula include 15-37.5 cr of mathematics. The remaining third of the study programme includes relevant courses required to give the student the knowledge and skills required to work autonomously as a graduate engineer in their respective fields.

1.4 Rationale for the work

At the University of Gävle, there is an ongoing strategic revision of education. Regarding all existing study programmes, the following perspectives are focused: (1) attractiveness of the programmes in terms of number of applicants, (2) the capacity for the University to offer a complete study environment in the subject, from undergraduate to Ph.D. level, and (3) utility of the study programmes in terms of demands from society and employability. In the revision, all bachelor in engineering programmes at the university have been suggested for a major reform, with the objective to strengthen connection to research and improve student recruitment. A desire that the number of engineering programmes should be reduced has been expressed.

The authors of this paper are all involved in reforming the engineering programmes. In this paper, we focus on attractiveness. We wish to elaborate on what can be done to improve student recruitment. Our purpose of presenting this at SEFI is to share experiences with others who are interested or involved in similar situations or processes.

Attractiveness could be problematized by asking to whom higher education is attractive. Initially, the authors took a broader approach when studying admission data of students from groups in society that traditionally have been underrepresented in higher education. More specifically this is linked to individual factors such as age, the educational level of parents, family income, immigrational background and geography. However, the pre-study concluded that in these cases the University of Gävle did not stand out in comparision to other universities in Sweden. Although showing skewed distribution, it was not different from sociaty as a whole. However, one criteria stood out as slightly diffrent and intersting to further elaborate on. This was gender and the attractiveness for female students to choose technical disciplines. Gender issues may be interesting, as several of the programmes have a very low proportion of female applicants.

2 METHODOLOGY

2.1 Measuring attractiveness

Attractiveness depends on many factors and can be measured in different ways. A review is presented by Widiputera et al. [9]. In our context, in order to effectively monitor the present situation and the future development, we have chosen to focus on three measures: Limits regarding admission, number of applicants, and presence of underrepresented groups, in our case women.

In Sweden, a commonly used measure of attractiveness of study programmes is the limits regarding admission. These limits concern the grades for students coming from upper secondary school as well as results from the Swedish Scholastic Aptitude Test (SweSAT), in Swedish *Högskoleprovet* [10]. The limits are defined as the lowest score among the admitted applicants. The values of previous years are of high interest to prospective students and they have an impact on what programmes students choose. The values are often seen by students as an indicator of the status or quality of a study programme. Students tend to apply for programmes where they get “use” for the grades or results that they have received.

The number of applicants is another significant measure of attractiveness. In cases where all applying students are accepted, the number of admitted students equals the number of applicants. As the number of admitted students may be restricted by other factors unrelated to attractivness, we argue that the number of applicants is a more valid measure of attractivness than the number of admitted or enrolled students. This measure is more important for the study environment and the economy of the education than the above described limits regarding admission.

Attractiveness can also be measured by what groups of students that are attracted by a programme. A way of increasing attractiveness, in this sense, would be to attract groups of students that are underrepresented on the programme. If only the gender balance is considered, this measure may be represented by a value, e. g. the percentage of women.

2.2 Data collection

To monitor attractiveness of the bachelor in engineering programmes at University of Gävle, we have examined data from the Swedish Council for Higher Education (UHR), Statistics Sweden (SCB), and the local university administration. These data are publicly available and can provide a picture of the present state and a point of reference for future comparisons when we wish to evaluate implemented efforts to increase attractiveness. In some cases we have used data only for 2021, but to get a more solid background description regarding women, we have used data for 2008-2021.

3 RESULTS

3.1 The present state

Regarding the bachelor in engineering programmes at University of Gävle in 2021, all applying students that fulfill the requirements were admitted. This implies that the study programmes presently don’t have limits regarding admission, and thus are likely to be perceived as low status. In order to increase attractiveness, a first goal could be to obtain values for the admission limits. This would require that some, or at least one, applicant is rejected. If the University chooses to take actions in this direction, we hope to be able to elaborate these ideas and study the effects on attractiveness in a future paper.

The engineering programmes at University of Gävle have few students. The numbers of admitted students are presented in Table 1. Several of these students are admitted through the preparatory educations ("basical year"), which implies that they don't contribute to providing the programmes with limits regarding admission, as described above.

The third column of Table 1 presents the percentage of women on average during the period 2008 - 2021. A star (*) after the percentage of women indicates that two different programmes have been offered during the period. In these cases, the value represents the average for students from both programmes.

In the fourth column, the number of years that the programmes have admitted two or less female students is presented. In parentheses, the number of years that the programme(s) have been offered is presented. That is, for the programme in Automation engineering "9 (of 10)" means that the programme has been offered for ten years during the period, and during nine of these there has been at most two female students among the admitted.

Table 1. Number of admitted students, percentage of women, and number of years when two or fewer female students were admitted to the bachelor in engineering programmes at University of Gävle.

Study programme	Students admitted in September 2021	Percentage of women, average during 2008 - 2021	Number of years with two or less women admitted
Industrial Engineering and Management	26	35%	0 (of 2)
Automation Engineering	9	10%	9 (of 10)
Building Engineering	49	33% *	0 (of 14)
Computer Engineering	43	11%	7 (of 14)
Electrical Engineering	12	14% *	9 (of 12)
Energy Systems Engineering	26	23% *	1 (of 12)
Environmental engineering	20	57% *	0 (of 5)
Land Management and Engineering	11	21%	3 (of 4)
Mechanical Engineering	25	15%	7 (of 14)

3.2 Findings in existing data and proposed actions

In the revision of education at the University, we have so far investigated the situation, identified problems, and started suggesting possible solutions. The reformation process will probably go on for some years. We will here share some of our findings.

Table 1 shows that the number of admitted students in 2021 varies between 9 and 49. Seven of the nine programmes admitted less than 30 students. Here, the value 30 is chosen arbitrarily as it represents a typical class size in some contexts. During the education, several students quit their studies prematurely. Most that quit do so during the first year of study. This implies that classes in the programmes will be small, unless students from several programmes can participate in the same courses. In the present programmes, many courses are associated to a unique programme. In the reform of the engineering programmes, we propose that the revised programmes would share courses to a large extent especially during the first year of study. This would provide a richer and livelier study environment.

A low number of students in connection with an uneven gender balance may worsen the difficulties for the minority. In table 1, the third and fourth columns indicate that 25% women seems to be a suitable limit in this context for when there is a risk of having two or less women admitted to a programme in a year. In our context, six of the nine programmes have an average of less than 25% women. As seen in the fourth column, there are two or less women among the admitted students in half of the years or more frequently when there are 15% women or less. In these situations, a woman has at most one fellow female student, which is a vulnerable position as the risk of being left alone is obvious, temporarily due to e.g. illness, or permanently if the fellow female student quits. In many of these cases, the woman is the only admitted student from the start of the studies, or there is actually no admitted female student. Larger classes would help to build a more sustainable study environment for women, where the risk of being alone is smaller. Therefore, class sizes matter. If women would feel less vulnerable, the gender balance may improve, which could further reduce the risk for women to be the only female student in class and improve the study culture regarding gender equality in the programmes. This could further increase the attractiveness of the programmes, for both men and women.

3.3 Conclusions and a proposed rule of thumb

Higher education in Sweden today has a clear goal to increase broader participation. This is about increasing the attractiveness of education for groups that have traditionally been outside of higher education. The rationale of this may be linked to both societal and industrial needs of competence development but also from a more democratic stand point that participation in higher education should reflect the constitution of the general population as a whole. Focus in this study has been to examine the gender distribution between different engineering programs at the University of Gävle. In order to increase attractiveness in the sense of broader participation, all programmes should strive to attract men as well as women.

One proposed action is to share courses between different engineering specializations. We have been working with an idea that a majority of courses in the first year of all engineering programmes are shared. It may contribute to a livelier study environment and improve economy, but it may also contribute to more gender balanced study courses. It reduces the risk of being the only female student in class.

We can observe two significant limit values in the average percentage of women. The first limit is 25% women, below which we can see a risk for having two or less admitted women on a study programme in a year. The second limit is 15% women, where having two or less admitted women on a study programme seems to be the normal situation, occurring at least every second year.

We must point out that these limit values depend on the number of admitted students. However, it may still be useful to keep these values in mind as a rule of thumb. The values are easy to obtain which is an advantage if they are to be used as indicators. They may guide e.g. programme directors and directors of study for when care must be taken regarding admission and gender equality.

We propose the following formulation as the rule of thumb for when actions regarding course sizes may need to be considered:

- When there are 25% women on average on a programme, the risk arises that women may be left without fellow female students.
- When there are 15% women, they are often left without fellow female students.

This model, or rule of thumb, will also provide a scheme for evaluating the need for more changes within the study programmes.

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PROJECT-BASED LEARNING USING SCIENTIFIC POSTER AS A TOOL FOR LEARNING AND ACQUISITION OF SKILLS IN PHYSICS SUBJECTS OF ENGINEERING BACHELOR'S DEGREES.

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ABSTRACT

This article shows the experience of working on project-based learning using scientific posters, on the study of the mass geometry of matter, with students of various Physics subjects of Degrees in Engineering of the School of Design Engineering of the Polytechnic University of Valencia. The development of this work has been carried out with a dual purpose: on the one hand, to improve the teaching-learning process of mass geometry; and, on the other hand, to improve the acquisition of skills by students. This matter, which is studied in the Physics subjects of the first year of the degree, forms part of the basis of the studies of resistance of materials and theory of mechanisms of subsequent courses. The inclusion of two sessions of laboratory practices, as an extension of the work carried out in the theory and classroom practice sessions, has allowed us to study more deeply the theoretical concepts of mass geometry and their application to a real project, improving the learning by the students. In addition, the presentation of the project through the scientific poster has facilitated the acquisition of cross-curricular competencies such as application and practical thinking, teamwork, effective communication, and critical thinking.

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1 INTRODUCTION

1.1 Context

This project was born in the subject of Physics-10270 of the bachelor's degree in Industrial Design Engineering and Product Development of the School of Design Engineering of the Polytechnic University of Valencia, taking into account that one of the professional opportunities of this bachelor's degree is the industry of the furniture. Later it is extended to the bachelor's degrees in Electrical Engineering and Mechanical Engineering, of the same School, being implemented in the subjects of Basic Physics and Physics Complements, respectively.

In the laboratory practices of these subjects is where the theoretical knowledge is applied to the experimental practice, carrying out tasks like those of laboratory research on physical phenomena studied in the classroom.

The initial decision to carry out this project was due more to a spirit of innovation and improvement than to a problem or difficulty in teaching Physics-10270. Although, despite the good academic results of the students, the experience in recent years courses showed us a slight decrease in the grades obtained in the laboratory practices with respect to the global grades of the Physics subject.

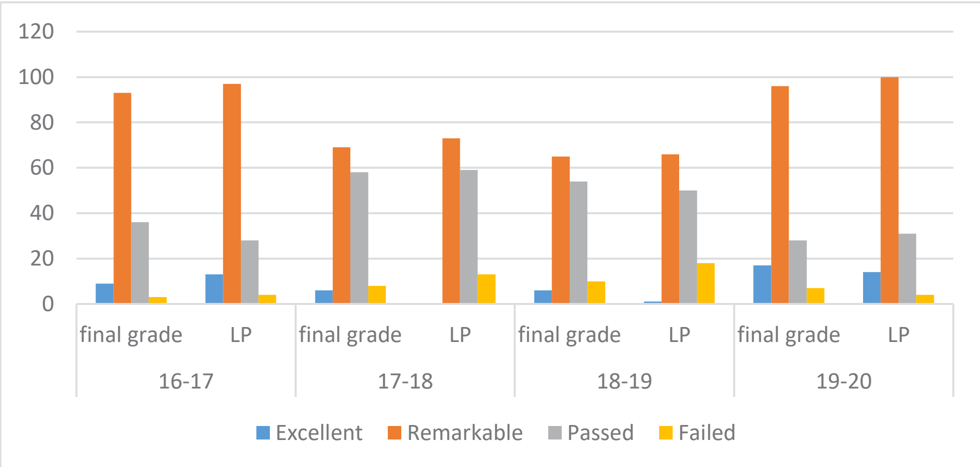

Fig. 1. Number of students and grades obtained in the final grade of the subject Physics 10270 and the average grade of the laboratory practices LP.

Even so, it is inevitable to think that, sometimes, the teaching of Physics, and the rest of the basic sciences, can be tedious; therefore, the inclusion of some methodological strategy can motivate students, and even "entertain" them [1].

1.2 Project-Based Learning (PBL) and Scientific Poster

The commitment to the PBL methodology is based on the conviction that the development of a project in engineering studies, even at a basic level, can be a great incentive for first-year students, as it facilitates the connection between training they receive and their future performance in the profession, in addition to the development of self-learning and creative thinking [2]. In fact, among the benefits of this method, it stands out that: it increases autonomous learning, prepares students for jobs, increases motivation, strengthens self-confidence, establishes connection between learning at school and reality, offers collaboration opportunities to build knowledge, increases social and communication skills, increases problem-solving skills... If we add to this the benefits of collaborative work in terms of increased interaction and critical thinking skills in the negotiated solutions, PBL seems to be a good strategy for improving the quality of learning [3].

For the transmission of the results of the project, the scientific poster format is chosen because it is expected that the students, who work as a team in the laboratory practices, will be able to build knowledge through the projects worked on, and to present them orally. Therefore, it is established as a teaching and evaluation tool within the course.

According to the Dictionary of the Spanish Language, a poster is a "banner that is fixed on the wall, without advertising purpose, or having lost that character". But we also understand the poster as a multimodal communicative genre, with text, graphics, color, speech, and even gestures, used to convey ideas. It is an alternative to the oral presentation, but with the same purpose [4].

Normally, the presentations of the tasks carried out in the laboratory practices are presented through written reports as a scientific article. In these works, we have verified that, very often, more than a true collaborative work, what is produced is rather the sum of pages created individually, despite the mechanisms and strategies that we carry out to try to avoid it. With the creation of a poster, we want to minimize this problem in some way, as well as the frustration or demotivation it generates.

In addition, we think that the presentation in poster format can be more stimulating, since the way of presenting the posters puts the communicator and the audience on the same level, facilitates the exchange of ideas and the comparison of results, and offers a panoramic vision of the different topics and contents presented. The poster is intended to see the other mode of presentation that takes place in academic and scientific conferences, with a more relaxed atmosphere, which promotes interaction between students in the meeting place.

2 METHODOLOGY

2.1 Objectives and Learning Outcomes

The main objective of this action is to initiate first-year students in the development of projects and their presentation through posters, so that they see the relationship between learning a basic training topic, such as mass geometry, and the future performance of the profession. The specific objectives of the action, related to the teaching methodology, are:

- Increase student motivation, through the development of a project, at a basic level, that gives meaning to the acquisition of knowledge.
- Improve the ability to apply the contents to practice, broadening the vision of the students' professional future.

- Promote the acquisition of cross-curricular competencies such as effective communication and critical thinking, through the delivery of the project in poster format and its exhibition.
- Quantify the degree of acquisition of knowledge by students.
- Quantify the degree of satisfaction of students and teachers regarding the effectiveness of the PBL methodology in the learning process.

Regarding the learning outcomes, it is expected that the students, upon completion of the project, will be able to:

- Detail the starting conditions for the design of a piece of furniture: materials, densities, shapes, etc.
- Analyse furniture elements by modelling the whole by decomposition into simple geometric figures.
- Calculate the basic parameters of mass geometry of furniture elements.
- Check the coherence of the results with respect to the selected reference system and axis.
- Prepare a report on the behaviour of a piece of furniture using the poster format for its presentation, paying attention to the correct use of scientific-technical language.

2.2 Work development

The work teams are made up of 5-6 students. The project is developed in two phases: first, a partial delivery is made, whose evaluation is used as feedback for the optimization of the work; and in the second phase, the final delivery is made, in which the complete development of the project is formalized, in poster format.

The development of the project is indicated in the following steps, briefly explained, considering that some of them are worked on at the same time, despite the exposed order:

<u>Sketch</u> (1.1): Each team will select an element of furniture to design, from those listed in the project script (chair, table, bench, shelf, staff, canopy, etc.), and will make a sketch of the design of the selected element.

<u>Modelling and decomposition of the element</u> (1.2): The team will model the furniture element in such a way that the simplicity requirement is met, to apply the calculation hypotheses. They will decompose it, into all the parts that are considered necessary, to analyse the element as a system of simple geometric figures.

<u>Table of materials</u> (1.3): The team will select the manufacturing materials of the different parts of the element, considering that it must consist of at least two different materials in its manufacture.

<u>Delivery of the first phase</u> (1.4): Each team will include the information from the previous sections in the script prepared by the teaching staff for delivery. Teachers will correct this delivery before starting the next phase of the project, so that students have the necessary feedback.

Choice of the reference system for calculating the centre of mass (2.1): Each team must analyse its element to select the reference system with respect to which its centre of mass will be calculated.

Choice of the axis with respect to which the moment of inertia will be calculated (2.2): Each team must analyse its element to select the axis with respect to which it will calculate its moment of inertia. This choice will be supervised by the teaching staff and their approval will be required to continue with the subsequent calculation.

Calculation of the centre of mass of the element (2.3): The team must apply the calculation equation for the centre of mass of material point systems.

Calculation of the moment of inertia of the element (2.4): The team must apply the calculation equation of moments of inertia of material point systems.

Preparation of the poster (2.5): All the elements described above in both phases of the project must integrate the poster that the work teams will present. The basic instructions for making a poster will be followed [4], leaving the structure arranged in title, authors, degree, introduction with hypothesis and objective, methodology and development, results, and conclusions.

Presentation of the poster (2.6): The day of presentation will be defined, in the course programming, as a congress. Teachers will oversee printing the posters and leaving them presented on the panels. The teams will explain their projects in the corresponding session.

Fig. 2. Exhibitions of the posters of the Mass Geometry Projects.
Course 20-21 on the left and course 21-22 on the right.

For the evaluation of the achievement of the objectives, the following were designed:

- Teaching materials for the acquisition of knowledge and development of the project.
- Two rubrics for the evaluation of the two phases of the project (first delivery and poster), in which the cross-curricular competence CT02 – Application and practical thinking was also assessed.
- The self-assessment questionnaires for the evaluation of the cross-curricular competence CT06 – Teamwork.

- The evaluation rubric of the cross-curricular competence CT08 – Effective oral communication, used by students and teachers in the exhibition of the posters.
- Questionnaires for student satisfaction surveys.

3 RESULTS

The two aspects that teachers most value at the end of each course are academic results and student satisfaction. Regarding the first aspect, a comparison of the average of the results obtained in laboratory practices 5 and 6 is shown, before including the mass geometry project, and the results obtained in these practices, after the change by the project, compared to the final lab grade (except the current course, which has not yet been completed). As can be seen, the change of the old practices 5 and 6 by the project has led to an improvement in the grades obtained.

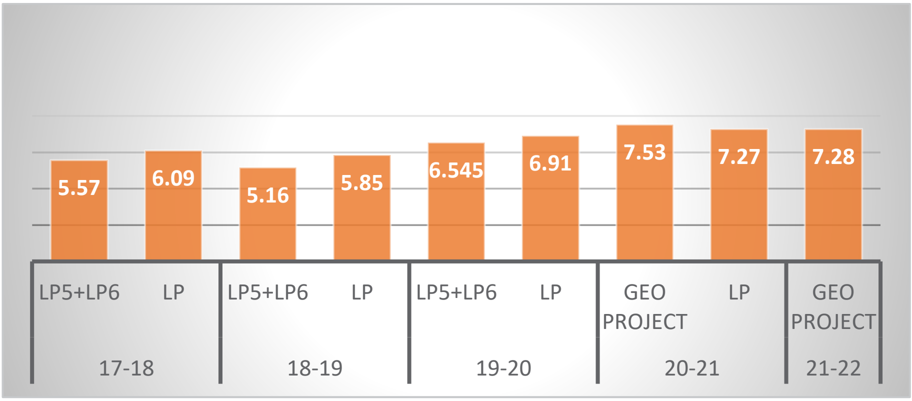

Fig. 3. Grades obtained in 5 and 6 laboratory practices, average grade of the GEO Project, and average grade of the laboratory practices LP of the subject Physics 10270.

Regarding the second aspect, it has been possible to observe a significant percentage of students satisfied with the work carried out, and a slight increase in the motivation of the students with respect to the work developed in the conventional laboratory practices, clouded by the sanitary restrictions that have not allowed much interaction in the development of work.

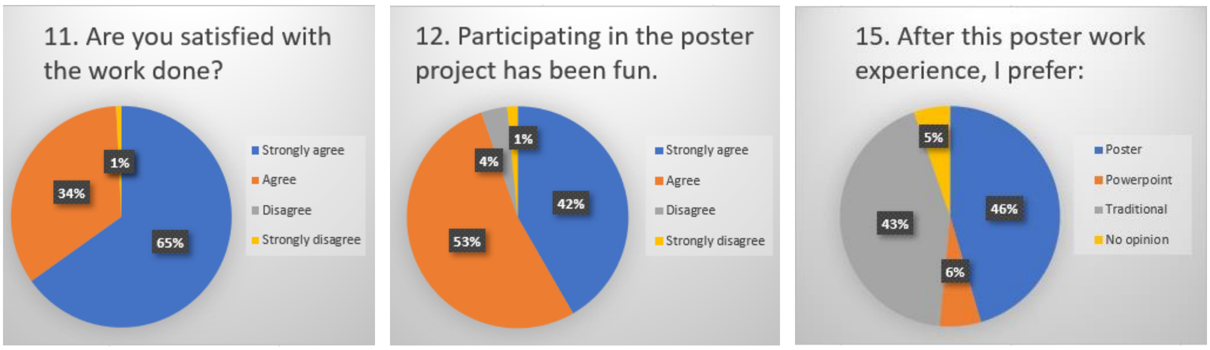

Fig. 4. Answers to some of the questions asked in the satisfaction questionnaire.

In view of the results of the questionnaire, it can be concluded that the application of the PBL methodology using Scientific Poster for improving the teaching-learning process of students of various Physics subjects of bachelor's degrees in Engineering of the School of Design Engineering has been successful. As a closure of this work, some representative posters of the students of Physics-10270 subject are shown.

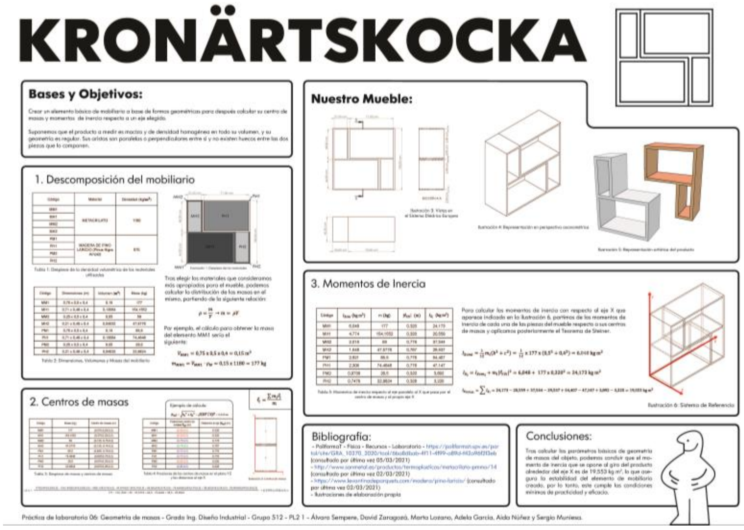

Fig. 5. Poster made by Á.Sempere, D.Zaragozá, M.Lozano, A.García, A.Núñez, S.Muniesa.

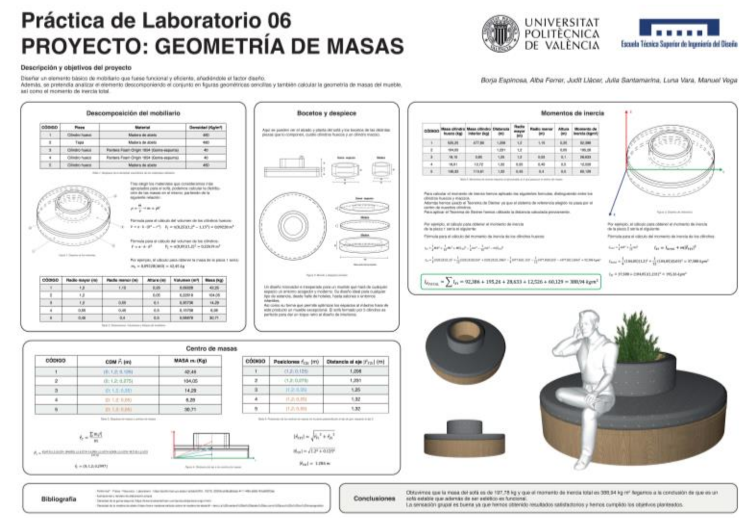

Fig. 6. Poster made by B.Espinosa, A.Ferrer, J.Llácer, J.Santamarina, L.Vara, M.Vega.

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INTERACTIVE COURSEWARE TO SUPPORT BLENDED LEARNING

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ABSTRACT

Covid-19 has been a game-changer in engineering education at the higher education level. Even beyond the pandemic, blended learning is there to stay. The design, execution, and delivery of blended learning can be supported by a plethora of fast-developing educational technology.
In this paper we share the experience of the evolution of one engineering course "Uncertainty in Artificial Intelligence" from a rather traditional design strongly relying on face-to-face interaction to a fully blended technology-supported course.

In particular, we share the experience of how an interactive courseware platform called "Nextbook", which allows students and teacher to directly interact on the course material, supported the design, implementation, and delivery. Student experiences measured using a questionnaire are supplemented with teacher experiences to present the following "lessons learnt": A well-chosen platform can help students find clear structure in a mix of types of material, and social annotation features make it possible to connect discussion and questions and answers directly to the course material. Further efforts are needed for engaging students to actively use the features of interactive courseware platforms.

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1 INTRODUCTION

Covid-19 has forced all teachers to rethink their education and most often forced them to move their education fully online. As we are now moving beyond the pandemic phase, it becomes clear that returning to the more traditional formats with a lot of face-to-face teaching is unlikely. Students have discovered the virtues of streaming, lecture videos, and other aspects of online learning. While reasons can be of pragmatic nature (less commuting, more sleeping, etc.) students also indicate pedagogic reasons (rewatching explanations of difficult content, more efficient handling of available time, etc.). The challenge for the future is how to create high quality blended teaching, that foster rather than destroy the social aspect of learning. Learning is a social event. Social constructivism, a sociological theory in educational sciences, clearly states that knowledge is constructed through interaction with others [1]. Discussing course material with others is shown to be related to better understanding and higher academic achievement [2]. Nevertheless, it is found to be challenging to ensure students participate in online discussions [2]. The creation of online learning communities could foster students' participation, by for instance allowing for social annotations [3].
In this paper we explore one example of how an interactive courseware platform with possibilities for social annotation can be used to shape blended learning, and how it supports social interactions in this process. This paper builds on the experience of the case studies of using social annotation platforms to connect discussion to course materials reported in [4].

2 PLATFORM, CONTEXT, AND IMPLEMENTATION

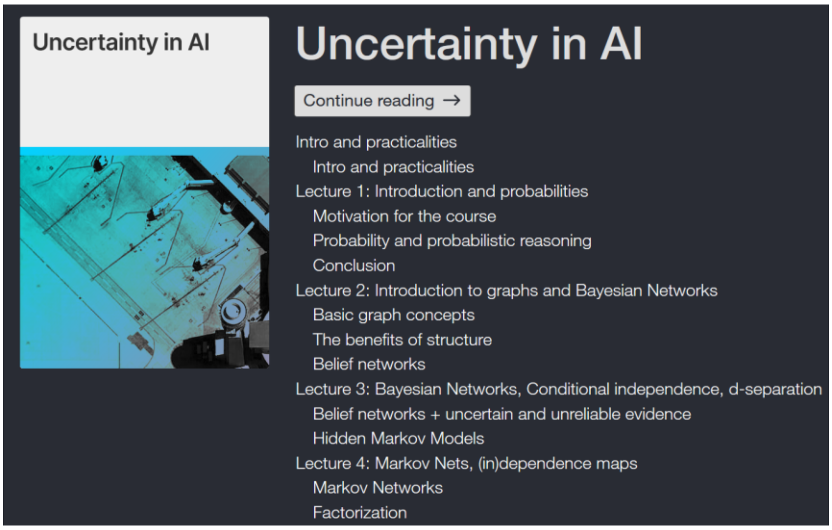

Fig. 1. Part of the outline of the online course material of Uncertainty in AI as available on the Nextbook platform

2.1 Nextbook

In the context of the Erasmus+ project Co-created Interactive Courseware (CiC), we explore the new interactive courseware platform Nextbook (www.Nextbook.be) and develop pedagogical use cases, teachers guides, and learning analytics to support the use of interactive courseware on Nextbook and in general. Nextbook (http://nextbook.be) is a free, online platform for "social reading" of textbooks, which envisions social construction (co-creation) in the future. Teachers can upload their textbook, augmented with video, 3D models, quizzes, etc. This augmented textbook immediately serves as a basis for social learning. Nextbook offers flexible reading on any platform as the book is transformed using web technology offering automatic scaling, free choice of font and text size, dark mode, etc. It also has functionality for reading out loud, a nice supplement on top of a dyslexia-friendly font for students with reading disabilities or challenges. Students can use highlights to mark important parts and even generate automatic summaries from these highlights. They can also add personal notes for later reference. From the social interaction point of view, they can select part of the text, image, formulate, … and start a discussion from this or ask a question. Questions or comments can be responded to in a chat-like manner and liked (up-voted).

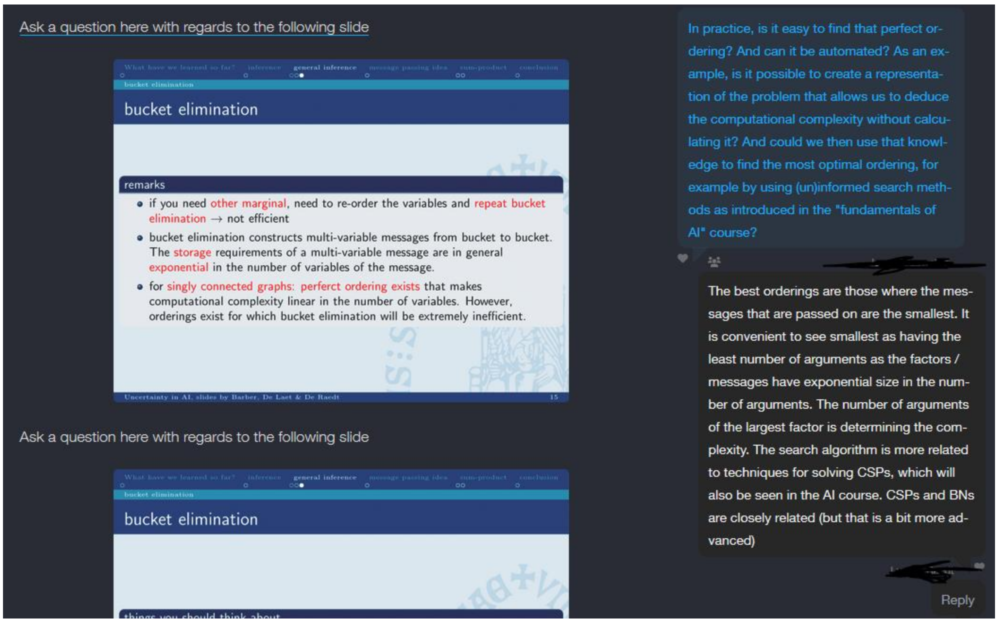

Fig. 2: Slides as used in the video, with the opportunity to discuss/ask questions.

2.2 Context

This paper focuses on the application of Nextbook in the context of blended learning in the 4 ECTS course Uncertainty in Artificial Intelligence, offered in the Advanced Master program of Artificial Intelligence at KU Leuven, Belgium. KU Leuven is a highly ranked research-intensive university both regarding research and education. The master of Artificial Intelligence is a multi-disciplinary one-year master that recruits many international students. Typically, the course of Uncertainty in Artificial Intelligence has around 250 students, and a high success rate of around 85%. Students entering the course have diverse background, with different levels of experience and skills in mathematics, probability calculus, and programming. Although some digitization was taken place before covid-19 (lecture recordings and video solutions of exercises), covid-19 forced the course to go fully online. To ensure a good online and flexible experiences, the two teachers of the course decided to replace the live lectures with a set of videos, where each video focuses on a particular topic. The lecture time slot itself was used for an online weekly Q&A session and elaboration of some additional examples.
After the initial fully online higher education, we have now moved to a new era of blended education. Teachers are expected to still offer online alternatives, but also provide on-campus activity of students. Rather than moving back to the traditional lectures with recordings, the teaching team decided to move to a fully blended format. The video material allowing the student to learn all the content of the course,

were kept but now supplemented with weekly on-campus Q&A sessions (that was livestreamed to accommodate for sick students or students not able to travel). During the weekly on-campus Q&A session, a quiz with exercises support interactive practicing of the course content, was done with the students.

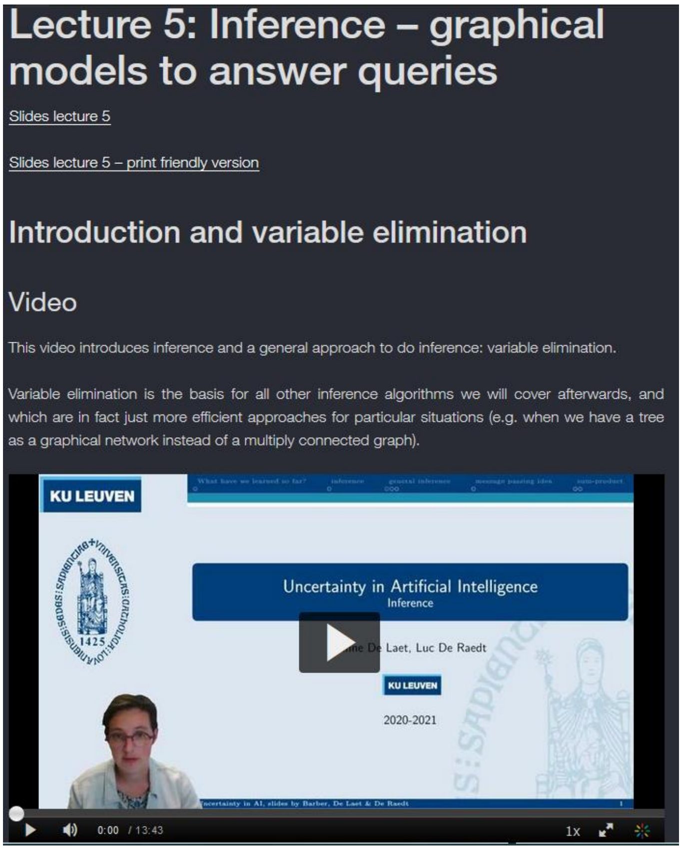

Fig. 3. A video as made available in Nextbook

2.3 Implementation

On the Nextbook platform an outline of the course was created allowing students to get a structured overview of the course content (Fig. 1). Each chapter represents one lecture that corresponds to the content a student must cover in one week. Within each lecture, sections were created for the different topics. For each topic, one video was created (Fig. 3). To allow students to discuss about or ask questions on the material covered, the slides used in the video were added below the video. A student could then add a remark or question next to the slide (Fig. 2).

Students were instructed to digest the material connected to a lecture before the Q&A session and to ask their questions at latest half a day beforehand, in order to allow the teachers to prepare the Q&A session. Answers to the questions were not only provided during the on-campus and livestreamed Q&A session but also in the Nextbook platform itself (Fig. 2).

3 METHODOLOGY FOR EVALUATION

Experiences were collected from the students in two ways: using the universities official Course/Teacher evaluation, and using an online dedicated survey, both were administered in the semester after students took the course.

The **official Course/Teacher evaluation** consisted of a fixed set of 12 questions that students rate on a scale from 1-6, of which 4 were related to the approach of delivering the course material in Nextbook: (Q1) There was sufficient consistency in

the course structure; (Q2) The study materials helped me process the subject matter; (Q3) I could ask someone of the teaching staff for additional explanation; (Q4) I was satisfied with the way the circumstances due to the corona crisis were dealt with in this course. Additionally, students could also leave open remarks in two categories (what did you like and what could be improved).
To get additional feedback on the use of the Nextbook platform in the course an **additional online survey** was sent out to all students in the course with questions targeting the use of Nextbook in the course and potential future use and improvements of Nextbook.

4 RESULTS OF SURVEYS

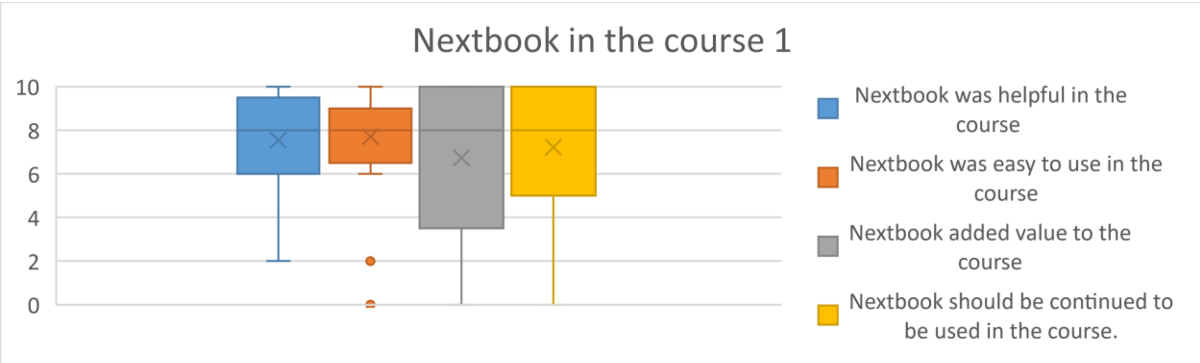

Fig. 4: Results of custom online student survey (N=33) – part 1.

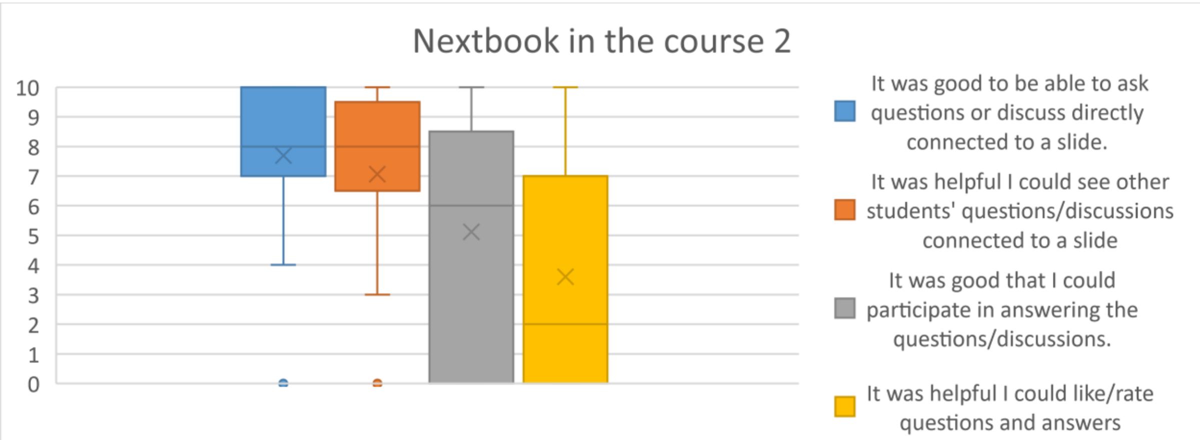

Fig. 5: Results of custom online student survey (N=33) – part 2.

4.1 Official Course/Teacher evaluation

43 students (26%) responded to the official course/teacher evaluation. The course was found to be highly consistent in structure (Q1: 5.28/6), and the material to be very supportive (Q2: 5.53/6). The opportunity for asking questions was rated very highly (Q3: 5.38/6), and it was indicated that the course dealt well with the corona circumstances (Q4: 5.47/5). Hereby the evaluation is in the top quartile of other courses evaluated with a similar student population at the university. In the open comments Nextbook was mentioned on some occasions, all in a positive manner “Nextbook was a very good online learning platform where we could directly ask question about a specific slide!”, “coherent online lecture material”, “Also, the recorded lectures as they were structured in Nextbook platform provided a great way

to find quickly any part of the study material.", and "Online book with direct questions".

4.2 Student survey

Fig. 4- Fig. 6 present the results of the custom online student survey (N=33). The open comments of the students are used in the discussion and recommendations below.

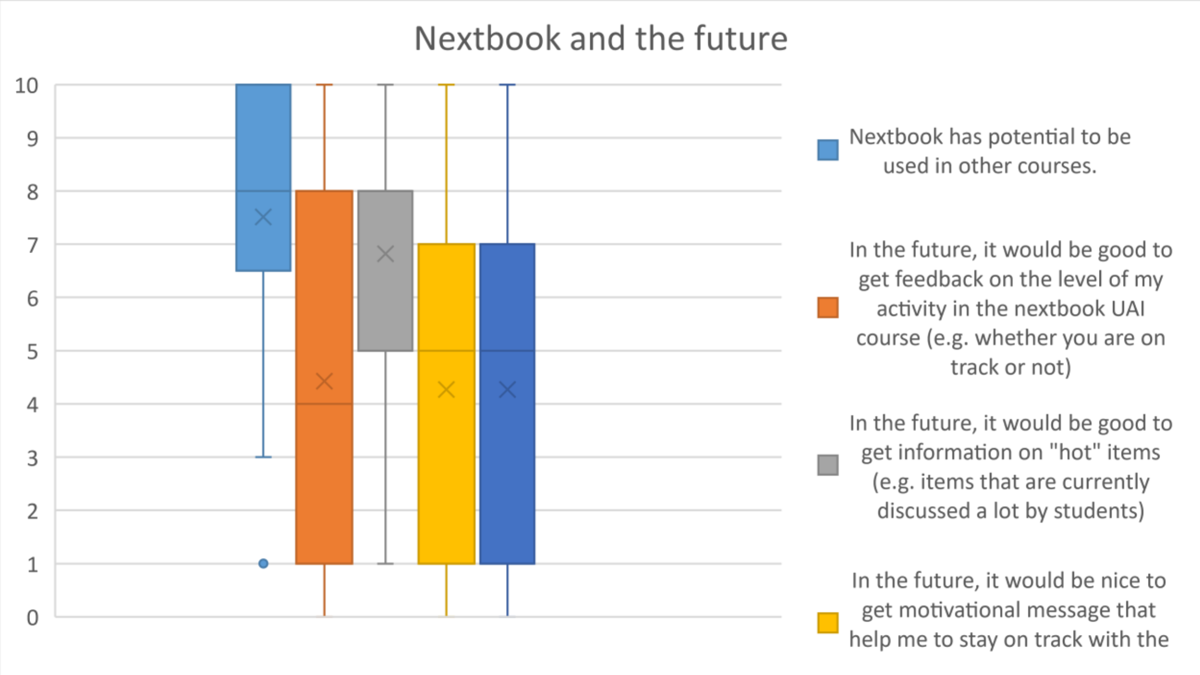

Fig. 6: Results of custom online student survey (N=33) – part 3.

5 DISCUSSION AND RECOMMENDATIONS

Overall, the way Nextbook was used in the course was appreciated by the students (Fig. 4) and was found te be easy to use (Fig. 4). As some students indicate doubts about the added value of Nextbook (Fig. 4), the discussion below digs deeper on some specific themes.

5.1 Structured integration of material

The points that was most appreciated about the use of Nextbook in the course is the **structure** that was provided. 13 out of 31 students explicitly mentioned the structured as positive aspect. Some examples: "It was very structured, which was handy for understanding and learning the material."; "Very structured."; Also, it's very structured, which can give me a better understanding of the whole structure and timeline of the course. "Everything is structured by topic which makes it much easier to digest and process. Also, easier to later find the relevant video in case of any questions".
Furthermore, **the integration of the different types of material** (video and slides) was acknowledged: "Having the whole course videos and slides blended together in the same place and quickly accessible"; "I wish more courses would use this type of combination of video lectures and slides on such a platform."; "[…] Also the mix of video and slides was particularly helpful."
Nextbook is not the only platform that could provide structure and integration of different types of material, and one could argue that the use of a platform as

Nextbook is “overkill” if it is only there for structure and integration. Therefore, the next sections dig deeper on the more social parts of the learning that Nextbook aims to strengthen.
Our recommendation Integration of different types of material in one overviewable structure is worth investing in, as students clearly value these aspects.

5.2 Connecting discussion to the course material

Students indicate that it is good to be able to ask questions or discuss directly connected to the course material (Fig. 5): “Ability to ask questions specific to parts of the course.”; “Students can post questions on a particular slide”; “Also nice to see questions of other students at the relevant slide instead of mixed together on a discussion forum.” One student indicates this is in fact the only added value of the platform “As a mechanism of asking questions, it worked, but that was about the only value of the platform for me.” The teachers however observed that only about 20 different students regularly used the discussion or questions/answer throughout the course. We hypothesize that most students look at the discussions and questions and answers without actively participating, as students indicate it is helpful to see other students’ questions/discussions connected to a slide (Fig. 6), and that they are less positive about the possibility to participate in answering questions and joining a discussion (Fig. 6) and liking or rating questions and answers (Fig. 6). The social aspect of the platform is therefore underused. A student states it nicely as follows: “I think this [asking questions connected to the course slide] exactly is one of the more powerful features. Reading the questions in the "flat list" of Toledo [the VLE of the university] makes it sometimes difficult to "link" the question with the text in the book. Having them both tied-up together would indeed be more interesting.”
The fact that students asked questions directly on the material was very helpful for the teachers in preparing their lectures and Q&A sessions. Rather than looking to a, often unstructured discussion board, the teachers could browse through the course material and immediately see which points were unclear to students. In fact, the teachers just projected the Nextbook slides with the connected questions during the live Q&A session in order to start an additional explanation.
Our recommendation Connecting the discussion to the course material is valuable and handy for the teacher, but additional efforts are required before it can be considered as real online social learning.

5.3 Future of Nextbook

Students agree that Nextbook should be used in the course (Fig. 4) as it provides added value (Fig. 4), and that it has potential to be used in other courses (Fig. 5). When asked about which Learning Analytics aspects would be helpful to be added (Fig. 6), students are more conservative. While they believe that seeing the “hot items” could be of value, they disagree that getting feedback on their activity level, or motivational messages Fig. 6). Like one student expresses, potential reasons are the level of experience and self-regulation of master students and the fear to induce additional stress: “Personally, I liked its simplicity. I think that adding the suggested extra information would just add stress when you happen to have a busy week. Closer following other people’s discussions might also add to that stress. In my experience most master’s students know how important it is to keep up with the material and can find discussions in case they have a question.” While individual

students do see value in such approaches to get additional feedback “Indeed give feedback on how you are performing at the moment and what to do better”.
Our recommendation Learning Analytics should be used with care and should primarily focus on showing students what are students are working on.

5.4 Other aspects

Different students express the concern that the course material on Nextbook is only available online, which causes more screen time, and makes them fear that the material will not be available anymore after they graduate.
The more interactive nature also triggers with some the fear to have to spend more time on the course “What I suppose, is that doing it in a classical style would require less time, while the notebook style is quite more dynamic but needs more time to spend to enjoy it fully.”, while other even ask for more interactive features “Maybe in the middle of some chapters some practical questions could be asked. I’m either multiple choice questions form or blank filling form.”
While Nextbook was in general found easy to be used (Fig. 4), some students still experience difficulties “I had difficulties with adding a question to the slides. I followed the instructions but for some reason it did not work.”. “About 40% of the chapters didn't function properly for me. For instance, I couldn't put the video to full screen or change the volume of sound through the browser.”. Or “I did not really use the ask questions function. It was my fault, but I forgot my password each time, which is required to enter comments or questions”. This is surprising as technical assistance was available throughout the entire course and every single technical issue that was reported was solved within a very short time frame.
Our recommendation Provide ample opportunity for students to ask for technical assistance, and to look for ways students could also use the course material offline and download after the course for future reference after they finished the course.

6 CONCLUSION

Interactive courseware has a potential to support blended learning. A well-chosen platform can help students find clear structure in a mix of types of material (e.g., videos, text, and slides). Furthermore, social annotation features of such platforms make it possible to connect discussion and questions and answers directly to the course material. While this feature is valued a lot by teachers and students, only a minority of the students actively uses it, and therefore we cannot say that there is already a real online learning community supporting online learning. To realize the full potential of social learning, additional efforts are required to trigger discussions and exchanges among students.

7 ACKNOWLEDGMENTS

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PROJECT BASED LEARNING FOR MATHEMATICS IN GENERAL ENGINEERING CURRICULUM

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ABSTRACT

The National Engineering School of Tarbes (ENIT) is a French engineering school with a curriculum from undergraduate to graduate studies for general engineers. Curriculum ends by an equivalent Master degree in sciences. ENIT students are

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particularly involved into mechanical, civil, industrial engineering, material science and design of integrated systems.

From the first year of study, students tackle theoretical tools for engineers. Moreover, in a curriculum composed of several different disciplines, connections between scientific subjects may be difficult to weave. As a consequence, student activities for solving engineering problems were developed. The basic concept is to clearly illustrate how theoretical tools can be used in an activity linked to engineering and more generally to student life.

In addition, future engineers must be acquainted and trained to ethic values, especially those used in team work. During team working, honesty and benevolence are important core values to be encouraged as a basis of trust that has been identified as one of the cornerstones for performing teams. Consequently, the principle of team working for students was adopted and humanities are associated into the project to manage ethical and professional standards.

Thus, the chosen teaching activity is a project-based learning team work that addresses on the one hand application of integration and derivation to expression of needs of consumable supplies and notions around professional ethics on the other hands.

1 INTRODUCTION

1.1 General context

The National Engineering School of Tarbes (ENIT) is a French engineering school with a curriculum of 10 semesters training general engineers. Curriculum ends by an equivalent Master degree in sciences.

The ENIT's mission is to develop a publicly responsible, creative, competitive individual who is receptive to science, latest technologies and cultural values; to promote scientific progress, social and economic well-being. The school is attractive and is able to respond to the environmental challenges and has a great social importance to the national progress.

In this context, ENIT is asked about its competencies, specifically its ability to anticipate developments and drive its actions towards progress. Aware of the stakes, the logic of the development of ENIT has consisted not only of preparing its future engineers in line with the needs of companies, but also of taking into account permanently and supporting the reality of its economic environment. Therefore, ENIT has the ability to put in place new training corresponding to new professions and to social evolutions.

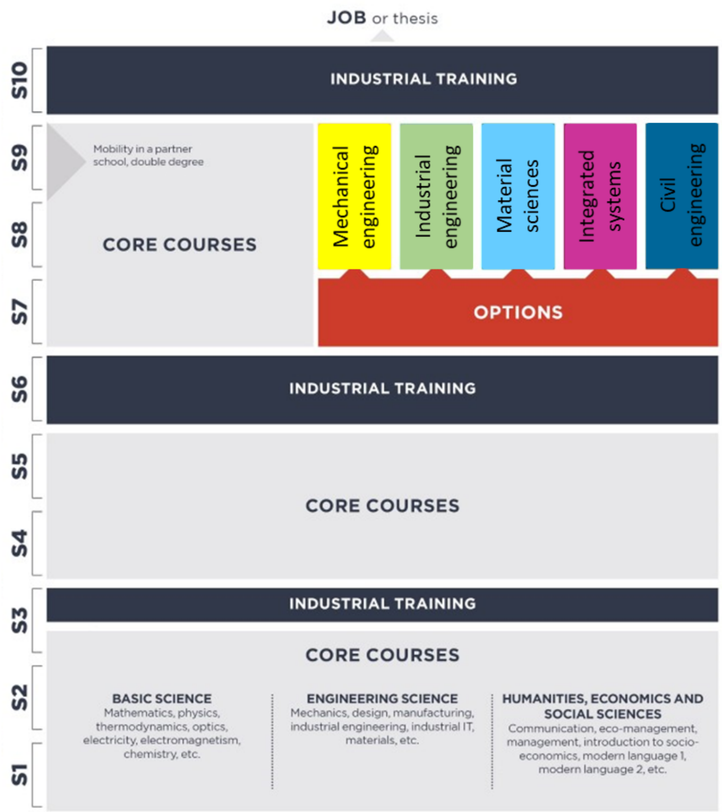

Fig. 1. ENIT's curriculum

ENIT mainly recruits students after high school of A-level. During the bachelor curriculum, the students follow scientific classes such as mathematics and physics but also classes of humanities, economics and social sciences. The part of engineering classes regarding classes of basic sciences increases each semester. During the master curriculum, the students follow core courses of engineering and also an option oriented to mechanical engineering, industrial engineering, civil engineering, material science or design of integrated systems. Moreover, as depicted in figure 1 where *Sx* means *Semester x*, industrial training lasts 2 semester and a half where autonomy of students is developed facing real industrial engineering projects.

1.2 Science and ethics as fundamentals for engineers

The engineers from ENIT can have technical and scientific jobs as well as management activities. The common point between all these jobs is the ability to model the world. Obviously, the model can be a mathematical one based on equations or logical links. But the model can also be an expression of links between people or communities using for example the ARDI (Actors, Resources, Dynamics and Interactions) co-construction method [1]. Based on this duality of models, the students are trained to mathematical modelling as well as humanities and social sciences from the beginning of their curriculum.

On the one hand, it is obvious that mathematics is a fundamental for modelling but is also a basic tool for physics as a common language to describe, solve and predict numerous phenomena. Moreover, in order to clearly apprehend the whole spectrum of applications, many bases are mandatory. That's why mathematics is deeply taught at the beginning of the curriculum.

On the other hand, humanities are also a fundamental of engineering. Indeed, engineers are working in teams, they must communicate and argue all day long. Consequently, the students must be trained to team work, to imagine their roles in team [2] but also to take advantage of collective intelligence.

The paper describes how these fundamentals are introduced to the ENIT's students. Section 2 deals with the activities proposed to incoming students in order to better understand the world and the job of engineers in its complexity. From these first steps, a project-based learning sequence is designed and described in section 3. Finally, conclusion and development opportunities that can be proposed are given in section 4.

2 ACTIVITIES FOR INCOMING STUDENTS IN UNDERGRADUATE STUDIES

2.1 Workshop: Engineering world in its complexity

The first activity proposed to incoming students lasts about 6 hours. It deals with an overview of the environment of engineers and its complexity. Two texts present a realistic situation that can occur in civil engineering companies. The first text exposes the case through the point of view of a client that has to deal with suppliers but also with the *make or buy* dilemma. The client expresses its supplying difficulties and the consequences to respect the delays facing unpredictable events such as the sanitary crisis or international war in countries providing raw materials. The second text outlines the same situation from the point of view of a team member of the supplier. Ethics is introduced with the moral dilemma between the duty regarding the client and the occupational health of co-workers as well as family considerations.

Even if the students are totally unaware of civil engineering, they are asked to work together to firstly model the case from the client's point of view and then to modify the model using the supplier's point of view. Here, the ARDI method is introduced through its application on the proposed example.

Moreover, at the beginning of the curriculum, incoming students don't know well each other. As a consequence, it becomes necessary to assume their own personality. The students naturally refer themselves as introvert or extroverted natures. In groups of 5 to 6 students, it is suggested to students to develop their active listening. Then, each student of the group can express its ideas directly or with the help of its colleagues.

At this stage, the advantages of collective intelligence are clearly underlined in order to introduce a new way of working together based on cooperation instead of competition. A reflective practice is initiated in this workshop with the aim of using and developing it all along the curriculum. The activity shows some students that are focussed on facts or key figures and some students more focussed on moral sensitivity and empathy [3].

Finally, the attention of students is oriented on the analysis of implicit and explicit parts of the texts that implies understanding and interpretation [4] leading to discussion and argue in the group.

2.2 Climate fresk

This activity is also proposed to incoming students and lasts about 4 hours. It is fully complementary with the one described in section 2.1. This workshop [5] is composed of different times where previous notions on team work are applied: ice breaker, puzzle time and collage, creative time, pitch, debate, talking about solutions.

The main goal is here to convince the students of taking into consideration emotions in their behaviour. Indeed, the managers and engineers often tossed out emotions from making decisions. However, the emotions should not be hidden in terms of quality of working lifetime. As a consequence, it seems necessary to better grasp the emotions especially linked to anxiety. The Plutchik's wheel of emotions [6] in figure 2 is here introduced.

Moreover, a particular focused is done to the time evolution of emotions regarding DABDA model [7]: Denial, Anger, Bargaining, Depression and Acceptance. It is required to move as fast as possible from denial or anger to acceptance. A 2D graph showing efficiency of action for climate regarding their personal or societal cost is established by students to demonstrate that a great change that seems difficult can be composed of individual changes that seem easier to realise.

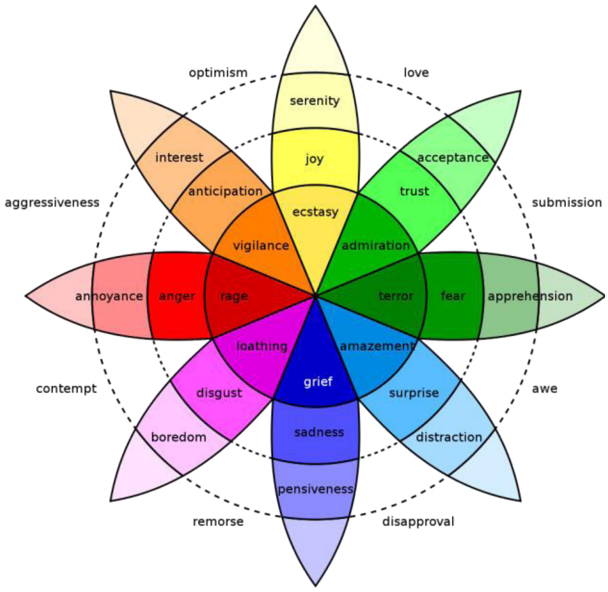

Fig. 2. Plutchik's wheel of emotions

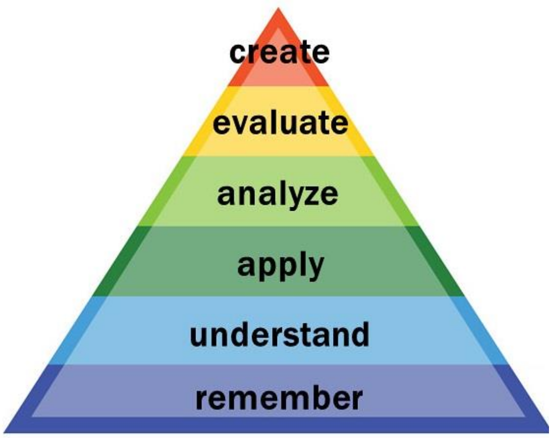

Fig. 3. Revised Bloom's taxonomy

2.3 Deconstruction of gender stereotype

Once the two previous workshops where working in teams is achieved, the behaviour of students is observed from the perspective of gender stereotypes [8]. First of all, the explicit gender stereotypes are underlined in courses where psychological aspects are addressed. The aim is to improve social and professional skills of students.

Moreover, through a reflective practice, implicit stereotypes are also decrypted. In order to uncouple behaviours from students, these ones are invited to participate to a forum theatre session where implied bad behaviours are caricatured in the external appearance of actors. It is proposed to the students to interact with the actors in order to try and check other behaviours.

These two activities last about 4 hours.

2.4 Project-based learning in mathematics

The last activity proposed to incoming students deals with the application of previous notions into a scientific context [9]. It lasts about 6 hours and can be split in two shorter activities. The students work in groups of 5 to 6 individuals.

In this activity, the main scientific goal is not to learn new knowledges but to improve some skills previously trained during high school courses. As incoming students come from different high school curriculums, it becomes necessary to define an activity about basic sciences. Regarding French curriculum, mathematics is a clear choice.

Moreover, regarding the previous activities, it is obvious that a project-based learning activity must be proposed to the students. Indeed, it allows them to apply previous skills such as active listening, cooperation, reflective practices, debating, talking about solutions and all of that with considering the analysis of any stereotypes and emotions during argue.

2.5 Individualized methodological support

All along the first year of study, the academic evolution of the students is closely followed by a team of teachers. This is achieved through the Individualized Methodological Support (IMS) program where the reflective practice is emphasised and guided depending on the students. A special focused is generally done on the working method of students and especially team work performed during revision process before exams.

A combination of previous activities and IMS program leads to a clear decrease of the number of students submitted to academic failure during the first year of studies.

3 DESIGN OF A PROJECT-BASED LEARNING SEQUENCE IN MATHEMATICS

3.1 Competency-based approach

Mathematics as basic science for engineers is often considered as a complex science by the students. They are mainly studied in the ENIT during bachelor curriculum during the two first years. Regarding the revised Bloom’s taxonomy (see figure 3) [10], the students mainly *remember*, *understand* and *apply* their knowledges and skills during courses of mathematics.

However, during the master curriculum, the mathematics are applied in engineering as a tool that must be mastered by the students. It is then asked to the students to develop abilities in mathematics together with acquiring new knowledges and skills in engineering. This induces a clear frustration for the students.

As a consequence, it has been proposed to rethink the teaching of mathematics in the bachelor curriculum by defining new intended learning outcomes. Considering the activities for the incoming students, they become able to reach *analyse* and *evaluate* steps of the Bloom’s taxonomy since the beginning of their curriculum in the application of mathematics. Obviously, this concept is firstly applied on knowledges and skills acquired during high school. In addition, work in teams is encouraged.

3.2 Scientific prerequisites

Considering the teaching of mathematics in high school, a problem-based learning sequence has to be defined where common knowledges and skills that can be turned to abilities during the proposed activity. Following a review of the curriculum in high school, knowledges and skills about mathematical analysis have been defined as the basis of the project especially derivative and integral calculus.

Moreover, during the high school, mathematical analysis is mainly developed through two main lines: *seek* and *model*. On the one hand, *seek* lies in analysing a situation, organising information and validating an approach. On the other hand, *model* is about converting a problem into mathematical language and validating a model.

From this overview, a pedagogical activity leading to work in team on a real problem has been built. It allows to analyse a situation - regarding the revised Bloom's taxonomy - i.e. to draw connections among ideas from different people, to listen, understand, examine and question their own perceptions and ideas comparing to each other's ones. It also allows to evaluate their work i.e. to argue and defend their point of view in a group and to present common conclusions. A feedback ends the activity with a constructive criticism phase between the different groups.

3.3 Ethics in project management

The proposed project-based learning sequence is also an opportunity to introduce the first steps of project management. As described in section 2.1, the students generally spilt in two categories: introvert and extroverted natures. At his stage, some roles in team work may be introduced. The nine Belbin team roles can be considered: three social roles (Resource investigator, Teamworker, Co-ordinator), three thinking roles (Plant, Monitor evaluator, Specialist) and three action roles (Shaper, Implementer, Complete finisher). However, the project is not sufficiently long to clearly define the nine previous roles in groups of 5 to 6 student through a given test. As a consequence, this part of the project is achieved in a reflective practice way. Indeed, the students are invited to note their own feeling about their role in the group and to think about it before ethics classes where the roles will be theoretically identified and where skills about their definition in a given group will be taught.

As a reflective practice, the main point lies in considering and analysing the advantage of cooperation and collective intelligence all along the project from the understanding of the problem, its modelling, its solving to the presentation and defence of a solution.

Some classical project management aspects are also introduced especially through the management of time. Therefore, it has been decided to propose two different projects of three hours each where time is firstly managed by teachers. They use a workflow where each phase is defined with a clear duration: presentation of the project (10 minutes), creation of groups (10 minutes), finding a solution (2 hours), writing a report (20 minutes), feedback (10 minutes).

In the phase of finding a solution, the students are invited to define their own workflow by evaluating the duration of main activities and tasks (analysing, modelling, arguing) and by monitoring their own planning and workload all along the project. Generally, the students begin the analysis of the problem using collective intelligence. Then, the finding of a solution starts with an autonomous thought. After several minutes, a confrontation of ideas is naturally initiate in the group. Finally, the writing of a report is done by a sum of individuals where the Belbin team roles begin to emerge.

3.4 Scientific details of the sequence

The subject of the project is defined as following: “A team of the ENIT's student office wants to paint the external surface of an old half-pipe. They request a subvention from the ENIT who grants them an amount of 300 euros. Their painting has an efficiency of 12m^2/L and a litre costs 21.17 euros (VAT included) for 0.5L or 77.17 euros (VAT included) for 2.5L." The question to answered is then: "Will they have enough money?".

The 3D model of the half pipe and a cross section are given in figures 4 and 5.

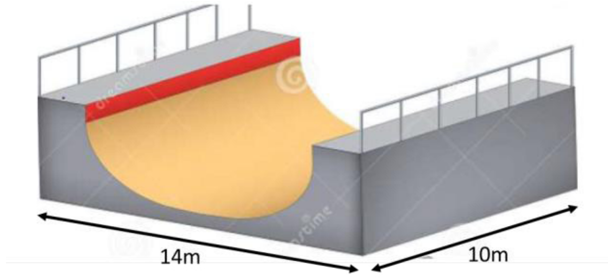

Fig. 4. 3D model

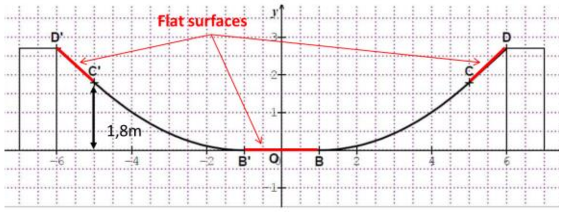

Fig. 5. Cross section

It has to be said that the half-pipe is symmetrical about y-axis. Moreover, the surface presents smooth connections at points C', B', B and C. Furthermore, surfaces from B' to C' and from B to C are defined by a parabola.

Using equations of parabola, linear equations and their derivatives, the students obtain a system of equations that must be solved to find the different parameters of the equations. Then a piecewise function can be defined to model the surface of the half-pipe. Finally, an integration must be performed to find the surface to be painted.

3.5 Evaluation of competencies

As it is the first project-based learning pedagogical activity proposed to incoming students, the evaluation of competencies does not lead to a grade.

First of all, a guided self-evaluation is performed by the students. There are asked to give a mark on a grading scale to 0 to 5 (0 means that competencies are totally unknown and 5 means that competencies are mastered) to several competencies in the fields of mathematics and humanities. Here are few examples of skills and abilities leading the definition of competencies: model a problem, calculate an area, calculate the derivative of a polynomial function, express an opinion in a group, exercise active listening, define my role in the group. This self-evaluation is compared before and after the project.

A collective evaluation of the competencies is then done by each group using a radar chart with six spokes: quality of the produced work, quality of the relationship with the teacher, quality of the analysis of the situation, involvement of each team member, organisation of the team and quality of the atmosphere in the group.

4 CONCLUSION AND DEVELOPMENT

4.1 Conclusion

In this paper, a set of activities proposed to incoming students in ENIT has been detailed. Working in teams and being a part of society have been used as a common link between activities. Moreover, collective intelligence and communication without tossing out emotions and empathy have been presented as ways of working efficiently in teams.

A focus has been made on a project-based learning sequence in mathematics involving humanities in the teaching. The project deals with presumed already acquired knowledges of the students during high school or previous activities. Mathematics is here considered as a heart activity in the wild field of engineering covered by the ENIT's students.

4.2 Evaluation and improvement

Some key performance indicators (KPI) can be defined for these activities. Obviously, KPI resulting from the evolution of the self-evaluation of competencies by the students must be studied. An increase in the acquisition or mastery of skills or abilities is a positive result.

Moreover, a global evaluation of teaching by students is performed at the end of each semester using an open dialogue with the head teacher but also with an anonymous survey with questions such as: “Do you feel that you are making progress in learning about your future profession as an engineer?” or “Do you have sufficient material conditions to work at school during courses?”.

Depending on the evolution of KPIs, activities can be rethought, better organised, developed…

4.3 Development

It is planned to develop project-based learning all along the curriculum. Once the bases about humanities, project management and team work are acquired, it becomes possible to have more and more project-based learning sequences from understanding to evaluation levels in the revised Bloom's taxonomy. Moreover, year after year, the students become more and more autonomous and learning can be realised with a lower rate of coaching. Coaching is then reserved for launching the project and periodically monitor the progression of the students.

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Transformation of a traditional face-to-face engineering study program into a digital online program - A case study of Global Production Engineering

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ABSTRACT

The need for Digital Education (DE) in higher education has been growing for the past years, as the landscape of education became more diverse and global. It has become apparent with the COVID-19 pandemic that, in terms of width, DE had been mostly neglected so far. In the past year, the master program Global Production Engineering (GPE) at Technische Universität Berlin has been enhanced by a complete digital track, called GPE-Digital. In order to design this online study program a student survey was conducted and lecturers have been interviewed. The results were analysed and requirements for both lecturers and students were identified. Chances and challenges have been identified and a "tool box" for teaching and learning was developed. It contains a multimedia studio, a learning platform, a cloud platform et cetera. Lecturers are supported to develop and adapt their lecture-concepts and to choose the tools needed, which led to a variance of teaching-concepts. In this paper, after presenting the findings of both the interviews and the survey, the "tool box" is presented and its various possibilities for implementation are shown by the example of four different courses offered at GPE-Digital. These examples contain both synchronous and asynchronous teaching and different approaches of preparing joint sessions and lectures. Finally, based on the courses the benefits and challenges are discussed and rough approaches for exploiting the benefits and tackling the challenges are given.

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1 TEACHING GOES DIGITAL

For more than 20 years distance learning or distance education is well-known [1] and until the beginning of 2020 it had rather a niche existence. However, during the pandemic distance learning experienced a boom like never before [2]. From one day to another many universities had to cope with the challenge of distance learning which was until then – even though the concepts were generally well-known – still rather a subject of research (having some implementations in e.g. evening study programs) than broadly implemented. Within a couple of weeks tools like Zoom, Microsoft Teams and WebEx were in daily use. To put this into numbers: While on December 31st, 2019, 10 million participants joined a Zoom meeting, on March 31st it was 200 million and on April 21 even 300 million people [3]. Suddenly, servers for educational clouds were working on their limits and were needed everywhere [4].

After two years of higher education in a pandemic experiences have been gained by various lecturers, e.g. [5] and [6]. Benefits which have already been identified before the pandemic could be widely confirmed [7]. A key benefit which is enabled by distance learning is an increased flexibility for students and lecturers, when it comes to their location but also in terms of when learning takes place. For synchronous classes only the time zones became an issue. Nevertheless, in terms of class-time distance learning offers further flexibility by offering recorded lectures and exercises.

Considering these and further benefits of distance learning which were experienced during the beginning of the pandemic the decision at the Technische Universität Berlin was made to enhance an existing face-to-face study program by a fully virtual branch. Global Production Engineering (GPE) is a full-time four-semester master program [8]. The curriculum is designed for international graduate students offering modules in the fields of production, management, engineering, new energy technologies and inter-cultural communication. Within this paper, the experiences of implementing a completely digital study program shall be presented and discussed.

2 SURVEY WITH STUDENTS AND INTERVIEWS WITH LECTURERS

As a basis for designing the digital study program a survey with the students of the face-to-face study program whose class took place virtually due to the pandemic was conducted in order to learn about their challenges in virtual classes, but also to learn from their suggestions for the design of digital classes. Furthermore, interviews with lecturers were made in order to figure out their main challenges digitalizing their classes and by that to get an idea of how a completely digital study program should look like in order to enable a smooth learning and teaching environment.

For the student survey 41 students were contacted. The goal of the student survey was to receive a feedback of the first steps of digital teaching and learning but also to have a basis for designing a fully digital study program. The main comments include the students’ expectations on the presentation of teaching material, which they expect to go beyond simple voice-over Power-Point presentations, the fact that students find seeing facial expressions and gestures profitable to learning and thus prefer live interactions with lectures and fellow students in presence, as they are hardly replaceable. However, they find the degree of freedom of asynchronous teaching in terms of learning times to be advantageous, perceive online tools such as quizzes, exams, external videos, Moodle platforms or course forums as an enriching offer that they would like to retain for face-to-face teaching.

A total of eight interviews with lecturers, who are planned to be included in the digital program, were conducted. Each interview took between 60 to 90 minutes. The main subjects during the interviews were the challenges during the digitalization of classes, the software and hardware which was used and its evaluation, experiences with the current learning platform, changes to the teaching concept and the learning goals due to the digitalization, changes in the communication with the students and its evaluation, acceptance of the digital classes based on the feedback that the lecturers received in their classes, overall positive and negative experiences during the digital classes and the transformation process from an lecturers' and students' perspective, changes in the teaching concept if the digitalization would be permanent, support which could be provided by the study program staff to support the lecturers, and hard- and software which could be used within a (teaching) studio.

According to the lecturers, the main challenge during the early phase was the lack of time to actually plan the transition, but to not directly transfer all face-to-face teaching material one-to-one to a virtual environment. Non-professional equipment often led to pragmatic solutions, but not necessarily to satisfying ones. Lectures were either pre-recorded and uploaded on an educational platform or were given online. This led to a massive decrease in interaction, but was realizable in the short period of time. However, exercises in laboratories had either to be postponed, cancelled and another task had to be given or exercises had to be completely changed so that physical attendance was not required. Software-wise mainly PowerPoint, Zoom, Kahoot and Mural were used next to the Moodle platform. The equipment used was rather "classical" hardware: laptop, camera, headset etc. The previously reserved usage of the Moodle-based learning platform changed rapidly. While many lecturers never had used the platform before, it immediately became a backbone of each class. The teaching concept of the lecturers did not really change - mostly because there was not a lot of time for any changes. Also, the learning goals of each class did only change if the exercise was affected. One major drawback which could be experienced by all lecturers was the decrease in communication with the students. At the time of the interviews no exams had been taken so far. Therefore, no statement could be given on how the digital teaching influenced the exam results. Generally, the students did not complain about the digital classes. Due to the pandemic it was accepted. However, the lecturers were told that the students are missing the interaction in class. Generally, the lecturers saw the benefits in terms of flexibility for themselves but also for the students. For a permanent change to digital teaching, the lecturers saw a need for a stronger involvement of the students during class. Further they identified a need for a better hard- and software. The results of this interview led to the design of the studio, which will be presented in the following.

3 IMPLEMENTATION

3.1 Requirements for the digital program

On the basis of the surveys conducted, the educational, didactic and technical needs were worked out and measures were derived to increase the facilitation of learning. After having discovered the drawbacks and problems with the digital education during the pandemic, particular focus was set on three categories: digital technologies, community building and educational concepts.

The technological requirements are to use adequate, modern technologies with high-end quality media, as students are used to a high standard of image- and sound quality. To build a sense of community, both for lecturers and students, a platform for regular and informal exchange is required, while the educational and didactic aspect has to be, while still regular, more formally presented. These requirements are met by developing a didactic and educational toolbox. To ensure a consistent high quality education, guidelines have been established. The toolbox and the quality guidelines are presented in the following section.

3.2 Conception of toolbox and the learning environment

Toolbox: Digitally driven learning and teaching is particularly dependent on the provision of technical equipment. This not only has to meet the requirements of didactics, support the transfer of face-to-face-based teaching concepts to digital representation and be user-friendly and intuitive for the users. The technologies also open up new possibilities for teaching, group work or interaction by new tools that were not available in face-to-face teaching and whose reasonable integration into the teaching concept must be checked individually for each lecture or module.

In order to support the lecturers in the digital implementation, a so-called toolbox was developed, which contains a wide range of technical aids and tools. Especially in the initial phase, each lecturer is advised and supported on the conceptual integration, trained on the application and supported in overcoming technical challenges by a team of 5 experts in digital teaching and film production.

The centre is the Green-Screen Studio (fig. 1 & 2), which enables the removal of the green background both in real time and in post-processing and replacing it with any background such as lecture slides, images, videos or websites (fig. 3 & 4). In this way, depending on the respective thematic focus of the lecture and educational goal, a suitable learning environment can be created in which the lecturer is placed and that gives students the feeling of still being in a classroom. Even the implementation of a virtual 3D environment has also been successfully tested, in which the lecturer walks through a factory, for example, while the background changes according to the perspective. This makes it possible to zoom into machines, view components in detail, hide parts or make them transparent, while the lecturer is in front.

To achieve a high degree of video quality, professional film lights (amaran 100d & swit) are used since insufficient lighting of both foreground and background can create disturbing digital artefacts. Two high-resolution 6K cameras (Black Magic) are used to record the teaching sessions, while 4K cameras (Brio Logitech) are used for live events. Especially when using green screen technology, cameras with low resolution should be avoided, as they can also produce unwanted artefacts. By means of a streaming software, in this case the Open Source software Open Broadcaster Software (OBS), any image composition can be generated on the computer and inserted as an emulated webcam on all conference tools (Zoom, WebEx, Microsoft Teams, etc.). Sound is provided via a clip-on microphone (RodeLink) whose signal is transmitted to the camera via radio.

To enable the lecturer to share notes in the same way as on a white board or chalkboard, the room has a 55-inch touch screen on which handwriting can be done with a special pen. Written texts can be shared handwritten or converted digitally into machine text. Another 55-inch monitor has been integrated to display the students' video images and a smaller monitor to display the lecture slides for the lecturer. In addition, the lecturers also have a touch screen stand PC and a Wacom board at their disposal, on which manual markings can be created in the slides directly.

An additional input device, an Elgato Stream Deck, was installed to make the operation of the extensive technology more intuitive for the lecturer. On this keyboard, the buttons can be assigned individually with shortcuts and personalized icons. As a result, when changing an application during a live event on the computer, the user does not have to create a complex sequence of clicks on the computer, but can start or stop an application at the push of a button.

The lecturers and students are provided with server-based applications for exchange, provision and communication, such as Zoom, WebEx, Next-Cloud, OnlyOffice and a Moodle learning platform, which are all operated entirely on the university's own servers for reasons of data security and sovereignty. Zoom and WebEx are used as communication software. Every lecturer and student get their own unlimited access and can generate meetings independently. Zoom in particular, with its large range of functions, compatibility, stability and user-friendliness, established itself as the main platform for communication during the COVID-19 pandemic. Functions such as breakout rooms support group work or can enable consultation with the lecturer in digital exams without disturbing other users in their work, also, the platform enables real-time translation of spoken content. At the same time, hiding the own video background or creating a virtual background allows students the greatest possible degree of privacy.

An adaptation of the open Moodle learning environment developed within the university is used as the central learning platform. This learning environment was developed with collaborative learning and teaching methods in mind and allows for the customization of classrooms that can be broken down into weekly or thematic segments. The platform provides a rich portfolio of functions, such as the provision of texts, videos, forums, calendars, glossaries, wikis, surveys, brainstorming tools, learning quizzes or tasks. Learning packages can be created and linked to individual learning progress. Other functions support peer teaching and learning and allow mutual assessment. The individual learning success of each student can be tracked by the lecturer over the semester and additional support can be provided if required. The platform has proven to be particularly useful for digital exams, as new forms of interactive questioning are possible and tasks can be automatically evaluated according to previous definition or digital exam reviews can be carried out. It must be mentioned that for the creation of content and the use of the range of functions, a basic experience in handling software tools is helpful, if not necessary. Practice has shown that inexperienced users, especially in the initial phase, needed special support from the team. In addition to the Moodle platform, external game-based learning platforms such as Kahoot are used, with which students can carry out location-independent learning quizzes in real time. Similar to a television show, the lecturer moderates the quiz, the students enter their answers via their smartphones, the correct solution is then provided and the individual results are evaluated.

The use of a lot of open source software as well as software provided by the university keep the costs for the technical equipment at a well justifiable level of roughly 12.000 Euro. The biggest cost drivers are the cameras (circa 2500€) and the touch monitor (circa 2000€). Another driver for costs is the large amount of data that needs to be stored and processed. For that, several hard drives (HDD for storage, SSD for production) as well as a computer (Mac Mini M1) for production have been acquired at around 1800€. Some of the equipment, like the touch computer were already available from former projects is be valued just under 2000€.

Fig. 1 & 2. Multi Media Studio and typical recording scenario

Community Building: To nurture a positively experienced learning environment, special attention was paid to the aspect of Digital Community Building. In a first step the students have been given an Introduction Event to the whole program. Furthermore, there are regular meetings for the students to give feedback to the program management and administration. Although high level, the meetings are informal. Besides administrative discussions and organizational difficulties, topics of these meetings are also personal or cultural exchange. Additional Community Building is encouraged through partly synchronous teaching with and without the presence of lecturers, e.g. in form of group assignments. Between the third semester and the students' internship, as well as their Master's Thesis, students are welcomed in Berlin to the optional Spring School. Students can meet in person and also get in touch with both staff and students from similar GPE-programs. Future Community Building measures are digital factory tours and fair visits as well as digital or hybrid attendance at conferences.

Quality Guidelines: To ensure consistent quality at high level, quality guidelines have been established. These are mostly mandatory. Lecturers are given templates for their teaching material. Videos are produced by professionals of the team and are conceptualized to shape the learning environment. The background is designed in the way, so there are not too many distractions, texts are readable easily, the room lecturers are presented in is large enough and many more details are considered. Additionally, lecturers are required to use the learning platforms, calendars and communication channels that are provided to ensure a standardized and consistent learning environment.

3.3 Exemplary Lecture Program

In engineering education, subjects are often divided into a lecture and an exercise or a project. The lecture conveys the theoretical knowledge, which is to be applied in the exercises and projects. [9] Most of the modules used as examples here are split into lecture and exercise. They are courses that are currently offered at GPE-D or planned to be offered in the following semesters.

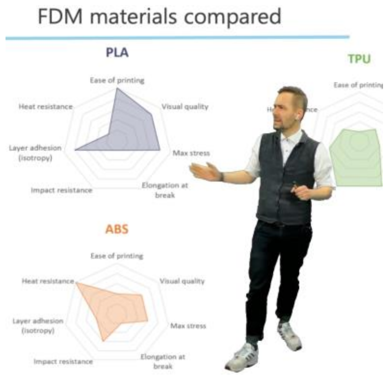

Fig. 3. Live Lecture on Additive Manufacturing

Fig. 4. Pre-recorded Lecture on Digitalization and Industry 4.0

Additive Manufacturing (AM): The module AM is split into lecture and exercise and is very application-oriented. The lecturer has decided, that it is better for his lecture to be able to communicate with the students during the sessions. For this, the green room is used in combination with OBS Studio to place the lecturer into the lecture's slides (fig. 3). This way it is possible to actively show and emphasize arguments and principles of AM. This is transmitted via Zoom, so the students get the impression, that the lecturer is actually standing in front of them. They can ask questions at all times, which enhances this immersion. The lecturer has multiple monitors to observe both his slides and the students in Zoom. The exercise for AM is planned in the Summer School, to teach the students printing strategies, troubleshooting, etc. For students who are not able to join the Summer School, printing via internet is provided. Students have to prepare their print-jobs and can observe via broadcast.

Digitalization and Industry 4.0 (DI4.0) and ***Manufacturing and Factory Planning (MFP):*** The teaching concept of the modules is also split into lecture and exercise. For the lecture professional videos are produced to according to the quality requirements of the program, an example is given in figure 4. Every third lecture is a live session and includes a Q&A for the pre-recorded topics for DI4.0 and a weekly Q&A including discussions of given homework for MFP; in this manner, facts are already established and discussions can be held at a higher level. The Videos for the lectures are usually not longer than 45 minutes to maintain concentration. The exercises are focused on the students' (former) jobs and held in a seminar-style course. The students are presented an assignment in a live lecture and have to present their work after regular Q&A-Sessions. In the DI4.0 exercise an action plan for the transition of companies to a next level of digitalization is asked, for the MFP exercise the students are assigned the planning of a bike factory. The difficulty as opposed to the presence courses lies in the coordination of time zones and finding common communication platforms.

Lean Management (LM): The module lean management integrates lecture and exercise. The lecture is partly pre-recorded and partly held live to answer possible questions. The lecturer also assigns groups of two or three students to summarize the topic of the last lecture. They are completely free in terms of realization. For instance, some students create small quizzes on "Kahoot". The lectures are complemented by short videos, which are tailored to specific subject areas. In these videos principles of Lean are illustrated by the lecturer standing in a virtual factory. The lecturer is able to move and explain all aspects in detail. The immersion of the lecturer standing in a factory can also be used in a live situation to go into questions.

4 SUMMARY

In this paper insights to the planning and implementation of completely digital track of a study course are given. During the planning phase a survey with students was conducted and interviews with lecturers were made. Both students and lecturers had first experiences in the digitalization of a study course due to the pandemic. The survey conducted with the student has shown, that students would have higher expectations on an online study course compared to the situation experienced during to the pandemic when classes suddenly had to switch from classroom to online teaching. Similar feedback was received by the interviews with the lecturers, who generally where able to switch to online teaching, however practical solutions for exercises and especially hands-on work like in laboratories or student workshops must still had to be found. Furthermore, the possibility of social interaction is still quite limited which should be tackled but cannot be completely solved. In the section of implementation, the (digital) technologies in use as well as aspects of community building, and educational concepts were highlighted. A toolbox, which contains a wide range of technical aids and tools, consisting of was presented. Finally, four digitalized modules using different concepts were presented as an example.

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Co-designing a curriculum for a sober techno- and eco-responsible engineering: transition to a new professional identity for a sustainable world

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ABSTRACT

In a finite world whose limits now seem obvious, future engineers are wondering what their profession will become tomorrow. To respond to this strong expectation, the PISTE[2] curriculum was opened in September 2021: a full semester in the final year of engineering studies at Grenoble INP-UGA (France). The program was co-designed with the students and the different partners. The objectives are to enable the students to experiment a new posture and to offer them the tools needed to meet the challenges they will face in a world in transition. A systemic, interdisciplinary approach, considering planetary limits and environmental and societal impacts, structures the whole semester.

This paper presents and argues the pedagogical design choices. With a view to continuous improvement, the strengths and areas for improvement are described.

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1 INTRODUCTION

1.1 Context

In a finite world whose limits now seem obvious (as highlighted by the Sixth Assessment Report of the Intergovernmental Panel on Climate Change), future engineers are asking themselves what their role and their job will be tomorrow. And for example, how can they contribute to achieving the UN Sustainable Development Goals? The global challenges are raising questions among young people who would like to give more meaning to their university education [4].

To respond to this strong expectation, this year we opened the PISTE program to a first class of 28 students: a full semester in the final year of engineering studies at Grenoble INP-UGA (France)[3]. The program was entirely co-constructed with the students and the teachers. The objective is to allow students to experiment with a new posture and to offer them the tools they need to meet the challenges they will face in a world in transition. A systemic, interdisciplinary vision, considering planetary limits and environmental and societal impacts, structures the whole semester.

This paper presents and argues the pedagogical design choices, based on empirical findings and elements from the literature: the overall structure of the program, the contents, the pedagogical methods, the assessment of learning outcomes and the specific support for students and teachers in this program.

With a view to continuous improvement and dissemination, the strengths and areas for improvement are described based on feedback from teachers and students, as well as from the program's co-leaders and the educational developer.

1.2 Approach

To train future engineers in the skills needed to resolve the challenges linked to the ecological transition, we have made the following hypothesis

- A systemic (the whole system in which the problem exists), interdisciplinary (without thematic barriers) and global (from needs and uses to the impacts of the proposed solution according to constantly changing contexts) vision is essential for understanding the transition issues [3].
- The pedagogical approach must be adapted to developing a new conception of the engineering profession, i.e. to be able to approach complex problems in a systemic, interdisciplinary and global manner [5].
- The assessment of learning must be aligned with these intentions and methods [1].
- Co-construction of content between teachers and students, and a collective approach to sharing resources (open science), in a climate of collaborative governance, are necessary because the training is intended to be transformative and emancipating [5] for these future engineers: at the levels of their professional

[3] This work was funded thanks to the french national program « programme d'invertissements d'avenir, IRT Nanoelec » ANR-10-AIRT-05.

identity, their behaviour, their conception of the world, their imaginations and their power to act.

2 METHODOLOGY

2.1 Program Design

We have proposed to build on the elements that we believe are essential for a successful transition in the world of tomorrow and to apply them in designing a 6-month program, during the penultimate semester of the engineering curriculum.

Systemic understanding and approach throughout the whole program

- Interdisciplinary, systemic and global learning, both in terms of knowledge and key skills and engineering posture, which enable the projects to meet their challenges.
- Taking advantage of the diversity of the actors, a variety of points of view, reflected in the diversity of speakers and students (open to all Grenoble INP-UGA components).
- The teachers come from different disciplines at Grenoble INP-UGA and Grenoble Alpes University, and local partners working in research centres, companies, and associations. All of them are involved in sustainable development in one way or another and attach particular importance to it [3]. An important part of the contributions is dedicated to human and social issues, which is a departure from the usual engineering curriculum.
- The courses contents cover a variety of subjects: assessment of the environmental state, analysis of planetary limits, sustainable solutions and adaptation solutions, levers for action, integrated resource management, history of industrialisation, sociology (techniques, uses, innovation), digital sobriety, public policy, green taxation, open science, project management, multi-criteria methods to help decision-making, methods centred on the user experience, carbon assessment, life cycle analysis, risk management analysis, energy performance, low-tech and right-tech.

Adapted pedagogy to develop a new conception of the engineering profession

- A framework that stimulates “transformative” [3] and “emancipatory” [5] learning, mutual understanding, empathy, and trust, as well as collaborative governance (sharing of information and ideas, cooperation, benevolence, mutual respect).
- Interactive teaching to include and engage all students [3, 5], and to reinforce learning and reflective assessment.
- The core of the semester is a group project (10 ECTS out of the 30 ECTS of the semester). The projects are concrete, real-world projects [3], starting from the user's needs and breaking away from the 'business as usual' growth model. The objective is to rethink the design and uses of a product, a component, a system, or an organisation.
- The project work is fed throughout the semester by theoretical and methodological contributions, which are scientific, technical, sociological, political, and economic.

The teaching offered is therefore designed around the projects: they provide useful insights for the students throughout the semester.
- The whole program is designed in accordance with the competence strategy of Grenoble INP-UGA [6].

Learning assessment method based on individual reflection

- Project assessment criteria include: reformulation of the specifications, state of the art in relation to the needs, complete free documentation accessible to the greatest number, life cycle analysis and impact assessment, choice of a solution that meets the needs of users and socio-ecological issues, quality of the report and the proposed solution. Particular attention is paid to the prototype (technical or methodological).
- The assessment of learning outcomes is designed with a view to constructive alignment [1]. It is based, for each of the three teaching units, on an individual reflective writing in which each student shows the links between the learning acquired and its reuse in the concrete framework of the project. This written work is then discussed during an oral presentation.
- The students are accompanied in their reflective work throughout the semester: individual feedbacks are provided on demand on draft versions of their written work; at the end of each oral presentation, teachers and students are invited to write together advise for the next session; workshops are offered during the semester about the assessment method and about the emotions lived during the semester.

Co-construction with the students, the teachers and the partners

- Projects are anchored in the territories. Subjects are proposed by three types of partners, reflecting the diversity of society:
  - public partners such as the municipality or a research laboratory
  - private partners such as companies engaged in transition processes or wishing to hire future engineers capable of addressing transition issues
  - partners representing civil society, such as associations directly linked to transition issues or associations wishing to address these issues without having the expertise
- The groups work closely with partners and potential users to co-construct technical or methodological strategies and solutions. Teachers mentor the groups to support them in carrying out the projects (project management and engineering methods).
- The projects address the challenges of transition: they aim to rethink the design and uses of a product, a component, a system, or an organisation, by developing low-impact, sustainable, documented and widely accessible solutions or strategies. These solutions or strategies should be answering a question directly useful for the user, promoting an open science approach, and fitting into a circular economy model, leading to a more convivial society.
- Regular adjustments occur throughout the semester, according to feedback, observations and questions from students, teachers, co-leaders and the educational developer.

2.2 Overall Framework

The teaching activities proposed throughout the semester encourage interaction between students and between students and teachers. Form and content are co-constructed: students and teachers alike can contribute to the construction of learning.

A climate favourable to learning is based on a set of values, mainly stemming from the currents of popular education, collaborative governance, and collective intelligence. This framework was built with and by the students at the beginning of the semester. Tools were proposed to them, and they appropriated them. The different dimensions of this framework are:

- Benevolence, towards oneself and towards others: we do the best we can, with what we have and what we are.
- Respect: each person has a point of view and diversity is a richness; being punctual, doing one's share of the work, being rigorous and demanding about quality, etc. are all part of respecting oneself, others, one's environment, and the work accomplished.
- Sovereignty: I speak as "I"; I am responsible for my words, my actions, my feelings, my choices...
- Co-responsibility: each person is responsible for respecting the framework and for ensuring that it is respected.
- Humility: nobody knows everything about everything (even the experts), everybody can still learn a lot.
- Legitimacy: everyone can contribute. If an idea has not yet been stated, it deserves to be put in the common pot to be discussed and exchange together on its relevance or not. Mistakes allow us to learn, every obstacle overcome is an experience that can help us move forward, every dead end explored deserves to be identified and shared with the community.
- Criticism and self-criticism: reality is complex and needs to consider a range of points of view (vigilance on a miracle solution or an absolute truth); an idea is distinct from the person who states it (vigilance on arguments of authority and debate of ideas rather than debate of people).

3 RESULTS

3.1 Observations and findings

During the semester, we regularly collected informal and formal feedback from students and teachers and this by different means. Informal feedback was collected during pedagogical workshops, through email exchanges and during two meetings organised with the students, the co-leaders of the semester and the educational developer.

An online questionnaire with 130 questions was proposed to students, at the end of the semester: 75 closed questions on a 4-level likert scale plus a "not applicable" option, 46 non-mandatory open questions, 7 yes-no questions, 1 number question and 1 grade question. The questionnaire was built with pre-tested questions mostly used to assess quality learning and teaching in French speaking Higher Education. It meant to measure the perceived alignment between the aims of the semester and to verify our initial hypothesis (see sections 1.2 and 2.1). 25 out of the 28 students took the time to answer.

In addition, the students spontaneously organised collective feedback, taking the form of a written document worked on in several group sessions.

Systemic Approach

Many comments show the interest of addressing societal issues, planetary limits, putting these questions into perspective, for example through a course on the history of industrialisation, and considering all the stakeholders, in particular with methods from sociology. In their collective spontaneous feedback, the students note in the general feedback paragraph: "The diversity of the courses offers a step back, while developing very technical and practical aspects.”

In the questionnaire, all the answers show that the semester has enabled the development of skills related to solving the challenges associated with the ecological transition. Among the skills developed, students cite

- *Having a systemic vision of the issues*
- *Understanding the mechanisms of climate change and the socio-economic mechanisms of the transition*
- *Having a greater capacity for critical analysis of the technical solutions proposed*
- *Be able to assess the social impact of a technique or technology and to measure the environmental impact with rigour (Life Cycle Assessment, carbon footprint, etc.)*
- *Imagine alternative solutions that break with the growth model*
- *Be an actor in the sustainable transition*

Pedagogy Framework

“The interacting pedagogy framework for sustainability education" [5] is built on two axes: one axe “describes a movement from individuality, structure, and predetermined outcomes to collaboration, agency, and self-actualization respectively” and the other axe “describes a movement from content-focused, objective learning resulting in knowledge and skills acquisition to process-focused, subjective learning resulting in novel ways of being and meaning-making” (p.8). These two axes determine four quadrants.

The core projects were perceived as being at the heart of the course (the courses feed into them) by 75% of the students. 84% felt that the project stimulated interest in the course. All of them felt that they could

- use their knowledge and personal skills (responsibility, initiative, autonomy, reflection) well for the project
- learn and develop their skills by doing the core project
- put the technical knowledge in relation to current societal issues in the project.

56% of the students felt that the teachers ensured their involvement in the proposed educational activities (courses, projects, etc.). 92% felt that a significant proportion of the courses offered activities other than listening to lectures. Among the most cited examples are: debates, open discussions, writing and manual workshops, practical work (applications), mini-projects, serious games, creation of common resources. 64% of students believe that teachers leave room for the co-construction of learning: students as well as teachers can contribute to this learning.

According to Papenfuss *et al.* framework [5], we consider that the major part of the teaching is in quadrant 2 (projects and problem solving, application and critical thinking) and quadrant 3 (experiential learning, transformation of the posture and conception of one's role as an engineer). A smaller proportion, consisting of lectures and readings, is more likely to be found in quadrant 1. Another more significant proportion is found in quadrant 4 (reflection, co-responsibility, legitimacy, future professional orientation): the climate that was established at the beginning of the semester and which, according to 84% of the students, lasted throughout the semester.

This climate aimed to change the usual roles in higher education, towards more horizontality between teachers and students. As the authors suggest, this climate remains difficult to maintain because neither teachers nor students are used to quasi-horizontal relationships. Teachers sometimes need to remind (themselves) of the asymmetry that persists (they are the guarantors of the learning framework and responsible for assessment); some students need to be reminded of the overall framework of higher education (they are responsible for their learning and are bound to respect the didactic contract established at the beginning of the semester).

Learning Assessment Methods

76% of the students consider that the assessment method is consistent with the pedagogical intentions of the semester. However, it deserves to be better structured and more harmonised between teachers. The instructions would benefit from being clearer and explained more regularly throughout the semester. Workshops for students and discussions during oral examinations with teachers were insufficient to prepare them to this unusual assessment method. Indeed, students and teachers expressed difficulties in appropriating the method.

Co-construction

The involvement of the students and the effects of this semester far exceeded our expectations: the students' profiles seem slightly different from the standard profile of students at the school, their expectations were undoubtedly high. The possibility of exchanging views with other people who share their values, in an open climate where everyone is legitimate to co-construct knowledge, has visibly shifted their perception of the engineering profession.

The surveys allowed us to better understand the profile of this first class of students. In fact:

- 68% had participated in the "climate mural" before starting the semester and 44% were a facilitator of this mural; 16% participated in the digital mural"
- 60% were coming out of a gap year that was valued in the curriculum
- 96% had made choices in their personal lives, before the start of the semester, related to the issues of transition and climate change (mainly on meat consumption and transport).

These particular profiles show a prior adherence to a set of values, goals and beliefs related to the transition. This adherence can be understood as a strong commitment in the sense of Marcia [2].

The students shared their questions throughout the semester about their future as engineers: a large majority expressed difficulties in finding an end-of-study internship that corresponded to their aspirations, and several questioned the validity of their future profession. In the end, everyone was able to find an internship that suited them (in a company, a research laboratory, or an association), and 76% of the students can now imagine a future that corresponds to them as a future engineer. Some comments in this end-of-semester questionnaire also show that some students have been able to resolve these issues. This resolution can be understood as a state of exploration in the sense of Marcia [2].

Extracts from student’s answers to the question "What has changed in me during this semester?” show a turning point in the perception of their career:

- *Today I think I could do a job related to my 5 years of study, which was not the case before.*
- *You can come out of an engineering school and not necessarily do a useless job.*
- *I will be able to make a very informed choice about my future job and the social impact it will have.*
- *I think I'll be a better engineer than I expected and I feel more in tune with the idea of being an engineer.*
- *I have deconstructed my ideal of the engineer and I am readier to have a disruptive job (...) I have more hope about the possibilities for an engineer to be an actor of transitions, to have a job that fits with his values.*
- *A much more serene approach to the professional world.*
- *PISTE has given me back some confidence in the future of the engineering profession.*
- *Above all, it gave me hope: the possibility of changing things.*
- *I had a trigger by telling myself that I would choose why I work and not be subjected to a "classic" engineering job in a company that does not correspond to me totally.*
- *My vision of engineering, my vision of the issues.*
- *My vision of the world, of socio-environmental issues and the role of the engineer.*
- *My vision of the engineering profession: you can break the conventions and still be an engineer.*
- *My vision of the engineer, of the society in which I live and my own desires (...) a change in thinking that I believe will never turn back.*

- *PISTE will be a turning point in my life. I probably would never have had the courage to propose my final internship to the school without this semester.*

Global Consistency

These results also allowed us to draw some key conclusions shared by more than 70% of the respondents:

- a very high overall satisfaction of students, teachers and local partners
- a change in the students' mindset
- confirmation, by students and teachers, that the core project is indeed at the heart of the training and that the courses are engaging and interactive
- effective co-construction in most of the learning activities
- the perception of a systemic and interdisciplinary vision, both in the projects and in the teaching.

Overall satisfaction was evident in all the discussions, the questionnaire and the collective spontaneous feedback written by the students.

3.2 Perspectives

As a result of this feedback, and with a view to continuous improvement, we are considering several developments:

- Clarification of shared documents (assessment grids, semester charter, etc.)
- More in-depth pedagogical support on the methods of assessment of learning, both for students and for teachers.
- Further development of sessions dedicated to welcoming students' feelings and supporting eco-anxiety (present at the beginning for some or developed during the semester for others).
- Opportunities for the teaching team to appropriate the framework and the common tools - e.g. collaborative governance, open science - are planned.
- A greater awareness of the teaching team to the interest of calling upon the educational developer to design the learning activities.
- More explicit sharing of prerequisites within the teaching team, to avoid some redundancies and gaps, mainly within the first teaching unit.
- Some changes in course subjects and contents.
- Opening to a wider public.
- Setting up an alumni network and a network of companies able to host end-of-study projects related to the semester.
- Longer periods of time to work on projects.
- Sharing of the different projects with the whole teaching team via short presentations (video, online document, or another format).

4 CONCLUSIONS

We can consider that this program constitutes a niche [3]. It is a place of experimentation, open to its environment, and the actors are particularly willing to co-construct and widely disseminate the impacts, strengths and weaknesses observed, as well as the avenues of evolution of this program.

The co-construction of the semester with all the actors concerned seems to us to be a factor of success of this type of program. In a quest for congruence between the intentions pursued and the means implemented, it seems obvious to consider the contributions of each person as essential and legitimate, regardless of their status. This approach also applies to courses, projects, etc. Transition issues concern the whole society. Each person can contribute. The diversity of points of view considerably enriches the solutions considered, both at the level of disciplines to provide a systemic vision and at the level of personalities to provide diverse perspectives.

Together, we constructed a framework inspired by popular education, collaborative governance and collective intelligence. This framework changes the place and role of learners and supervisors. It opens up co-construction and requires sharing values such as benevolence, sovereignty, mutual respect, criticism and self-criticism, humility. This framework allowed for collective and individual work on professional posture. This work is essential to reinvest the role of the engineer in a world in transition.

We did not conduct more specific individual interviews to explore the question of identity. In the light of the observations and data collected, we presume that some students are on the threshold of an identity realisation while others may be in phases of foreclosure or moratorium in the sense of Marcia [2]. We do not exclude that the development of professional identity, especially at such a young age, may still show forward and backward steps: it is possible that they may experience times of questioning about engagement and/or exploration.

We also proposed pedagogical activities consistent with the objectives [1], to develop the skills needed to solve the challenges linked to transition and, in particular 'transformative' pedagogy [3,5]. The pedagogical approach - built around real projects and supported by local structures – is designed to develop complex learning. It encouraged teachers and students to weave links between each course and their projects, and to experience innovative pedagogical activities. Pedagogical support for teachers and students in these unusual teaching methods (activities and assessment of learning) has proved necessary but still insufficient.

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FROM STUDENT TO EXPERT IN A WEEK

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ABSTRACT

It can be challenging to effectively impart higher education content to students. We experienced such difficulty in a lecture series with invited senior scientists presenting their area of Biotech research. Instead of a vivid exchange with the expert, we observed limited and restrained student contributions. In qualitative interviews with these students we learned that they perceive their knowledge disparity as too big and the fear of being embarrassed by asking "stupid" questions obstructed their participation. This let us to radically rethink the course design resulting in our own interpretation of flipped classroom, peer learning and student empowerment. We designed an engineering course that focuses on providing master students with the best possible environment to gain theoretical knowledge in a new field within a limited time period (currently: six weeks - six topics) aiming to empower them in these topics by acquiring new knowledge on their own. Based on seed questions and tag words, students conduct background research and create a team presentation for an invited field expert, thereby getting prepared for a subsequent in-depth discussion with the expert. The current layout is the product of an iterative process over the course of five years, and several rounds of fine-tuning within each year, based on extensive student and instructor feedback. Students particularly appreciate the positive in-course atmosphere with a focus on growth-mindset, the strong experience in teamwork, being taken seriously, and making contact with field experts and frontiers of current knowledge.

1 INTRODUCTION

We designed a lecture series intended to bring students of the Biotechnology Master's programme rapidly to an advanced level of understanding of bioanalytical methods. Our plan was to capitalise on the rich expertise found in the Berlin area as one of the leading cities for German science, so we invited experts to present their area of research to the students. Our assumption was that students would benefit

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from top-level teaching by the experts and, as a side effect, make contact with excellent research groups for potential master thesis projects.
The original course format was a classical lecture series with two 90 minutes slots per week. We taught our core expertise and allocated the remaining slots to field experts. After running this course twice, we concluded that engaging scientific experts to teach their respective topics with passion and profound domain-specific knowledge provided an excellent framework for professional teaching. However, the oral exams with the students also revealed a substantial shortcoming. The topic-specific experts had condensed the content that they normally teach to PhD students and postdocs in field-specific scientific courses over a week or two into three to six hours, which was the time allocated to them. While none of the students had any questions - a possible signal of complete understanding - we interpret this now as a sign of information overload. None of the students had conquered the knowledge that they had been provided with, as evidenced by the oral exams and further interviews with the students.
To address these shortcomings, we fundamentally reconceptualized the course by implementing a mixed method format built on flipped classroom [1] and project-based learning concepts [2]. Here we report on the process, the design and the experience of running the course in its reworked form for five years.

2 METHODOLOGY

2.1 Research questions

The low learning outcome despite the substantial framework of expertise strongly indicated the need for a new course concept. So, we went into ideation defining the following main needs:

- How can the students gain confident command of the current state of development of selected bioanalytical methods in the life sciences within the restricted time boundaries of the course?
- How can we maximise the value of leading experts in their respective technologies that volunteer teaching this course, while keeping their time commitment minimal?

We reframed the first question into the core idea of the course in a more accessible way: How would a couple of friends ideally learn the theory of a new technology within one week, or even less? How can they achieve that repeatedly for every topic without feeling lost or overworked?

2.2 Methodology of course development

With the problem explained in the introduction and the needs summarised within the research question(s) we created a course prototype based on a mix of concepts like flipped classroom and project-based learning in expert groups with a focus on activating learning methods.
For the first version of the course (prototype, Fig. 1) we reserved three subsequent days per topic with the experts being invited on day 3. This initial format was used to further learn about the participants' needs by critical observation and regular feedback sessions after each topic round, directly linking to the implementation of minor adaptations (fine tuning) for the following topic.
Based on these experiences and a vast feedback collection we iterated the course for the next year that again was the basis of the following iteration loop. With that strategy we were able to adapt the course structure to its current format (year 2021) that is further described in the results section.

2.3 Evaluation of learning success

In order to display the learning success for each course topic, we designed a questionnaire (see Fig. S3) and asked students to evaluate their confidence levels within each subject on a scale of 0 (lowest) to 10 (highest).
We started data collection on a voluntary basis in 2018 with a printed 2-page questionnaire that was expected to be filled out before the start of the course and then regularly after each course day. Sheets were collected at the end of the course and data points displayed as box-and-whisker plots, individually for each topic (fig. S1), and as a mean of all topics (Fig. 2).Students were also asked to evaluate their team-, research- and presentations skills before and after the course based on a similar scale (Fig. S2).
The same type of paper questionnaire was used in 2019 and, since 2020, has been replaced by a digital survey with identical topic and skill related questions, now only being accessible at the time of data collection.
To also get the impressions of the invited experts, we asked them to rate the students' performance in an informal feedback session after the course. Finally, we graded students with a portfolio exam (compare section 3.2).

3 RESULTS

3.1 Prototype development and theoretical background

From the initial shortcomings we learned that students need preparation time to learn basic concepts and translate these into further questions to feel comfortable to interact with and hence effectively benefit from the experts. One way of doing that would have been to give students selected materials prior to the expert lecture to be worked through at home. That way of flipping the learning from the classroom to out-of-class might have already resulted in prepared students and more time in class for further discussion of the content [1]. However, in other courses we have observed that only a certain number of students follow these recommendations, and even fewer master the content in depth. Also others have observed insufficiently prepared students, even if the pre-work was mandatory [1, 3]. To help students focus and assist whenever needed, we decided to integrate the preparation phase into the classroom.
In their review about problem- and project-based learning, the authors describe that a problem to solve might act as an incentive for students to learn and can be used as a central principle to enhance students' motivation [2]. So instead of just letting students prepare with topic related material, we expected them to create a team presentation about the method within two days that finally should be presented to the expert. Proven to enhance deeper understanding [4, 5] we implemented peer learning by splitting the course into expert teams of four to six students. Each team was then randomly assigned one predefined subtopic of the collective final presentation, meaning that each team was responsible to prepare the content not only for the expert but also for their peers. Regular progress updates should ensure that the group does not lose sight of the bigger picture and has assigned times to help each other across teams.
At the end of each topic a feedback round with students and instructors should provide insights for a potential fine-tuning of the next topic round.
We further assisted the participants by providing a clear daily structure with two progress presentations as intermediate goals, accessible team support and a coworking-friendly environment by dividing a seminar room into movable team

spaces with coffee and tea being available over the whole course time.

3.2 Description of the prototype

We came up with a course prototype held in summer 2017 with 19 participants (compare Fig. 1 to see the basic course structure), that were briefed about the concept and our expectations in a pre-meeting.
In randomly assigned teams, students were supposed to work through five topics successively, with three eight-hour days devoted to each topic. They brought their own laptops and had internet access through the university Wi-Fi. For students without a mobile device we provided a laptop for the duration of the course.
The first day was designed to get an initial understanding and perform further research about the assigned subtopic. In a plenary session, the outcome was shared with the whole group and the structure of the joint presentation drafted collectively.
On day 2 the collected information was intended to be condensed and accumulated into presentation slides and the final presentation rehearsed in the afternoon.
The resulting lecture composed of the four group presentations was presented to the expert in the morning of day 3 followed by a discussion. The rest of the day was used to conserve the acquired knowledge into a collective document (wiki). A voluntary seminar was offered at the end of day 3 after a feedback round.
To foster perseverance, each day students could earn a small proportion of portfolio points for collaboration and punctuality. Presentations and the prepared slides were graded as well and summed up with the points achieved in a final test at the very end of the course.

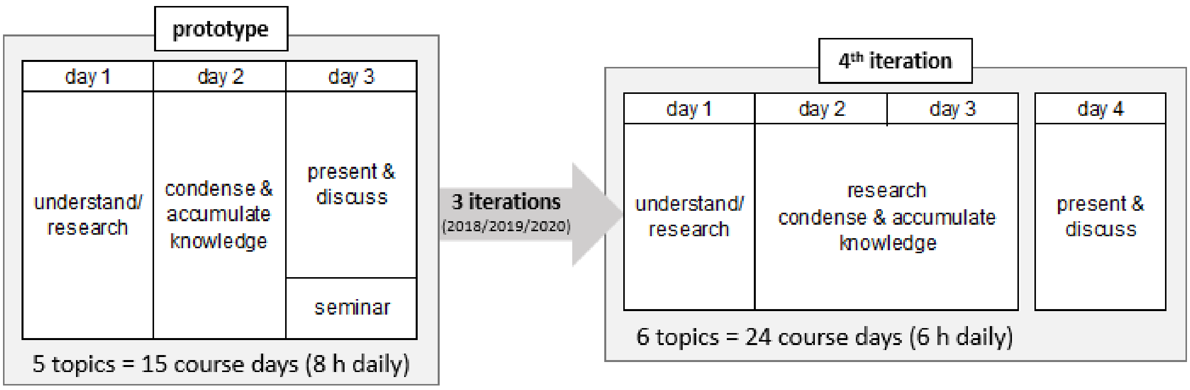

Fig. 1 Course structure development from prototype in 2017 to the last version in 2021. The prototype started with 3 days per topic (8 h daily) including an optional seminar and was iterated to the current format of 4 days per topic with a daily workload reduced to 6 h, including a course-free day before meeting the expert, if in accordance with calendar dates.

3.3 Lessons learned from the prototype

After having run the prototype of the course we learned that the concept itself worked out very well - vivid discussions with the experts have been observed as well as clearly positive feedback from the students stating that they have learned a lot about the topics and themselves and gained confidence in important soft skills, such as teamwork towards a hard and heavy deadline, as well as presentation and research skills. That matched the results of the self-assessments summarised in Fig. 2 (and more detailed in Fig. S1) and Fig. S2. Besides that, the motivating and clear course environment was praised repeatedly.

Nevertheless, eight hours a day for three weeks with only the weekend in-between was very demanding for most of the participants. It was not possible to do anything else than this course. It was also reported that the time per topic was not enough and students would rather have more time to digest the accumulated knowledge and learn more about the other subtopics. It was also requested to have more narrow-framed subtopics and topic specific guidance to not get lost during literature research. The optional day 3 seminar was attended by only a small subset of the group; non-participating students reported that they were just too exhausted to join. From the lessons learned during the prototype course we developed the basic setup of the course, which is still valid to date and described in section 3.4.

3.4 Basic setup of the course and its overall development over time

With the basic course structure, we created a “space to learn” where we assist student teams in preparing a presentation for invited field experts and fellow students by providing seed questions and topic related keywords. Within the now three days long research and content creation phase (6 h/day) we provide guidance whenever needed and a micro-timed schedule with organised time slots for information exchange between the teams (compare Table 1). On day 4 the lecture is presented to the invited field expert who detects and fills potential knowledge gaps and answers further questions. The expert also gets the opportunity to present their own research - now to a prepared audience that is confident to discuss the content. The learned content of all teams is then assembled into a document (wiki) and from 2020 onwards, read and enriched by all students via perusall, a social e-reader that should “turn the online reading assignment into a social experience to encourage students to engage with the material and with fellow classmates outside of class” [6].

When conducted in person (2018 and 2019), each team had an assigned team space within a seminar room. For regular meetings of the entire team, the room was transformed multiple times a day. During the research and content creation phase (day 1-3) instructors were present at preassigned times, and could be called in via digital communication. We started off with the course organisers being the only instructors, and then expanded successively by calling onto the help of other members of our research lab with more advanced topic-specific knowledge. Since 2020 we also provide an introduction lecture on day 1 to clearly define the level of expectation and learning goals.
When conducted online (2020 and 2021), we used a video-chatting service with breakout rooms for the sub-team meetings. As a noted benefit of the online format, we could expand our set of field experts internationally. We set up a channel in a messaging app to allow students to communicate with each other and instructors throughout the course. This kept in-course chatting away from other digital channels and allowed a clean differentiation of learning and leisure time. The collective student notes and presentation slides were created in a freely accessible online editor, allowing students to simultaneously work on the respective documents.
As due to the local pandemic situation the initially planned final exam could not be offered in 2020, we demanded homework instead. That consisted of finalising an assigned part of the knowledge collection (wiki) after it has been proof-read collectively. The handed-in documents were then marked individually. Having had the positive side-effect of further deepening the understanding of the topics, we decided to keep that substitute for further iterations.

Each tool contributed an essential component to the course communication. Note that students very much focused on this block course for its duration, and these tools essentially formed major elements of their work environment. As students are working in small teams, they can also help each other if aspects of these tools should be less familiar to some of them. A course page in our university Moodle system served as the central information platform with all details needed.

Table 1: tentative weekly course schedule at the beginning of the course with (intermediate) presentations framed in blue.

Day 1	Day 2	Day 3	Day 4
10:00 morning round	10:00 morning round	10:00 morning round	10:00 day/expert intro
10:10 overview lecture	10:05 prepare rough presentation	10:05 present improved presentation	10:05 presentation & discussion 10:05 student presentations 11:05 break 11:15 expert questions 11:35 expert research presentation 11:50 discussion / open questions
11:10 subtopic assignment	10:35 speakers present rough presentation	12:00 lunch break	13:00 lunch break
11:20 subtopic-team-research (I) solo research, lunch break, share with team and define tasks/sub-subtopics	11:50 prepare presentation (I)	13:00 finalize presentation, start team-wiki	13:40 complete team-wiki
14:00 subtopic-team-research (II) work on tasks/sub-subtopics, discuss presentation plan with mentor, combine tasks/sub-subtopics into presentation draft	13:00 lunch break	15:00 internal rehearsal and proceed on team wiki	15:20 answer survey
15:50 check out	13:40 prepare presentation (II)	15:50 check out	15:30 feedback
16:00 end of day 1	15:50 check out	16:00 end of day 3	16:00 end of day 4
	16:00 end of day 2		

3.5 Learning outcome

The experts commented extremely positively regarding the students' performance, both, about the presentation and the subsequent topic discussion and repeatedly renewed their commitment for the next years' course.
When looking at the self-assessed confidence levels summarised in Fig. 2 (and more detailed in Fig. S1), it is visible that participants greatly improved over the four course days in both the in-person and digital formats.

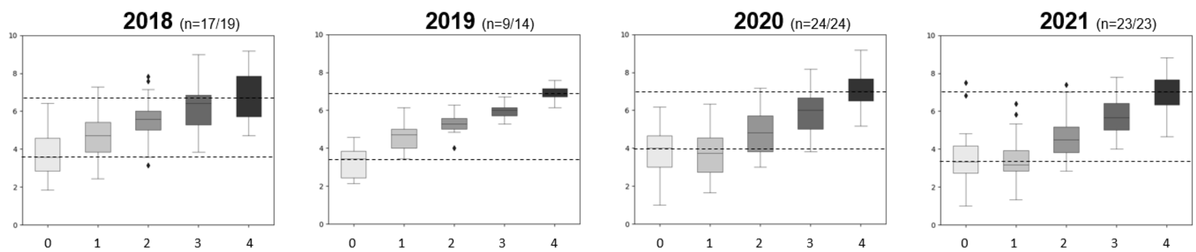

Fig. 2: Self-assessment of topic confidence levels before the course (0) and after each day (1 - 4) plotted as a mean over all topics. Each plot shows a year (2018 – 2021). Scale used on y-axis: "0 = absolutely no idea" to "10 = feel like an expert". The dotted lines highlight the median before and after the course.

Notably, when offering the course in-person the learning curve rose constantly while in the digital format in 2020 and 2021 confidence levels often dropped after the first day but rose even steeper within the following days. This features similarity to the Dunning-Kruger effect pointing out that people being unfamiliar with a topic tend to overestimate their initial knowledge [7]. Beside the influence of shifting the course into a digital format, we also provided a clear pre-lecture on day 1 confronting participants with the expected depth of knowledge. Figuratively spoken, this might have pushed them from “Mount stupid” into the “valley of despair”, that however helped them to enter the phase of “enlightment” more easily within the next days. The non-observed drop after day 1 during the in-person version of the course might be due to the missing pre-lecture but also could be led back to the way data has been collected - students were indeed reminded to fill out the paper questionnaire regularly, but we observed some students filling it out not until the very end of the course, possibly resulting in distorted self-estimation.

CONCLUSION AND OUTLOOK

The increased topic confidence of the students and the positive feedback obtained by all stakeholders (students, instructors and experts) let us to conclude that we managed to create an environment to assist students in gaining theoretical knowledge in a new field within a limited period of time. Empowering students to benefit from invited field experts by providing a prior team mission (the final presentation) should be transferable to a multitude of disciplines and we highly recommend trying it out.

Based on our observations we plan the post-pandemic version to be hybrid by allowing students to work from the comfort of their homes during the research and content creation days and, on the presentation day, coming together in person to allow practising in-person presentation skills, strengthen the positive course atmosphere and intensify contact with the field experts through in-person experience. We intend to keep our digital work space as described above, and hope to maintain participation of international field experts digitally. We expect the resulting mixed in-person and digital presence of attendees during the presentation and discussion to require careful planning and set-up of technical infrastructure. Importantly, we will continue our weekly feedback rounds, which will plausibly lead to changes of these plans. We will remain open to adjust the opportunity space provided by this course to maximise the learning experience of the students.

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SUPPLEMENTARY MATERIAL

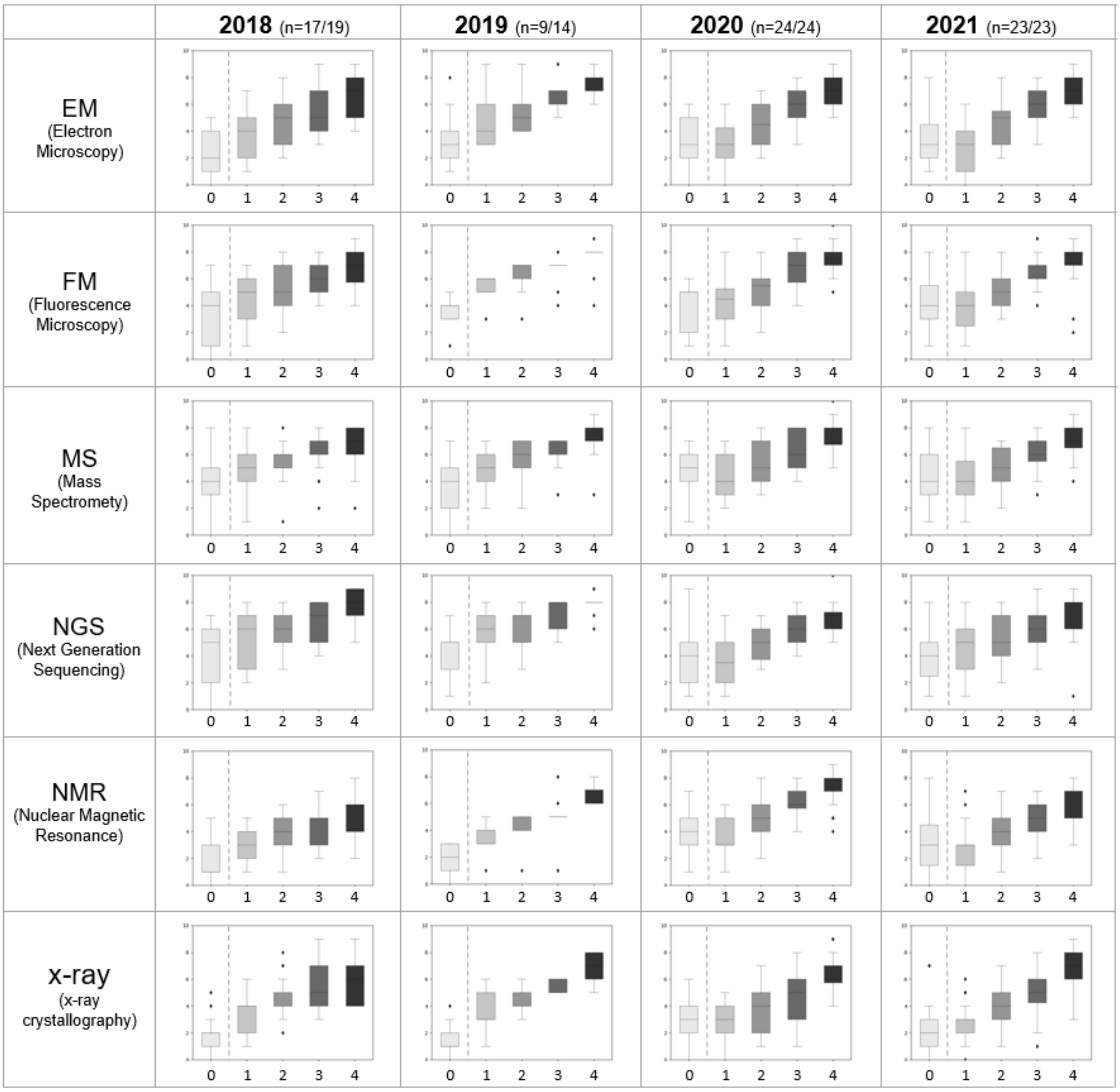

Fig. S1: Self-assessment of topic confidence levels before the course (0) and after each course day (1 - 4) for the years 2018 – 2021 with a scale on the y-axis of "0 = absolutely no idea" to "10 = feel like an expert".

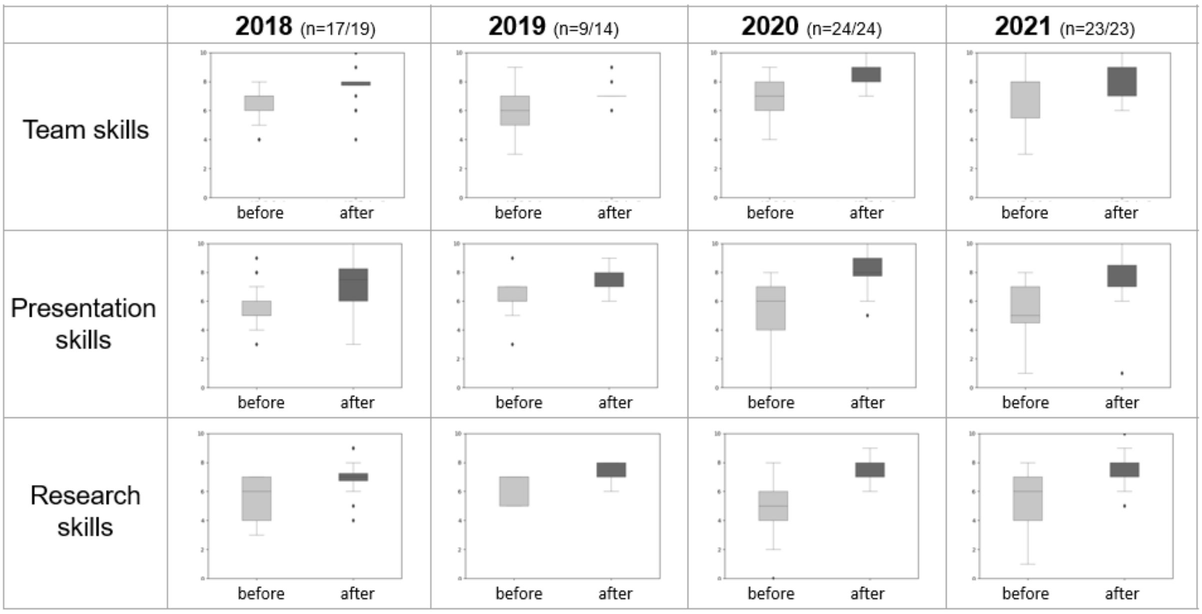

Fig. S2: Self-assessment of soft skills confidence levels before and after the course (team, presentation and research skills). Each plot shows a year (2018 – 2021) and the confidence level between 0 (lowest) and 10 (highest).

Advanced Bioanalytics 2018

Are you...
- ☐ female
- ☐ male
- ☐ other

What M.Sc. semester are you? ○ 0 (still in B.Sc.) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 and more

How would you rate your <u>research skills</u> **before the course**?

○ 0 (no idea where/how to start) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)

How would you rate your <u>presentation skills</u> **before the course**?

○ 0 (even thinking about presenting makes me feel stressed) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (presenting? No problem!)

How would you rate your <u>team skills</u> **before the course**?

○ 0 (teamwork makes me feel scared) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (no matter with whom - let's do it together!)

Please assess your level of confidence within the topic of <u>mass spectrometry</u>...

before the course: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 1: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 2: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 3: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 4: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)

Please assess your level of confidence within the topic of <u>x-ray crystallography</u>...

before the course: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 1: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 2: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 3: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 4: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)

Please assess your level of confidence within the topic of <u>electron microscopy</u>...

before the course: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 1: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 2: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 3: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 4: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)

Please assess your level of confidence within the topic of <u>fluorescence microscopy</u>...

before the course: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 1: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 2: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 3: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)
after day 4: ○ 0 (absolutely no idea) ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 (feel like an expert)

Fig. S3a: Page 1 of the questionnaire used for self-assessment and feedback collection (paper format)

Please assess your level of confidence within the topic of NMR...

before the course: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 1: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 2: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 3: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 4: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)

Please assess your level of confidence within the topic of NGS...

before the course: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 1: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 2: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 3: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)
after day 4: 0 (absolutely no idea) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)

How would you rate your research skills **at the end of the course?**

0 (no idea where/how to start) 1 2 3 4 5 6 7 8 9 10 (feel like an expert)

How would you rate your presentation skills **at the end of the course?**

0 (even thinking about presenting makes me feel stressed) 1 2 3 4 5 6 7 8 9 10
(presenting? No problem!)

How would you rate your team skills **at the end of the course?**

0 (teamwork makes me feel scared) 1 2 3 4 5 6 7 8 9 10
(no matter with whom - let's do it together!)

How would you rate the course (0=disappointing, 10=excellent)?

0 1 2 3 4 5 6 7 8 9 10

Would you recommend the course to other students? Why (not)?

What did you like?

What would you improve?

Fig. S3b: Page 2 of the questionnaire used for self-assessment and feedback collection (paper format)

A PRACTICAL APPROACH TO STATISTICS THROUGH SRP

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Conference Key Areas*: Mathematics at the heart of Engineering, Curriculum Development, Engineering Skills, Lifelong Learning.*
Keywords*: statistics education, project-based teaching, study and research paths, anthropological theory of the didactic, lifelong learning.*

ABSTRACT

The paper explains the design and the first part of the implementation of a project within the subject of Statistics with first year students in a Bachelor's degree in ICT Systems Engineering in Manresa School of Engineering, part of the Universitat Politècnica de Catalunya. We use the methodology of *study and research paths* within the Anthropological Theory of the Didactic and under the paradigm of "Questioning the world".

The project topic is the "water". The experience is linked to a broader UPC-driven project, called AquaeSTEAM, based on questions to spark new ideas and science

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and technology solutions to solve water-related problems. After narrowing down the issue to concrete problematic questions, the students analyse data published in IDESCAT, the Statistical Institute of Catalonia, related to water consumption, both domestic and industrial, factors related to climate change, such as temperature and pluviometry, among others, and will also carry out a survey to link all these studies with the water footprint.

The implementation sheds light on the conditions needed to integrate project-based proposals in the traditional organisation of the subject. It also provides information about the changes that may take place to facilitate the integration, in both the subject's content and instructional structure (lectures and tutorials). The conditions required are then compared with other experiences of study and research paths in engineering education carried out these past years in the Anthropological Theory of the Didactic.

1 INTRODUCTION

This paper presents an inquiry-based instructional proposal called *study and research path* (SRP) we implemented this academic year 2021-22 in the subject of Statistics of the bachelor's degree in ICT Systems Engineering in Manresa School of Engineering, one of the schools of the Universitat Politècnica de Catalunya (UPC). Like other European universities, UPC has been going through a methodological transformation in education for some years, especially from the adoption of a competence-based curriculum within the European Higher Education Area, but it is the first time an SRP is implemented at this school although some other project-based activities had been carried out before in the same subject, by one of the authors [1]. The analysis of an experience at secondary school was presented and discussed at CERME Conference this 2022 [2].

Study and research paths belong to the theoretical framework of the Anthropological Theory of the Didactic and respond to the pedagogical paradigm of *questioning the world* introduced by Chevallard [3]. In contrast with the prevailing paradigm of *visiting works* that gives priority to the works of knowledge students must learn, in this new paradigm, questions go first, and knowledge works are only used and studied to elaborate answers to the questions. An SRP begins with a generating question that is given to the students who address it under the guidance of the teacher(s). In the process of answering the generating question, new derived questions arise that the study community (made of teachers and students) need to answer to develop the inquiry. Addressing the derived questions requires searching already available information (knowledge works, empirical data, etc.) and studying it. It also requires testing it and developing the available resources to elaborate the final answer.

Barquero et al. [4], present different modalities of SRPs implemented in university education during the past 15 years and illustrate different strategies for integrating them into traditional course organisations. They also analyse the effects produced by a change in the generating question within a given course and modality. In terms of the share of responsibilities between the teacher and the students – the *didactic contract* –, these authors show the importance of introducing an external instance (like a fictitious client or consultant) that raises the generating question and to whom the final answer is addressed. This strategy supports the new didactic contract that needs to be established and the means used to validate the final answer. It is the "client" and not the teacher who determines what a good final answer is according to the initial demands. Therefore, the validation criteria can be separated from the pure instructional ones.

This contribution presents an SRP that introduces a new modality in what concerns the choice of the generating question. Instead of being proposed by the teacher or by an external instance, it is the students who are asked to choose it according to their interests in a fixed theme: the water. This new option has given rise to special features in the development and management of this SRP and also in the students' learning, which will be listed in the last section. It will be interesting to analyse them from the ATD point of view in upcoming works. To get there, section 2 summarizes the design and the first steps of the SRP and section 3 discusses the development of the main question of the SRP.

2 DESIGN AND FIRST STAGE OF THE SRP

2.1 Setting the context

This SRP design and implementation were subject to some conditions found in the school. The subject of Statistics is taught in the first year and second semester of the bachelor's degree in ICT Systems Engineering at Manresa School of Engineering, at UPC. The group consists of 40 students and the subject is developed in two weekly sessions of two hours each, one session for the full group and the other session for half of the group, at the computers lab, where the SRP has been developed for several weeks. The syllabus, exercises list, and lab questions, and assessment criteria are shared with other degrees where Statistics is taught at the same time. Because of that, the SRP could not play a primary role in the subject, and it had to share space with traditional lectures and tutorials. However, the assessment was slightly modified to give the SRP a weigh of 20% divided into a final report (10%) and a poster with an oral exposition (10%). Nevertheless, it is expected that the benefits provided by the SRP will indirectly influence positively the percentage coming from other evaluation activities. In addition, the subject has been assigned the evaluation of the competence of autonomous work.

From the previous experiences and the competences assigned to this subject, two aspects were taken into account: empowering students' autonomy and promoting learning around quality and data management.

Unlike other SRPs previously implemented at the university level, this one does not start with a main question proposed by the teacher. Here students were asked to propose their own questions in the framework of a general topic: the "water". In this way, the experience is linked to the project AquaeSTEAM and focuses on the role of water in our daily lives and its relation to science and technology. AquaeSTEAM is a project co-funded by FECYT to promote scientific culture and to build up resources to be used at all educational levels with an interdisciplinary approach in relation to the Sustainable Development Goals (SDG) of the 2030 Agenda for Sustainable Development, approved by the United Nations on 2015. The project promotes the habit of questioning the world, proposing several questions and suggesting different approaches to each one.

2.2 Brief description of the first part of the SRP

The first activity carried out in class gave the students an insight into what they were going to study in the subject. It also illustrated the process followed from the consideration of an initial question until finding a final answer. It is an activity in which each student receives a dice and they have to decide whether it is tricked or not. In this one-hour activity, the students start gathering data, they see how to organise it, the main points of descriptive statistical analysis, a bit of probability and the beginnings of statistic inference [5].

After this activity, the SRP was presented to the students. Instead of the teacher presenting a generating question, which is a key element to starting an SRP [6], this responsibility was passed on to the students who had to think about a question they would be interested in answering around the given topic. Students organised themselves in small groups.

The first step for each group was to start doing some research and gathering information to formulate a question. The second step was to link questions with data and define the aim of the study and which variables are going to be analysed. Some derived questions showed up and students were invited to build up a question and answer map, which will be completed throughout the project. Figure 1 includes an example from one of the groups illustrating the structure of some derived questions.

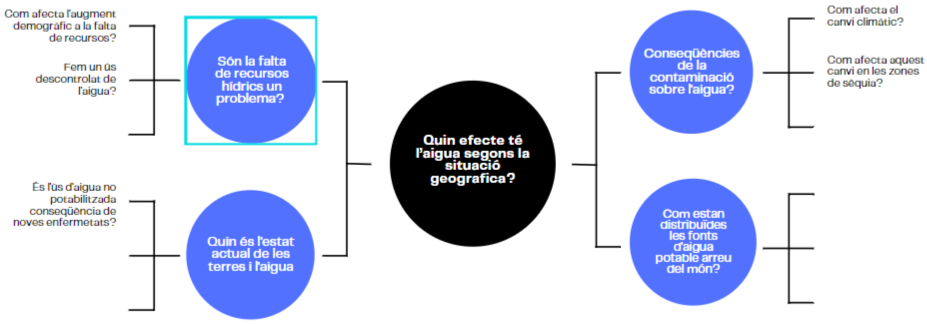

Fig. 1. Questions map of a group of students

Before beginning to look for any answer, a third step was required: the analysis of the study proposal, namely the viability of the study, by analysing the kind and quality of the data provided. This is one aspect that very often remains in the shadow in educational contexts. The study community, composed of the students and the teacher, was in charge of that during several sessions. Examples and exercises on descriptive statistics were discussed, and time was devoted to discussion and peer reviews. More details on this part are described in [7]. Questionnaires were used to make the application of a rubric easier and also to gather information from the point of view of didactic research. Results will be discussed in section 4.

3 DEVELOPMENT OF THE MAIN QUESTION

Since the data provided by the students were not in most cases easily "studiable" and to begin with all the questions in parallel will be too wide, the teacher looked for common ground to focus the work on a common issue: water consumption. Both domestic and industrial consumption was going to be considered, with data provided by official sources. In future stages of the SRP, each group of students could channel these first findings toward their initial question and could help them narrow it down.

Each group chose a region of Catalonia for their study, keeping a relationship with their initial question, and checked what data was available in the IDESCAT (Institute of Statistics of Catalonia) for each municipality, which could be related to water consumption. It was agreed to study the following variables: number of inhabitants, sex, age ranges, domestic water consumption, industrial water consumption, surface, price of water, unemployment, number of inhabitants enrolled in Social Security, sports facilities, touristic accommodations, home building and municipal waste. Eleven regions were studied: Bages, Berguedà (as central regions), Vallès Occidental, Baix Llobregat and Barcelonès (as metropolitan regions), La Cerdanya and Vall d'Aran (as northern mountaineous regions), Ribera d'Ebre and Baix Ebre (as southern regions), La Selva (as north-coastal region) and Pla d'Urgell (as rural region). Each group carried out a descriptive statistical analysis and checked the correlation between variables.

Some of the results of this analysis can be seen in the following graphics and tables. The analysis was not reduced to usual histograms or pie charts, but students experimented with other graphics. For example, Figure 2 shows two charts. On the left, the box plot is associated with the various variables, allowing us to compare what it is telling for each. On the right, it is illustrated how the same group of students experimented with sophisticated graphs to show the comparison of values of the variables for the different municipalities in the region.

Concerning the study of correlation, Table 1 shows the summary of the correlation coefficients between domestic or industrial water consumption and the different variables, carried out by another group of students.

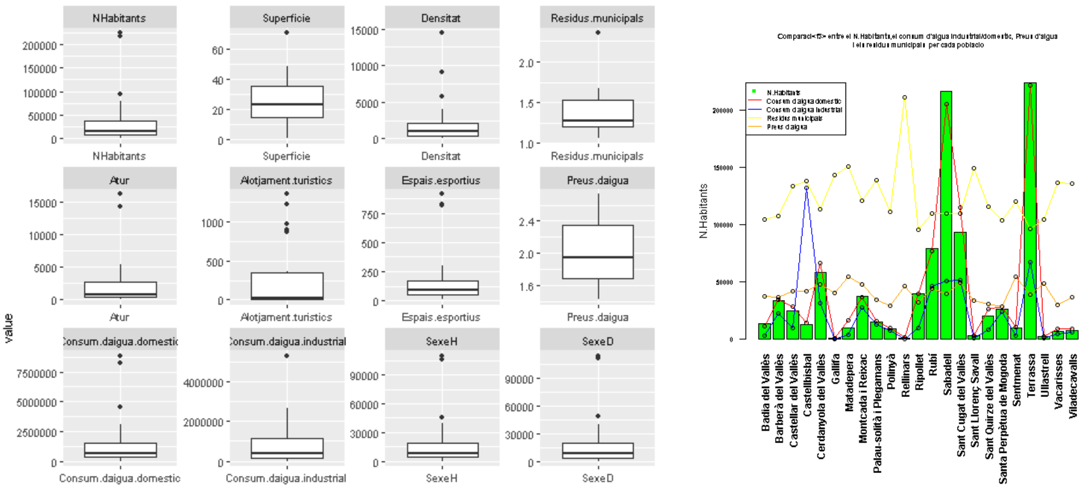

Fig. 2. Plot boxes for several variables and simultaneous comparison of variables by municipality (Vallès Occidental)

Table 1. Coefficients of linear correlation (Berguedà)

	Coefficient of linear correlation (r)	
Variable	**Domestic consumption**	**Industrial consumption**
Inhabitants	0.9944899	0.7686851
Surface (km2)	-0.1910381	-0.04068739
Price of the water (€/m3)	0.3382914	0.3876078
Unemployment (mean of people)	0.9941054	0.74788869
No. of inhabitants enrolled in Social Security	0.9924128	0.77418386
Sports facilities	0.8695737	0.68088891
Touristic accommodation	0.6494041	0.44081208
Home building	0.9724515	0.69912799
Municipal waste (tones)	0.9960272	0.75759798

After sharing this part of the study, the students have the chance to carry on with their first proposal of the SRP, in case it was good enough to do so or have the chance to change the first approach, set a new main question to be answered. In the first case, they have the chance to merge all their findings until that moment (previous research and first proposal, and analysis of the region about water consumption). In the table below, it is shown the first proposed generating question, the region afterwards studied and the definitive generating question of some groups of students. The question in green represents the question that has been maintained, the questions in yellow represent the questions that have been kept but have been narrowed down and the cases in red represent the questions that have been totally changed.

Table 2. Generating question proposed – Region studied – Final question

FIRST QUESTION	WATER CONSUMPTION IN SPECIFIC REGION	FINAL QUESTION
Has the 2020 confinement affected the level of water consumption in Barcelona?	El Barcelonès	Has the 2020 confinement affected the level of water consumption in Barcelona?
How much water do nuclear plants consume?	La Ribera d'Ebre	How much water does Ascó nuclear plant consume?
How does water brought by rivers in Catalonia vary?	El Baix Llobregat	How does water brought by river Llobregat vary?
What effects has society had in water?	El Berguedà	Do the political views of the inhabitants of El Berguedà affect on water consumption?
Is it possible to maintain a swimming-pool efficiently not letting fungus grow?	La Selva	What is the water footprint of the technology of first-year ICT Systems students?

The following stage will be reported and analysed in upcoming works.

4 ANALYSIS AND FINDINGS ON THE FIRST STAGE OF IMPLEMENTED SRP

Questions proposed by students were creative, and the map of derived questions showed their interest in water issues and SDG in general, part of the goals of this project. The main difficulty was to link the questions with suitable data, as their knowledge about how to manage data was limited, and in some sense lower than what was expected. However, it led to going deeper into that part, usually disregarded. Some sessions on data management and analysis were introduced, complemented by a peer reviews activity that increases learning opportunities for the students.

The perception of students about their learning process was collected through a questionnaire, with the aim they could see where the question is driving them. When asked about the limitations of their initial proposals, they confirmed our analysis with answers such as: "Improper and/or unnecessary data were provided" or "The main question was too wide". When asked about what they learnt from review activity (own one, peer and teacher reviews), they also wrote explicit answers such as: "Different approaches and how the others have used the data", "To carry out a good descriptive analysis and to select proper data", "To check if the revision and our data were correct", "Possible mistakes we hadn't taken into account previously", "Possible relations between variables", "Inspiration for our project", "Aspects the others can improve and so can we".

From the analysis of the development of the generating question some interesting features related to autonomous work and critical sense could be listed too.

- Students used more complex graphics, other than the usual histograms or pie charts, and experimented with them for several variables.
- Some new questions appeared due to the use of real data, and students argue: "*When grouping the data in classes (number of inhabitants), some criteria cannot be met. Most of the municipalities in "El Berguedà" have less than 1000 inhabitants, but the capital city has a lot more (16.682) and we do not know how to set the classes: either we make more than 20 classes or the class (0,1000] contains more the 30% of the data.*"
- Students also experimented on software further than the presented option: "*We have decided to calculate the classes using R and not R Commander. It is more efficient since it generates a table with two columns: one with all the classes and the other one with the absolute frequency of each of them.*"

Experience is still in progress and this "in vivo" analysis was very interesting and fruitful because it allowed feedback on the same experience.

An a posteriori analysis will be conducted from the point of view of the ATD. However, since it is the first SRP experience at UPC, it makes sense to sketch some comments related to the first phases. Following Barquero et al. [4], when the generating question "is taken seriously", that is, when the teacher lets the question lead the inquiry, she does not know the paths that will be followed and assumes the role of a guide who helps students progress in their study, organizes the sharing of results, orients the search of new information, etc. Since the question is open, the teacher does not know the answer – and many times there is no unique answer to the question – and the decisions made during the SRP (by the teacher and the students) are not based on pedagogical criteria – to better learn such or such topic – but are subordinated to the sake of finding an answer to the generating question. In the case here considered, students were requested to formulate their own questions related to the topic. A logical consequence is the increase of complexity for the teacher to guide several parallel inquiries at the same time.

In terms of the didactic contract, this choice produces a change in two directions. On the students' side, it increases their responsibility with delimiting the question to address and finding criteria for it, which entails the learning of new competencies and knowledge. However, some groups could experiment with the frustration of having to abandon a path already taken that later appears to be unproductive. New responsibilities also appear on the teacher's side, like managing the students' proposals and finding criteria to guide the delimitation of the questions. SRPs' questions need to be addressed in real-time, and their selection or rejection can be tainted with a certain subjectivity: what makes a question worth studying? What (and who) determines if it can be properly addressed or not? What are the assumed conditions? A new study, at the end of the activity, will shed light on these questions.

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Actions for Academic Performance Improvement of University Newcomer Students in an Electronics Introductory Subject

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Conference Key Areas: *Student Engagement, Mentorship and Tutorship*
Keywords: Academic performance, Electronics course, University newcomer students, Student engagement.

ABSTRACT

The subject Electronics for Telecommunications (ET) is taught in the first semester of the Telecommunications degrees at the Castelldefels School of Telecommunications and Aerospace Engineering (EETAC). The academic performance is relatively low compared to the same course taught in a double degree of Aerospace and Telecommunications, in part justified by the large difference in the university access marks of the students between both degrees. Several actions have been implemented in courses 2019/20 and 2020/21 to address this issue, especially in theory classes where student attendance is lower than in laboratory sessions. Implementation difficulties have arisen because the presence of the COVID pandemic. Even so, performance has greatly increased, especially at the first semester of each academic year. In addition, a student survey shows a good satisfaction with the introduced actions and others in process of introduction or assessment. Some of the actions, particularly those to be applied in the theory sessions, could be easily extrapolated to other first-semester courses of the degrees.

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1 INTRODUCTION

The subject ET (Electronics for Telecommunications) belongs to the first term (1A) of the Telecommunications Bachelor degrees and the double Bachelor degree of Aerospace and Telecommunications at the EETAC (Castelldefels School of Telecommunications and Aerospace Engineering) of the UPC (Universitat Politècnica de Catalunya). Enrolment in Telecommunications degrees is 120 students (100 in September and 20 in February) and 40 students in the double degree. In the first semester of each academic year, there are separated class groups of Telecommunications and double degrees, but on the second semester, they share the same class groups.

Student pass rate of the degrees was analyzed for the three academic years before the implementation of the proposed actions (16/17, 17/18 and 18/19). During the first semester of each year, pass rate in the double degree was relatively high (approximately 70 %). However, in the Telecommunications degrees pass rate was significantly lower and declining from 41.9 % in 2016/17 course to only 19.4 % in 2018/19. In the second semester of each year, with shared class groups, most of the students are repeaters and from Telecommunications degrees, and the pass rate ranged between 46.7% and 34.4%.

These large differences in the student pass rate between both degrees are mainly justified by the respective admission marks (ranging from 5.0 to 14.0 in Catalonia). Telecommunication degrees have admission marks of 5.0 because not all places are filled. Double degree has an admission mark that has increased from 9.29 in 2016/17 to 10.38 in 2018/19. Furthermore, average access marks of double degree students are 2.5 to 3.5 points higher than Telecommunications students. Additionally, students' profile is heterogeneous in the Telecommunication degrees and more homogeneous in the double degree (students with good aptitude and attitude, in general).

The ET subject is organized in theory classes (large group, 50 students maximum) and laboratory classes (small group, 25 students maximum). Theory classes are based on lectures and resolution of exercises. Laboratory sessions consist on experimental developments based on preliminary laboratory assignments. Theory accounts for 60 % and laboratory for 40 % of the final grade.

Double degree students attend regularly to both theory and laboratory classes. On the other hand, as the course advances, student attendance to theory classes for Telecommunications groups decreases while attendance to laboratory sessions keeps more regular due to continuous assessment [1]. Theory classes include midterm and final exams. Laboratory marks are higher because students work in groups of two or three members. In this way, some students benefit working with mates who have better performance, thus improving motivation and marks than working alone. Lecturer continuous feedback in laboratory classes can also make a difference and become another positive factor [2].

Our aim is to increase the student pass rate of the ET subject, in particular for the Telecommunications degrees and by increasing the theory exams marks. We believe that a greater pass rate will be possible increasing students' engagement, motivation and implication. Therefore, several actions are proposed and some of them already implemented to achieve this goal.

2 PROPOSED ACTIONS: DESCRIPTION AND DEVELOPMENT

We propose 7 actions, 3 have already been implemented, mainly focusing on theory classes, and 4 are going to be implemented in the next academic course, mainly focusing on lab classes. We describe these actions and their motivation, methodology and development during 4 semesters corresponding to the courses 2019-20 and 2020-21.

2.1 Action 1: Initial tutoring meeting

Most of first semester students enrolling the ET subject each academic year are university newcomers. Our School organizes welcome sessions for discussing most commons issues and an initial academic tutor is assigned to each student for guiding them through the first year of the Bachelor degree studies [3]. In addition, each lecturer has several tutorial hours (6 h for full-time personnel) at his office for solving the students doubts and questions about the subjects he teaches. This last resource, which can be very useful, is, however, not much used by new ET students, especially those in Telecommunication degrees. Students show prevention for attending tutoring time at the lecturer office, maybe because this resource is not usually present in pre-university studies.

In order to palliate this issue, we propose the ET lecturer meet all their students for a first interview within its tutorial time at his office, generally 5-10 minutes long. Students can attend alone or in groups, for example those used for the laboratory classes. The lecturer fills a form sheet with student personal information (name, age, pre-university studies and access mark) and informs the student on common academic issues: lecturer tutorial time and purpose, weekly study time, class attendance control, proposals of exercises, and bibliography. These indications are also given in the initial theory class and are intended to reinforce the message through personal interaction. Students can also put open questions they consider to the lecturer. The main goal is to first personally interact with the students to promote their use of the lecturer tutorial time from the very first week in order to improve their academic success. In addition, there are some questions addressed specifically to repeater students to find out why they failed the subject and agree with right proposals for succeeding in the new course.

This action was carried out the first two semesters and also the fourth. In the third semester, partly due to COVID pandemic, it was replaced by a midterm tutoring for those who failed the midterm exam.

2.2 Action 2: Attendance control at theory classes

At laboratory classes, attendance is monitored indirectly because students are assessed at each session. However, assessment of theory content is carried out by means of 2 exams, one at midterm (accounting for 25 % of the overall assessment of

ET) and another at the end of the semester (accounting for 35 %). By default, attendance is not monitored at theory classes. Unfortunately, and for many subjects, student attendance decreases while the course advances, especially in Telecommunications degrees. This has a strong impact in their possibilities of passing the course.

Therefore, we propose implementing an attendance control at theory classes. While it may seem like an out-of-place measure at the university level, it is considered to be beneficial for newcomer students. In this way, missing students can be contacted by the lecturers (by e-mail or in laboratory classes, if they attend) to find out the reason for non-attendance and try to redress the situation, if necessary, by mutual agreement.

In the first semester, time for problem discussion (Action 3) was used for attendance control. In the second semester, however, it was stopped after classes became remote due to COVID. In the third semester, even though theory classes became remote some weeks later, attendance was yet monitored thanks to Google Meet (the used remote platform) that sends attendance automated reports. In the fourth semester, again in face-to-face mode, attendance was surveilled and annotated trough an attendance tool available in Atenea, the virtual platform used in the UPC. Students who were repeatedly not attending theory classes were contacted, mostly by e-mail, and some of them returned to classes.

2.3 Weekly exercises proposal

In order to encourage students to attend theory classes, a weekly list of exercises is proposed as homework. At the beginning of each class, students discuss problem solutions with each other and then the lecturer and the students solve the problems on the board. Students who do not do the exercises regularly are contacted to be able to correct this situation.

This action was implemented in all semesters, including those in which classes were remote. In the first semester we annotated who did them while discussing the exercises in groups. In the second semester, however, this control was not performed when switching classes to remote format. In the third semester, despite most classes were remote, the control was activated again creating tasks in Atenea where students scanned their solutions and submit them before the session. In the fourth semester the control was implemented in the same way.

2.4 Action 4: Demonstrator of the final laboratory project

In the last two laboratory sessions, students implement a short project that covers many of the course topics. The project focuses on measuring and controlling the temperature of a small-scale room. Students have to implement it in a breadboard. This action proposes to implement a prototype in printed circuit board (PCB) in order to show it to the students as a demonstrator. Fig. 1 shows the prototype and its schematic implemented with the Proteus software (Labcenter), which also allows its electronic simulation. The demonstrator will be shown at the beginning of the ET course to increase the motivation and interest of the students towards the subject and also before they start the lab project. In addition, PCBs without the components (students buy the components at the beginning of the course) will be freely distributed to students that want to solder and test the project in the PCB. The demonstrator has been just finished and will be used in the following courses.

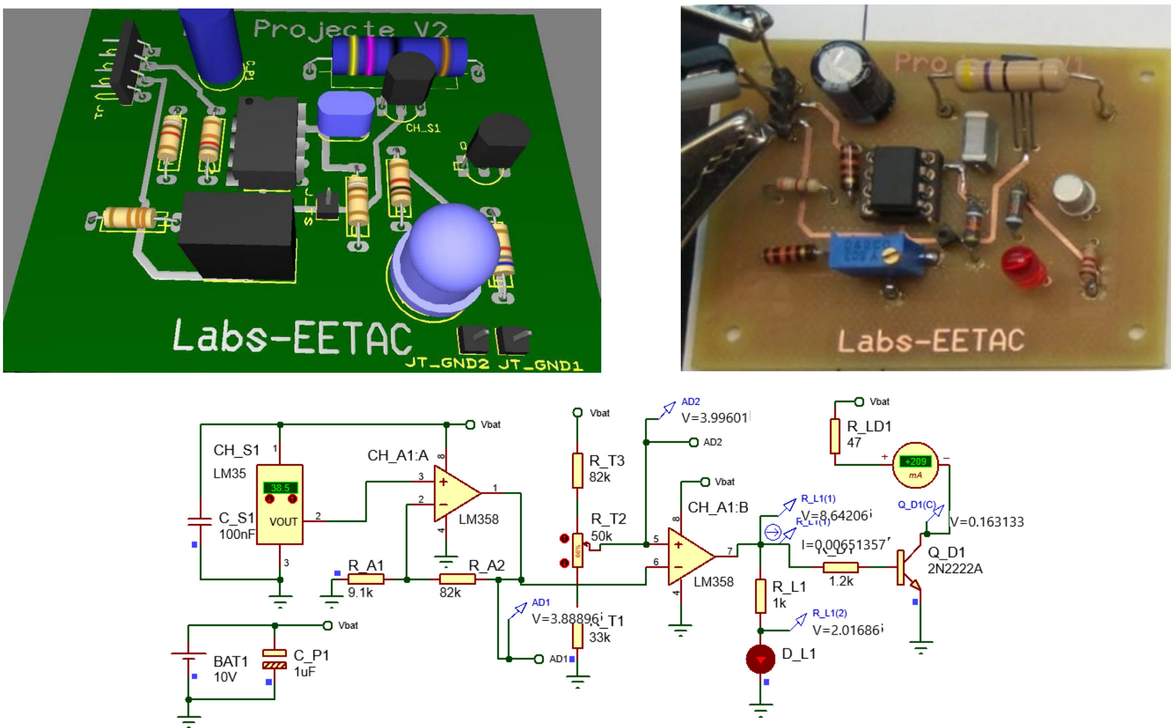

Fig. 1. Laboratory project prototype and its simulation with the software Proteus (Labcenter).

2.5 Action 5: Additional module for the final laboratory project

Fig. 2 shows a digital thermometer based on Arduino that will be used to monitor current and reference temperatures when connected to the prototype of the final project. The module will be used by student lab groups to give more visibility to the work done. This module will also be used as an application example for CSD (Digital Circuits and Systems), a second-year subject, thus promoting interaction between subjects. As the demonstrator of action 5, the module has just been finished and will also be used in the following courses.

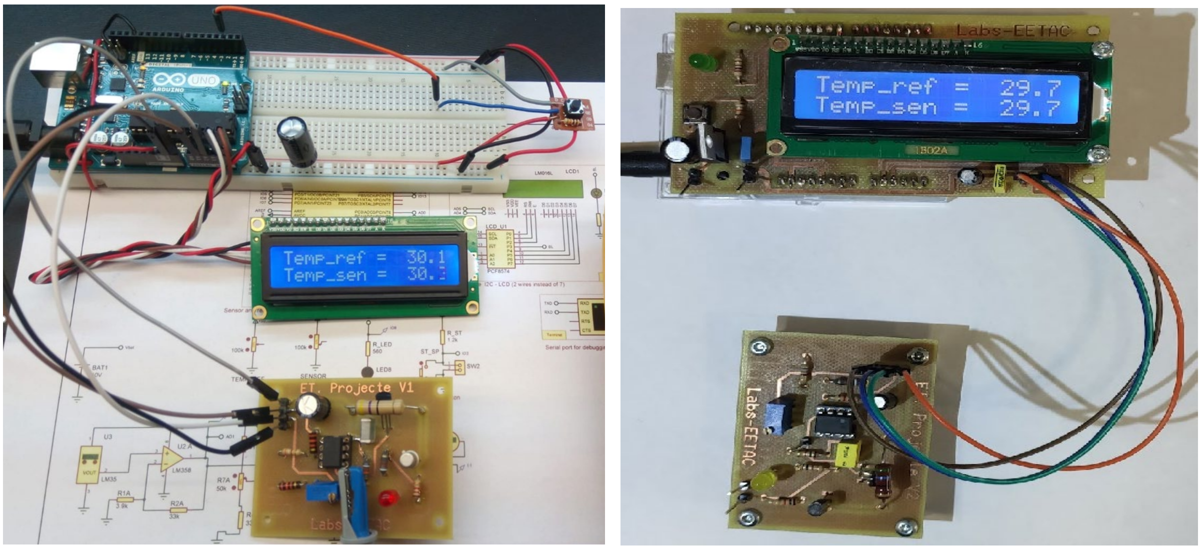

Fig. 2. Displaying current and reference temperatures with the additional module .

2.6 Action 6: Portable multi-instrument device

We have acquired 12 portable multi-instrument devices to be used by the students outside the laboratory (Fig. 3) [4]. The device can be connected to a laptop via USB. Its use can allow students to better prepare the experiments, especially to those student groups who present major difficulties in following the lab classes at a good pace. It would also allow to organize remote labs (at least in part) if laboratories were closed for unforeseen reasons, as was the case during COVID pandemic. In this case, more devices should be purchased to reach all students or establish a loan system. The devices will be distributed to the students in the following courses.

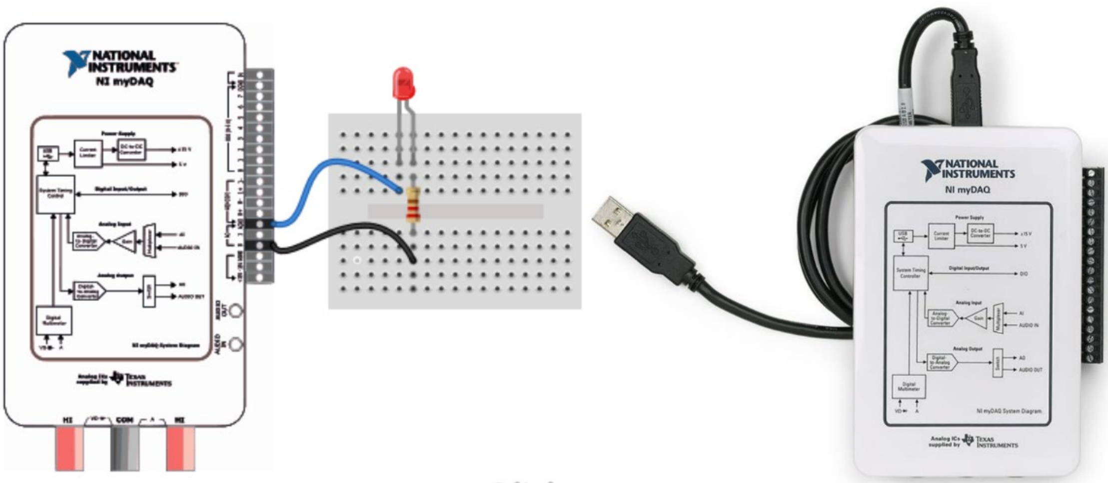

Fig. 3. NI myDAQ, portable multifunctional instrument from National Instruments.

2.7 Action 7: Initial preparatory course

Before starting September classes, the School offers optional preparatory courses of 15 hours in basic subjects (Physics, Mathematics, and Graphic Expression) [5], aimed especially at students from secondary and vocational school who are lacking comprehension on these basic topics and need to review some of these concepts in order to have a better starting of the studies at the EETAC. Even though no electronics previous knowledge is required for ET, we have proposed the same kind of introductory course. Its first edition will be in September 2022.

The intention is to address it especially to students with low university access marks, with no or little prior knowledge of the subject and/or with little or no experience with the basic laboratory instrumentation. The ET preparatory course will consist of some introductory theoretical and laboratory lessons. It is expected registered students have a better initial adaptation to the ET subject and hopefully increase the pass rate.

3 STUDENT SURVEY AND FINAL ASSESSMENT

3.1 Student survey

At the end of the 4th semester, 45 students filled in a survey to assess the proposed actions. Table 1 shows the results, showing for each action the number of students that find it useful or not useful. Some of the students did not know or answer.

Table 1. Results of the survey about the actions to 45 students

Action	*1*	*2*	*3*	*4*	*5*	*6*	*7*
Useful	30	36	43	36	34	36	35
Not useful	7	7	2	4	3	4	4
Don't know/answer	8	2	0	5	8	5	6

Based on the results of the surveys, it is considered positive to continue with actions 1 to 3. Actions 4 to 7 are also considered useful and will be initiated in the following course starting at September 2022.

3.2 Student performance

The project has been developed in a complicated context due to the COVID pandemic. Table 2 shows the student pass rate during the first semester (S1) of each academic year. Included are the 2 semesters where the improvement actions have been implemented as well as the immediately preceding one (*2018/19*, in *italic*). If we compare the latter with the 2019/20 academic year, the overall pass rate rose significantly, from 35,1 % to 53,8 %. In the case of Telecommunication degrees, the pass rate doubled and also rose significantly in the double degree. In the 2020/21 year, there was a slight drop, which we attribute in part to the situation caused by COVID. Anyhow, the pass rate is higher than it was before this project began.

Table 3 shows the pass rate of students during the second semester (S2), where there are not differentiated groups between degrees. As can be seen, the number of students fell in the 2019/20 semester due to the increase in pass rate during the first semester, which is a positive fact. In addition, pass rate also rose significantly with respect to the 2018/19 year. In the 2020/21 year, the pass rate was again relatively low and equal to that of the 2018/19 year.

Table 2. Student pass rate of ET during the first semester. In italic the academic year (18/19) before the improvement actions were applied.

	Total			Telecom Degree			Double Degree		
Course	**Stud**	**Pass**	**%**	**Stud**	**Pass**	**%**	**Stud**	**Pass**	**%**
18/19-S1	*151*	*53*	*35.1*	*103*	*20*	*19.4*	*48*	*33*	*68.8*
19/20-S1	160	86	53.8	117	49	41.9	43	37	86.0
20/21-S1	149	70	47.0	109	37	33.9	40	33	82.5

Table 2. Student pass rate of ET during the second semester. In italic the academic year before the improvement actions were applied.

	Total		
***Course**	**Stud**	**Pass**	**%**
18/19-S2	*79*	*30*	*38.0*
19/20-S2	55	29	52.7
20/21-S2	71	27	38.0

4 CONCLUSIONS

Several actions have been implemented and other are in progress in order to improve the academic performance of university newcomer students in an electronics introductory course. The actions are both addressed to theory and laboratory classes. The actions were well rated by students in a survey and the academic performance of both Telecommunications and double-degree students increased.

5 ACKNOWLEDGMENTS

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WHAT WORKS (AND WHAT DOES NOT) TO INCORPORATE ETHICS AS A CROSS CURRICULAR COMPETENCE?

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ABSTRACT

In 2013, an ambitious plan was implemented at Universitat Politècnica de València aiming at ensuring that all graduates achieved a set of 13 transversal competences which would make them excellent graduates not only from a technical point of view, but also beyond.

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One of these competences in which we want to train and assess our students is "ethical, environmental and professional responsibility". This paper presents the study carried out to check whether this objective is achieved or not for graduates from six different degrees taught at UPV.

To this end, we analysed activities developed within each Bachelor degree curriculum, studying the suitability of each activity to the level of knowledge required in each course. We also analysed the perception of students and lecturers in charge of incorporating this transversal content within their subjects.

In view of the results obtained, "good practices" are proposed, indicating the activities carried out which have succeeded in increasing the students' training and knowledge related to this topic. Activities, which, despite being carried out for a certain purpose, do not manage to work on and assess this cross curricular competence, are discussed.

1 INTRODUCTION

The work presented herein summarises the main findings of the work carried out by the educational innovation and improvement team (EICE Remyp_07), by analysing the way in which the cross curricular competence of ethical, environmental and professional responsibility is worked and evaluated in several bachelor degree courses taught in different schools at UPV [1].

In particular, we focus on indicating the different teaching methodologies used to incorporate this cross curricular competence in the classroom and we analyse which of them have been most successful into their application.

To carry out the analysis we analysed materials used in subjects developing the competence within six degrees taught at UPV. This information was provided by the faculty teaching the specific subjects of the bachelor degree curriculum in which these competences are worked on and evaluated.

2 RESULTS

The specific description of the activities to be carried out for the achievement of the cross curricular competence is uneven, with a high number of subjects detected (27.45%) that do not describe them in detail [2].

After analysing the activities described by the faculty, interviews were conducted with lecturers to deepen their knowledge of activities carried out in the classroom. Even after the interviews, some of the proposed activities were not clear.

The way in which the incorporation of cross curricular competences at UPV degree programmes was approached has room for improvement. Once again, the workload was "passed on" to lecturers, who a priori had to work on and evaluate contents they did not necessarily are experts.

Participation in training courses was facilitated, but on a completely voluntary basis and as an additional task to the usual daily teaching and research tasks. On the other hand, there has been a lack of institutional evaluation of the way in which these competences are being incorporated, with control being limited to the marks obtained by students (without considering whether we are evaluating these competences correctly). This fact leads to a loss of interest in correctly carrying out the difficult task of incorporating cross curricular competences into specific subjects.

Among the most common activities, one can mention the case study, used in 19.61% of subjects, followed by project-based learning and reading, both used in 11.76% of subjects (Figure 1). There is a very strong correlation between some methodologies and the particular Bachelor's degree.

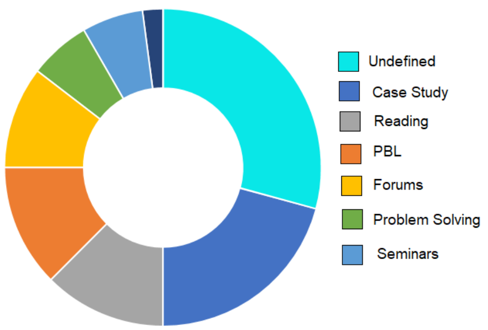

Fig. 1. Methodologies used for developing the UPV cross-curricular outcome [2]

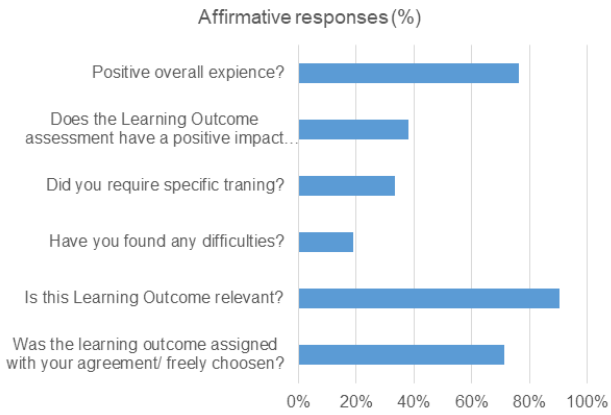

Fig. 2. Lectures´opinions [2]

However, it is remarkable that most lecturers are willing to incorporate this content into their subjects along with other specific content. Most of them are also willing to design activities related to it. However, in a competence such as ethical and professional responsibility, it is essential to have knowledge of ethics in order to be able to do it correctly (although around 80% considered that they had no difficulty in incorporating it, Figure 2)

3 RECOMMENDATIONS FOR GOOD PRACTICE AND CONCLUSIONS

Having analysed all the material provided by lecturers in charge of working with and assessing the cross-curricular competence, we can highlight:

- It is necessary to train students who are to be assessed on the cross-curricular competence. Ethical, environmental and professional responsibility is not something that students have innately, nor is it something "personal" or belonging to the private sphere of individuals. For this reason it is imperative that students are trained prior to carrying out the activities in which they will be assessed.
- It is very difficult to assess both aspects of the competence in a single activity. As it has been shown, in most cases only one of the two parts of the competence is worked on and assessed effectively. For this reason, better results are achieved by developing activities that work on and assess the part related to environmental

responsibility and other activities that work on and assess the ethical responsibility linked to professional performance.

- It is very important to link activities designed for the assessment of the cross curricular competence to the content of the specific subject, and if it is not possible, at least to the bachelor degree scope. Doing so, students become aware of the importance of responsibility in their professional performance.
- Lecturers in charge of working with and assessing the part of the competence related to ethical and professional responsibility need guidance in training and designing activities for assessing students. Approximately 40% of the activities that are currently being carried out in the classroom do not work on or assess this competence despite the desire to do so [2].
- Students have four academic years (the duration of the bachelor degree) to achieve a certain proficiency level of the transversal competence. This means that it is necessary to design the training in an evolutionary way, increasing the level of difficulty and complexity of the activities throughout the curriculum. It is desirable to develop coordination between lecturers who are going to work on this transversal competence throughout the degree, in order to correctly design the activities and increase the degree of complexity without repeating content, and taking into account the progress in the development of the competence.
- Accordingly it is interesting to start in the first years (first proficiency level) with less complex activities (identification of unethical and unprofessional behavior, for instance [3-4]). As the curriculum progresses, more complex activities such as the resolution of ethical dilemmas that require knowledge in order to be able to argue the most appropriate solutions can be proposed.

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CHALLENGE-BASED LEARNING CURRICULUM DEVELOPMENT: A SUITABLE FRAMEWORK FOR ENGINEERING EDUCATION (CONCEPT)

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ABSTRACT

Collaborative learning communities are becoming popular in engineering education. The department of Industrial Design at Eindhoven University of Technology (TU/e) has almost 20 years of experience in the organization of small-scale and challenge-based education (CBL). In Industrial Design, students work in 'collaborative communities' called *'squads'* that share an interest in specific application domains. Within the squads, vertical learning takes place and students from different bachelor

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and master years exchange experiences and learn together in a learning community while solving open-ended societal challenges. The purpose of the research was to map the characteristics of two ID *squads* (for the purpose of this study we will name the squads *Vitality and Crafting Everyday Soft Things (CEST)*, and study the educational elements influencing students' learning. In nature, the two squads share the same educational principles, however, the differ in the organization of education and the level guidance provided, decreasing, to some extent, the open-endedness characteristics of CBL. To conduct the study, we used the constructive alignment as a research framework to map the alignment between vision, teaching and learning activities and assessment of the *squads*. Results show alignment of the Intended Learning Outcomes (ILOs) with teaching and learning activities, and assessment in the two *squads*. The analysis draws attention to the similarities and differences between the two *squads,* specially in the manner of structuring learning. Finally, the suitability of the framework to analyse the CBL curriculum in engineering education contexts is demonstrated. This research opens up opportunities for future studies to investigate learning in small communities.

1 INTRODUCTION

Design is a discipline that fosters creative thinking to design products and systems and solve innovative real-life problems. Design is a complex, multifaceted problem-solving activity involving various cognitive abilities. Creativity and spatial ability are considered critical in design process. The work of a designer is perceived as 'making' the artifact or a description of what that artifact should be like and the communication around that specific design. Communication and socialization are essential elements of design education to prepare students for the workplace, therefore, replicating industry practices are important elements in the learning environment in which students learn and work collaboratively with other students [1]. Furthermore, communicating and socializing through participation in a community of practice [2] is a promising environment for learning representing authentic working places acquiring meaningful learning, developing competencies and skills, and shaping an identity as a designer.

From students' point of view learning communities are suitable environments that provide benefits for learning. According to Dodge & Kendall [3], students benefit from learning communities as they discover together *how concepts learned in one subject can be applied to projects assigned in another; can work together to solve class-related problems; reinforce students' own skills by teaching and mentoring fellow students in various subjects; learn how experts in each field coordinate classroom activities across disciplines; adapt to multiple faculty members' perspectives and classroom environments; make friends with students enrolled in the community; arrange a convenient class schedule of closely integrated courses; and increase their chances for success in personal, academic, and professional arenas'.* Furthermore, the goals and activities of the learning communities organized around workforce skills learning communities can stimulate students to practice skills, gain motivation and develop self-regulation [4]. Challenge-based learning

(CBL) is an educational concept and method by which students work together in open-ended, real- life and multidisciplinary wicked projects [5-6]. Within the context of ID, students work in *squads, i.e. learning communities,* to propose innovative solutions to global challenges.

In this study, we focus on investigating the characteristics of two *squads* as learning communities that foster students' learning. We apply a framework for this study to research two *squads* using the context of the constructive alignment [7]. The purpose of this study was to research the following questions:

1. What are the characteristics of the organization and structure of the *Vitality and CEST squads*?
2. How does the organization of the squads supports students' learning?

2 THEORETICAL CONSIDERATIONS

The notion of communities of practice has been related to the idea of having novice students to work collaboratively with experts in order to learn from each other and transfer knowledge and skills to less experienced students or staff [8]. Other researchers identify communities as 'discourse communities' or 'communities of practice' [2] as a means to socialize. Socialization in this regard is considered a powerful paradigm in which the scenarios to exchange experience from experts to novices provide useful opportunities for learning. Differences among these concepts lies in the formal or informal approach to learning. While Swales' idea of 'dicourse communities' focuses on academics interacting with different disciplines, Lave and Wenger's approach emphasises an informal way of learning where 'communities' and 'apprenticeship' are central to involving people based on common interests participating in a joint project or task.

Modelling expert practices has been characterized in the literature under the educational concept of 'cognitive apprenticeship [9] emphasizes processes employed by experts to handle complex tasks and teaching cognitive and metacognitive (as opposed to physical) skills and processes. Critical to the notion of learning communities and communities of practices is the theory of situated learning [2] in relation to CoP as a self-defined and self-developing approach. Researchers differ about the added value of external support such as facilitators or moderators. Other investigators of this concept [10], however, highlight the importance of the role of 'academic staff developers' who can be considered crucial in the 'harmonization' process when new academic staff join a CoP to streamline learning.

In the last decades, the concept of 'learning communities' and 'communities of practice' have become an instrument to materialize informal learning in organization, and, more specifically, for the purpose of this study, in learning organizations such as universities [6]. Collection of examples in this regard include 'models' for classroom organization of communities [11], or for the stimulate learning through a process of socialization [8] as a mean to promote practices that represent the workplace environments where informally learning occurs through the interaction with more experienced colleagues. The theoretical insight behind this rationale lies in that learning takes place during the process of co-participating and co-creating by socializing with practitioners resembling authentic scenarios or withing the working places [12].

Grounded on these theoretical insights, we investigate the characteristics of the *squads* as learning communities, and more specifically, we pay attention to the impact of the educational organization of the *squads* on students' learning.

3 *SQUADS* AS LEARNING COMMUNITIES

Squads are the learning environments in which students learn and work together. Squads are thematic contact points for structural contacts between research and education as well as between academia and industrial/societal partners. Squads represent the expertise areas or disciplinary domains that give form to the content on the curriculum and cover all diversity in design elements and offer students a rich and diverse learning environment. Squads, as thematic learning communities, consists of academic staff, BSc and MSc students and external stakeholders, who collaborate on shared interests for the duration of a semester. The learning organization of the squads promotes selfdirectness and students can choose among a variety of projects. Furthermore, squads integrate the research interests of three to four academic staff members and PhD candidates, with the societal interest of clients, user groups and experts from practice, often represented by one or two Industry Liaisons, and the educational interest of 2nd and 3rd year Bachelor students and 1st year Master and 2nd year Master research students.

Cultivation and socialization processes allow students to become part of the previously described community. Teachers act as role models and model important values and implicit beliefs that students experience. The organization of learning fosters, therefore, feeling of community that stimulates the sense of belonging and inclusion amongst students, staff and partners. This allows the squad and the squad structure to become rich educational eco-systems that promote educational experimentation, innovation and differentiation.

The creation of smaller communities in a squad is an important mechanism to channel students' learning processes using horizontal peer learning (same year and same project) and vertical peer learning (different year, similar project and same squad). Peer learning is a valuable way for students to learn by receiving feedback from more senior students or equals and providing feedback to less senior students and equals.

4 METHODOLOGY

4.1 Context

Our study was conducted in the department of Industrial Design, in the context of two *squad* teams, which included several projects with a great variety in student characteristics (e.g., bachelor or master level) and project characteristics (team or individual projects, open-ended).

4.2 Data collection

Data were collected using a qualitative method approach to gain in-depth information about the structure of the squads, and the alignment between vision on education implemtation, Intended Learning Outcomes, Teaching and Learning activities, and Assessment. Observations of coaching situations were conducted for 1 semester. Interviews with students, coaches and experts from the industry were conducted at the end of the course. Interviews lasted approximately 45-60 minutes, and the participation was voluntary.

4.3 Participants

We conducted interviews and observations with coaches, industry experts and students from different levels (e.g. bachelor, pre-master, master, etc.). In total 31 interviews were conducted with students and 8 coaches were alongside with weekly observations of *squads* teaching and learning activities. An overview of participants can be found in Table 1.

Table1. Overview participants from Vitality and Crafting Everyday Soft Things (CEST) squads in this research

Participants	***Vitality Squad***	***CEST Squad***
Coaches	3 (1 internal 2 external industry coaches)	4 (2 internal coaches and 2 industry experts)
Teaching Assistant	1	
Bachelor students	3 (1 group)	4
Final Bachelor Project (FBP) students		1
Premaster	4	2
Master	9 (4 individual projects, 2 groups: 1 group with 3 and I group with 2)	2 master students.

4.4 Data analysis

Data were analyzed using thematic content analysis. An iterative process was followed where the two researchers read the transcripts of the interviews several times and followed an open coding approach. After several discussions, they developed a coding framework applied for all interviews**.** The Constructive Alignment model by Biggs and Trang (2011) [7] was used as a framework to map the characteristics *Squad* A and *Squad* B, in order to understand the differences and similarities of the organization of these two squads that may impact the learning of the students.

5. RESULTS

5.1 Mapping characteristics of the *Squads*

Despite the fact that *Squads* are different in expertise and thematic areas, they share similar educational principles and characteristics including the focus on the development of students' self-directed learning skills and the development of their professional vision and identity by working on projects where students can acquire and apply their design knowledge and skills. Another commonality among the squads is that they share the same way of assessing students learning with the use of a rubric that describes all competencies students are expected to develop (Table 2).

Table 2. Overview of general educational characteristics of the squads

Squads common educational chaterisctics	**Collaborative learning community**
Self-directed learning (SDL) is on of the pillars of the educational model.	**Coaching:** students are coached to make own choices on courses that best match their interest, at project level but also on career development. **Personal Development Plan (PDP**): students set learning goals and reflect on progress.
Professional Vision & Identity (PV&I)	Vision and identity as a designer are fully embedded in the reflections and designs students produce.
Application/acquisition knowledge	Knowledge is acquired and applied in design steps students go through in iterations. New knowledge is generated and used again by prototyping, etc. (Mid-term) Demo Day is a feedback and assessment moment to demonstrate designs, prototypes, etc. Students get feedback used to improve the product upo which they are assessed.
Assessment	**Rubrics** are used to provide feedback during the process, and finally, to assess students.

5.2 Linking vision with implementation: Constructive alignment from a curriculum perspective

The results suggest that squads provide an active learning environment of collaboration among students of different levels.

Regarding, constructive alignment both squads identified broad Intended Learning Objectives including knowledge acquisition, knowledge application, self-directed learning and professional development as designers. To achieve these objectives,

both squads have adopted a Challenge-based learning approach as means of their education.
This entails providing students with real-life, open-ended, and hands-on projects. The squads as learning communities provide to students a wide range of teaching and learning activities that aim to foster the ILOs.

The organizational set-up of the *squads* is similar (e.g. learning takes place in the form of a community where students from different bachelor and master levels provide peer feedback, learn from coaches and industry liaisons, and share themes' interests), promotes ***vertical learning*** as a structure.

Common activities targeting ***knowledge acquisition*** in both squads involved: weekly workshops on key topics that would assist students to get some baseline information for their project.

In terms of ***peer learning***, both squads provided an interactive open space for students to interact and learn from each other. ***Cross –coaching*** did take place in specific times of the semester before midterm and final demoday in *Squad Vitality* while in *Squad CEST* all coaches had a discussion with all groups on a weekly basis.

Regarding ***knowledge application***, in both squads students were encouraged to ***work on prototypes*** that were exhibited in the rooms so other students and coaches could provide feedback on their evolving efforts.

Self-directed learning was encouraged by giving to studnets autonomy to focus on interesting projects about them as well as coaching throught the semester to scaffold the process. In both squads, similar activities (e.g. individual feedback on PDP, coaching on self-directness and vision on professional identity, peer feedback, etc.) stimulate SDL.

Differences between the *Vitality and Crafting Everyday Soft Things (CEST) squads* are the structure provided to guide students learning. While in CEST s*quad* students get general information about organization of the activities and deadlines for delivery of products with no further indication of how deliverables must be submitted; Vitality s*quad* provides more strict guidelines on the form of the deliverables framing the students' expectations more closely. Finally, regarding ***final assessment*** as described above both squads employ the same rubric for assessing studnets'developmet of key competencies. For students assessment process was clear but still the criteria for assessment were considered quite subjective.

Table 3. Overview results mapping squads characteristics

Mapping characteristics squads	***Vitality Squad***	***CEST Squad***
CBL	General Intended Learning Outcomes (ILOs) for *Vitality squad* are provided. Open-ended: projects have no predefined end goal. Students need to define their own project objectives after consultation with external clients and their coaches Hands-on: designing interventions for behavioral change at an individual or systems level Real-life: projects focus on designing solutions for healthier lifestyles. Projects are often in collaboration with industry clients	General Intended Learning Outcomes (ILOs) for *CEST squad* are provided. Open-ended: Students formulate own project that meets own learning goals and fits within CEST s*quad* ILOs. No guidelines are given and therefore problem is ill-defined depending on students' own directions. Real-life: Projects framed in a design to contribute to societal and industrial interests. Students contact stakeholders (some time outside the university) to test or validate product. Multidisciplinary: challenges converge several disciplines, e.g. design, business, society, health components, etc., depending on the challenge goal.
T&L	Workshops are provided in the first half of the semester for students to acquire important baseline knowledge that could be useful for their project Weekly inspiration shot activities aim to foster students' creativity and develop skills (e.g., photography) that are useful for their project or deliverables Weekly coaching sessions Cross-coachings sessions in two predefined moments during the semester and ample opportunities for feedback on demand Workshops on PDP and individual coaching sessions on demand (Mid-term)Demo Day is meant to serve as milestones for students' project development and opportunities for practicing important professional skills	Workshops aimed at providing 'just-in-time' content and knowledge on a specific topic, i.e. are organized. Focus on provided knowledge needed to apply in solving the challenge. Friday morning feedback moment organized where coaches and industry experts provide feedback and advice. Peer feedback from students is organized and cross-coaching is from different experts to support students' learning. Individual feedback on PDP. (Mid-term) Demo Day is meant to encourage students to practice some professional skills

Assessment	Rubrics used to assess students' competencies development Assessment is based on various deliverables that assess not only students' final product but also highlight their progress and development throughout the semester (e.g., prototype, final report, final report on PDP, presentation etc)	Rubrics are used mainly for assessment. Rubrics are not fully always used for feedback.

5 CONCLUSIONS

In this study, the organizational structure of two *squads*, *Vitality squad* and *CEST squad* , as learning communities is investigated. Mapping the organization of learning following Biggs and Trangs' model (2011) [7] is applied and shows similar characteristics in the structure and alignment between the learning outcomes, teaching and learning activities and assessment. Among the most helpful teaching and learning activities include the provided workshops to support students' just-in-time knowledge acquisition, the feedback provided on progress as part of the weekly coaching, and cross-coaching sessions that supported students' learning in the design process. Students also appreciated the informal learning moments and collaboration between different groups and teams.

Likewise, vertical learning and self-directed learning are clearly identified in both squads. This shows that the ID educational model with its educational principles on learning is widely applied in the organization of the squads to promote learning. This has been confirmed in the students' interviews.

Interesting to see is that differences are mainly encountered in the level of structured guidance provided to the students when conducting project activities. Although guidances does not hinder learning, it highlights a difference in the application of the CBL educational form and SDL, in which students are expected to take the lead in the learning process.

Finally, this study shows the suitability of the famework [7] used to map and analyse the characteristics of the squads as a learning community, and more specifically, the alignment between the learning outcomes, the teaching and learning activities, and the assessment methods of the two squads researched.

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IN THE SEARCH FOR THE FUTURE ENGINEER: THE EELISA DISCIPLINARY BROADENING WORKSHOP EXPERIENCE

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ABSTRACT

The emerging adhocracy of sustainability in every field of life, do also claims its legacy in the field of education, particularly in the discipline of engineering. Institutions necessitate to adapt their curriculums to the possible changes so that the engineers of the future are ready to address interdisciplinary and evolving challenges in their careers. As a European University Alliance aiming to define and implement a European engineering model, EELISA project has a dedicated work package to explore and propose various approaches to address this challenge by deploying disciplinary broadening workshops. This paper scrutinizes the initial outputs of the first full-day workshop organized by three partner universities of the alliance under

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the theme of “Cities and Communities” in October 2021, and opens it to a broader discussion.

This paper is structured in four parts while deploying qualitative research methods to analyze the collected data. Initially, it expresses the role of EELISA University, the state-of-the-art skills of today’s engineers and the challenges for enriching them to materialize the vision of European engineering, including bridging and expanding disciplinary domains. The second part explains the workshop structure that was organized under four interdisciplinary subtopics related to the theme to increase the involvement of various engineering and non-engineering academics and professionals. Then the workshop outputs, the participants’ brainstorms about the skills, competences, proposals to overcome challenges and barriers are conveyed. The final part summarizes the workshop results and introduces valuable inputs to the search for the European engineer profile and the roadmap of the EELISA.

1 INTRODUCTION

1.1 EELISA European University

The **European Engineering Learning Innovation and Science Alliance (EELISA)** is the first alliance of Higher Education Institutions from different countries in Europe meant to define and implement a **common model of *European engineer*** rooted in society. The alliance of nine universities from seven countries has a mission to transform European higher education into the seed for a future in which society masters global challenges with smart and sustainable solutions enabled by engineering. EELISA envisions a higher education system that enables student citizenship participation and employability by:

- *Evolving interdisciplinary engineering learning*
- *Fostering knowledge and technology transfer*
- *Stimulating inclusiveness and diversity*
- *Connecting academic excellence to social impact and commitment*

The EELISA project has nine work packages to realize the mission and vision of the project ranging from curriculum development to education management and accreditation, from establishing communities for societal challenges to the link between Education, Research and Innovation, from effective internships to mobility with inclusive student participation.

1.2 Disciplinary Broadening Work Package

EELISA project has a dedicated work package called “Disciplinary Broadening” (WP8) with an ultimate goal of enriching the skills of the engineers of the future after an exchange with other disciplines and reciprocally incorporating engineering methods in other areas by realizing tasks of

- Identifying interdisciplinary needs of the engineer of the future
- Designing of bridging models for multiskilling in engineering education
- Identifying engineering skills needs of other professional domains
- Designing bridging models between engineering skills and other professional domains
- Implementing multiskilling pilots for other disciplinary domains
- Gathering feedback and adapting pilots

The objective of the work package is to nurture international and interdisciplinary stakeholders of academic and non-academic members of our communities, who address complex problems. EELISA’s vision of European Engineering will help us bridge and expand disciplinary domains, and focus on skills needed by engineers as well as engineering skills needed by other professional fields.

1.3 Disciplinary Broadening Workshops

The main activity of the Disciplinary Broadening Work Package of the EELISA Project is a series of full-day workshops. These workshops are designed to help EELISA meet the specific goals of the work package by starting with the description of skills of the engineer of the future in various disciplines and exploring ways of enriching engineering skills with non-engineering competences and introducing engineering skills to other professional domains. Workshops help collect inputs from the stakeholders with various profiles including academics, higher education administrators, student representatives, representatives of scientific societies, industry/society stakeholders and policymakers, and representatives of placement offices.

Outcomes of the disciplinary broadening workshops will provide direct input into the effort of defining the European Engineer Profile led by WP2 of the EELISA project. This effort is not limited to workshops but also utilizes interviews with top professionals in Europe, surveys with various stakeholders, and the literature. Identification of professional skills is not a brand new point of interest.

European Society of Engineering Education has a dedicated Special Interest Group on “Engineering Skills”, where Murphy et al. emphasize the importance of the regional variations in the definitions while elaborating on common issues within the formation and education of the engineer [1]. A-STEP 2030 project underlines the importance of skills for engineers to address challenges associated with the Sustainable Development Goals (SDG) [2], which are in line with two pilot tracks of the EELISA project, **Smart, Green and Resilient Cities** and **Sustainable and Smart Industry**. Crean et al. obtained similar needs in particular for the concepts of society and sustainability as part of a study on mapping the development of professional skills in a structural engineering program [3]. The interdisciplinary approach is another aspect that came out of the study by Flament and Kövesi especially to address the addressing sustainability issues [4]. Beagon et al. [5] identified sustainability competences from the perspectives of students, industry and academics in four European countries. Their findings are mostly in line with the findings of the European [6] and International [7] framework competences. Disciplinary broadening workshops have the potential to contribute to the literature.

2 METHODOLOGY

2.1 Cities and Communities Workshop

The theme of the first workshop was “Cities and Communities”, which took place online on October 26th, 2021. Including three faculty members from the host institution, the organizing team of the workshop consists of eight professors from three EELISA partner institutions.

The flow of the full-day event contains two keynote speakers in the morning and afternoon sessions, a single panel discussion after the keynote in the morning, parallel interactive workshop sessions managed on a Miro board before the noon and after the second keynote in the afternoon, and a closing discussion session for the organizing team to wrap up the outcomes of the workshop.

2.2 Parallel Workshop Sessions

Four subtopics of the Cities and Communities Workshop include **“Infrastructure and Mobility”, “Energy and Climate Change”, “Culture and Inclusiveness” and “Buildings”**, which are discussed in four breakout rooms, BR1, BR2, BR3, BR4, respectively. In each track of focus, the workshop coordinators accordingly aimed to attain participants’ responses on four interconnected inquiries that constitute the essences of the disciplinary broadening attempts: *mapping the skill gaps, mapping the disciplinary boundaries and learning* in the morning session*; and proposing innovative teaching and learning activities*, and proposing the *bridging models* in the afternoon session (Figure 1).

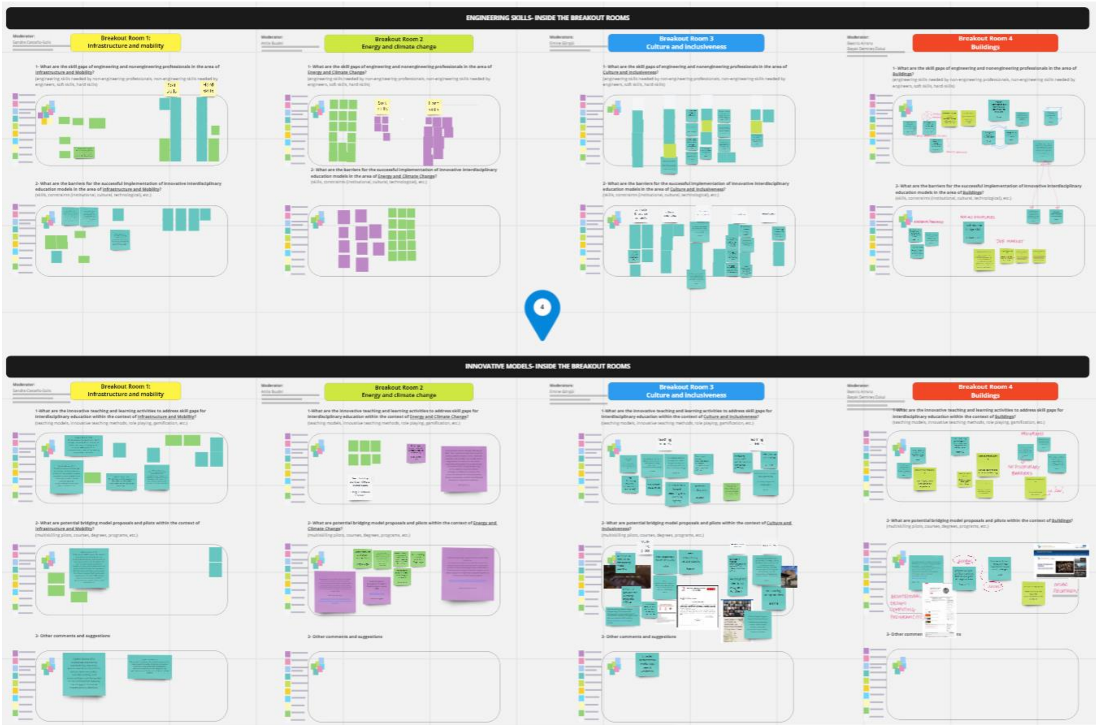

Fig. 1. High-level preview of the miro board designed for the workshop.

3 RESULTS

3.1 Workshop Participant Profile

Among 64 registrants, 44 attended the event, 30 of which were female. The participant profile was predominantly from academia including faculty members, Ph.D. students, and staff. During the discussions in the breakout rooms, some of the participants from academia shared their work experiences or collaborations with partners from public bodies, industry or NGOs. In addition to that, the keynote speakers’ profile and speeches during the event indicate ties and interactions with various stakeholders.

- Roger Hadgraft (Keynote Speaker 1): “Educating Interdisciplinary Engineers for Future Cities and Communities”

    - Overview of a recent review of engineering education in Australia conducted by the Australian Council of Engineering Deans and some examples of curriculum changes to achieve these outcomes.
- Hatice Sözer: “Preparing students to the professional life”
    - Interdisciplinary project-based educational program, InterPROfessional Projects Program at the Illinois Institute of Technology at Chicago, to prepare students for a dynamic and competitive global environment.
- Gülcemal Alhanlıoğlu: “A method proposal for gaining practical practices in higher education”
    - Practice of working together with other disciplines by trainings to introduce business life and laws & regulations, economic knowledge and practice of working together with other disciplines.
- Bettina Szimonetta Jäger: “My journey into the world of complexity”
    - Interdisciplinary work experience at the municipality and collaboration opportunities between the university education and the local government from the perspective of a doctoral student with a non-engineering background.
- Paolo Dario: “The RoboTown vision: bridging research and innovation, education and societal impact”
    - The interaction between local entities and disciplines to integrate robotics into living environments and cities.
- Zeynep Erden Bayazıt: “Spanning Boundaries in Education: Fire-Up Changemaker Community Experience”
    - Overview of relevant interdisciplinary, interinstitutional and intersectoral challenge-based innovation activities supported by a partner entrepreneurship and innovation centre.
- Birgül Tantekin Ersolmaz (Keynote Speaker 2): “Opportunities, Challenges and Good Practices in the Accreditation of Interdisciplinary Programs”
    - Main features of outcome-based accreditation and discuss the opportunities and challenges for accreditation of interdisciplinary programs.

3.2 Workshop Results

About the initial inquiry on mapping the skill gaps, most of the participants in each sub-track reflected their responses based on hard and soft skills. These skills were reflected either as the missing qualities, or the ones that were obliged to be attained from diverse disciplinary backgrounds of engineering and non-engineering groups.

When the outcomes are categorized in similar groups, the urgencies for enhancing the ***trans-disciplinary knowledge skills***, ***system thinking***, ***assessment skills***, ***robotic skills***, and other related skills on ***control and automation***, skills for ***sustainability*** as well as ***business and management*** appeared as the emerging ***hard skills*** for the disciplinary broadening (Table 1).

Table 1. Thematic categorization of hard skills for disciplinary broadening in breakout rooms

Trans-disciplinary knowledge production	Social sciences skills for the engineering (BR3)
	Social science skills for non-engineers (BR4)
	Health science skills for non-engineers (BR4)
	Psychology skills for non-engineers (BR4)
	Analytical skills for non-engineers (BR2) (BR3)
	Indigenous knowledge (BR3)
	Science knowledge (BR1)
	Lack of the knowledge regarding the strategic and legal context (BR2)
	Analytical skills for non-engineers (BR3)
	Thermodynamics (BR1)
	Utilities (thermal, electrical, etc.) (BR1)
System thinking	Systems thinking, relating concepts (BR1)
	Ability to understand indirect and direct impacts (BR2)
	Problem identification and definition and redefinition- for engineers (BR4)
	Synthesis of different type of data (BR2)
Assessment skills	Awareness capabilities (BR1)
	Vulnerability assessment (BR2)
	Adaptation-oriented evaluation (BR2)
	Professionals: research methodologies and perspectives from STS (BR4)
Robotics, control and automation	Robotic skills for non-engineering background (BR3)
	ICT skills for non/engineering professionals (BR3)
	Infrastructure and building informatics, communication systems(BR1)
	Energy storage technologies (batteries, thermal storage, etc.) (BR1)
Green skills	Sustainable energy technologies (BR1)
	Green financial tools (BR2)
	Sustainability management skills (BR2)

	Socio-economic aspects of climate studies (BR2)
	Ecology and sustainability management skills (BR3)
	Misinterpretation of the relationship among sustainability and climate adaptation (BR2)
Business and management skills	Business administration and entrepreneurship skills (BR3)
	Business administration / entrepreneurship skills will be needed for successful implementation of ideas (BR3)
	Audience analysis and management tool (BR3)
	Change and innovation management skills (BR3)

On the other side, related with the ***soft skills*** we observed a broader variability of issues being reflected in each sub-track. When the outcomes were categorized accordingly, the urgencies of ***communication skills***, skills for ***resilience***, ***inclusiveness in multi-levels***, ***collaboration***, ***multi-disciplinary*** and ***system thinking*** as well as ***creative thinking skills*** appeared as the emerging skills for the disciplinary broadening (Table 2).

Table 2. Thematic categorization of soft skills for disciplinary broadening in breakout rooms

Communication (conflict resolution-knowledge skills)	Communication (BR4)
	Social skills (BR1)
	Language skills (BR1)
	Psychological skills (BR2)
	Relationship with friendly and flexibility (BR3)
	Professionals: conflict resolution (BR4)
Resilience	Dealing with uncertainty (BR4)
Multi-level of inclusiveness	Human centered approach (BR3)
	Take care for disadvantages groups (BR3)
	Thinking with ngo and also global and local problems (BR3)
	Awareness capabilities (environmental and social awareness) (BR1)
	Environmental and social awareness (BR4)
	Dealing with real world limitations (designers) (BR4)
	Problem defining and re-defining (BR4)
	Collaboration culture (BR1)

Collaborative skills	Collaboration skills with engineers and design studios (BR3)
	Empathy and problem solving skills (BR3)
	Teamwork (BR1) (BR3)
	Time-management (BR1)
	Sense of responsibility (BR1)
Relating concepts and applying them to multidisciplinary projects, systems thinking	Working in multidisciplinary teams (BR1)
	Introducing multidisciplinary projects at first courses (BR1)
	Industrial exposure (BR1)
	Lacking knowledge in social areas (BR1)
	Re-assigning the notion of complexity in non-engineering background (BR3)
Creativity, curiosity	Thinking outside the box (BR4)

Briefly, in this initial inquiry about required skills for disciplinary broadening, immediate hard skills for enhancing interdisciplinary and trans-disciplinary knowledge such as management and robotic skills and advanced knowledge on sustainability were proposed while blending them with advanced knowledge of humanities and social sciences. Besides, analytical and qualitative assessment skills have been addressed throughout the breakout rooms. In addition, advanced communication skills, problem finding and solving skills, system and complex thinking skills and creative thinking skills further emerged as soft skills that are required for advanced disciplinary broadening.

About the initial inquiry on the ***mapping the disciplinary boundaries and learning,*** most of the participants in each sub-track developed their responses based on hard and soft skills that are required and to be attained from both disciplinary backgrounds of engineering and non-engineering.

So, during the parallel discussions in the breakout rooms, inquiries related with the *tertiary or higher education* ***culture****,* ***curriculum****,* ***teaching strategies*** *and* ***methods****,* ***institutional challenges****,* ***global challenges****,* ***bureaucratic structures, funding opportunities*** *and* ***sectoral linkages*** emerged as the forthcoming issues, that can be further detailed into further permutations with each other.

About the initial inquiry on the ***proposing innovative teaching and learning activities,*** most of the participants in each sub-track developed their responses on the basis of hard and soft skills that are required and to be attained from both disciplinary backgrounds of engineering and non-engineering.

When the inquiries are examined in detail, recommendations about ***curriculum improvements*** are visible on behalf of enhancing the content of courses in terms of interdisciplinary and trans-disciplinary broadening of knowledge while ***updating them in relation to global challenges such as sustainability***. Beyond content, ***educational operations*** such as student numbers capacities, teaching capacities, international collaborations and extracurricular activities, are also highlighted in the discussions.

Based on the synthesis of the workshop content by the rapporteur and organizing team, a number of operational statements have been identified including ***interdisciplinary degrees, graduation design projects and courses, credited interdisciplinary activities, industry-sponsored internships, industry-sponsored courses, industrial design department project courses, eelisa-wide courses, integrated engineering programs, interdepartmental student activities outside the classroom, mobility for innovative teaching/learning activities, experience-based activities, conference participation, competition activities, center of excellence in engineering education*** *and* ***center of excellence in mobility and infrastructure***. Supporting information for these operational statements included the target students, learning outcomes, teaching forms, required infrastructure, and involved academic sectors for guidance.

Workshop results constitute relevant information for various work packages of EELISA. Some of these are direct inputs to various work packages and tasks, while other work packages may found them useful. For instance, the skills explored during the workshop are potential inputs for the task of proposing a shared definition of the profile of the European Engineer by WP2. The innovative learning and teaching activities, and bridging models proposed during the workshop are direct candidates for the design and implementation of WP8 multiskilling pilot applications in engineering education, which will be managed in coordination with the WP2.

Other indirect relevant information from the disciplinary workshop series may help WP3 representatives to reassess and update the curriculum for contemporary teaching inquiries and paradigms, diminishing workload; to inspire many different learning activities such as solar decathlon, by communities developed by WP4; to guide implementing institutional collaborations via diverse teaching methods of small project competitions, vertical studios, joint research studios, international training opportunities, exchange of qualified researchers and graduate students organized by WP5; to guide establishing sectoral collaboration in the research facilities, sectoral needs and knowledge integration to the curriculums, enhancing institutional budgets by WP6; to enhancing students engagement to real-world problems, problem finding activities for students, providing connections with different stakeholders and NGOs, extensive inclusiveness in developing innovative curricular and extra-curricular activities by WP7; to urge organizing relevant events; meetings, workshops, seminars, decathlons, online dissemination such as newsletters, open-source digital archive of events by WP9.

4 SUMMARY AND ACKNOWLEDGMENTS

The first disciplinary broadening workshop of the EELISA project provided a brainstorming opportunity for the partners of the European University Alliance partners to initiate the search for the interdisciplinary skills of the European Engineer of the future under the theme of “Cities and Communities”. The theme presents a perfect match with two pilot tracks of EELISA project and Sustainable Development Goals. Workshop results underline the skill gaps of today’s engineers, the barriers as well as the need for exchange between the engineering and non-engineering professionals. Potential proposals started to pile up for potential multiskilling pilots to be designed and implemented as part of the EELISA project.

EELISA’s second disciplinary broadening workshop in 2021 was on “Sensing Sciences and Technologies”. There are at least five workshops in progress in the year 2022. The themes of them include but are not limited to the following : “Architecture and Archeology”, “Digital Philology”, “Teaching Sustainable Development”, “Data Science for Industries” and “Managing Cities”.

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ON THE CONNECTIONS BETWEEN THE CDIO FRAMEWORK AND CHALLENGE-BASED LEARNING

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ABSTRACT

Challenge-based learning (CBL) is a learning approach that has received increased attention during the last years. In some of the publications about CBL the connections to the CDIO (conceive-design-implement-operate) framework is discussed, and the purpose of this paper is to discuss these connections further. CBL has connections to both Problem-based learning (PBL) and Project-based learning (PjBL), but while these are learning approaches, the CDIO framework has a program perspective, including aspects of learning approaches, and hence a wider scope. The connections and differences between CBL and CDIO are discussed based on the components of the CDIO Standards.

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1 INTRODUCTION

Challenge-based learning (CBL) has received increased attention during the last years, and numerous papers have been published. In some of the papers there are references to the CDIO framework, and connections between CBL and the CDIO framework are discussed. The purpose of this paper is to study these connections and discuss the similarities and differences in some more detail. The paper starts with brief overviews over the CDIO framework and CBL in general, and this is followed by some comments about the use of CBL within the ECIU University initiative.

The CDIO framework has existed for more than two decades, and it has been developed within the CDIO Initiative. The CDIO Initiative started as a project involving the three Swedish universities Chalmers University of Technology, Royal Institute of Technology (KTH), and Linköping University, and MIT (Massachusetts Institute of Technology) in the USA. After some years the project evolved and grew into a network of universities all over the world, with an annual conference and several other activities. The key references presenting the CDIO Initiative and the framework are [1] and [2]. For example, via the web site [2] it is possible to reache the Knowledge library, which contains a large collection of papers from previous CDIO conferences.

The framework consists of four key components:

- A characterization of the role of an engineer.
- Goals for the desired knowledge and skills of an engineer formulated using the document CDIO Syllabus.
- Goals for the properties of an engineering education program collected in the document CDIO Standards.
- Methods and tools for systematic development and management of education programs.

It should be stressed that most of the components that form the framework existed and have been known before the CDIO Initiative was formed, and that the key point of the CDIO framework is that the components have been put together in a systematic way. Therefore the CDIO framework can be described as *structured common sense*. Originally the framework was developed for engineering education, but over the years it has been generalized, adapted, and applied in other disciplines outside the engineering field, and examples of this can be found via the Knowledge library [2].

Two of the earlier references discussing the connections between CBL and the CDIO framework are [3] and [4]. The paper [3] presents interesting experiences from Master's theses carried out using CBL in a multidisciplinary setting and with sustainability focus. An important component in [3] is a also the use of the Chalmers Challenge Lab, which is a learning space specially designed for CBL activities. In [3], CBL is presented as an evolution of CDIO, but to a large extent this is based on the view that CDIO is equivalent to project-based learning. In [4] the authors discuss challenge-driven education (CDE) in an international context, and CDE is seen as more or less equivalent to CBL. Also, in [4] CDE is described as an evolution of PBL, where the acronym stands for both project-based and problem-based learning, which means that they are considered to be quivalent. Even though the paper is about CDE the authors use the word project repeatedly when talking about the actual work of the students. However, these comments are not meant to criticize the authors of these paper, but more to illustrate that clear definitions of the different learning approaches are missing.

As mentioned, numerous papers dealing with various aspects of CBL have been published during the last years, and the paper [5] presents an excellent literature overview based on almost one hundred papers. One of the main conclusions of the paper is that the interpretations and applications of CBL vary a lot, and that there is a need for a more unified view of CBL. Some of the common features of the approach include open ended tasks, multidisciplinary and team-based learning activities, interaction with external stakeholders, and often emphasis on challenges related to sustainablitiy. CBL is also seen as a suitable approach to enable for the students to develop various skills. Several of these aspects are discussed in the comparison with CDIO in the sections below.

One context where CBL is an important component is the ECIU University, which is one of the pilot projects within the European Universities initiative from EU. ECIU (European Consortium of European Universities) is a network of thirteen European universities and is running this pilot project together. More information about the ECIU University and the use of CBL within this context can be found via [6]. In [7] the authors discuss the connections between the CDIO framework and the development of the ECIU University in general, which also includes brief discussions about the connections to CBL.

The connections between CBL and the CDIO framework are maybe known to many members of the engineering education community, but since aspects and concepts, despite this, sometimes are mixed up, it is motivated to make an attempt to clarify similarities and differences further.

2 METHODOLOGY

The results and observatons presented below are based on literature studies, various presentations, and participation in both the CDIO Initiative and the ECIU University project. To enable a systematic treatment, the connections between CBL and the CDIO framework are discussed using the CDIO Standards as reference. Thorough descriptions of the CDIO Standards can be found via [1] and [2]. The main purpose of the CDIO Standards is to define twelwe important components for the design, management and execution of an education program. The twelwe items of the CDIO Standards can be split in the following main parts:

- The context, the role of the graduate, and learning outcomes. 1 - 2
- Intregrated curriculum, including an introduction to the intended role. 3 - 4
- Design-implement experiences and related workspaces. 5 - 6
- Integrated learning and active learning approaches. 7 - 8

- Faculty development and student learning assessment. 9 – 11
- Program evaluation. 12

The subsections below are based on most of the elements of the CDIO Standards.

3 RESULTS

3.1 Program perspective – The context

The starting point of the CDIO framework is a characterization of the role of the graduate, connected to Standard 1. Also, the framework has been adapted to other disciplines with corresponding characterizations of the role of the graduate. This relies on a program perspective, where the education program is aiming for a professional role. In the literature CBL is sometimes discussed in a program perspective, but more often as a learning approach as such. The overview in [5] gives that the main part of the applications of CBL can be found within engineering and computer science, but the learning approach itself should be suitable for most types of education contexts. Also, Standard 12 is about Program evaluation, which is a very important aspect of any type of education program. The question if the design and execution of the education program enable for the students to reach the intended program goals is fundamental, but it is based on the program perspective. Hence, Standards 1 and 12 show that the CDIO framework has a wider perspective than CBL.

3.2 Integrated learning experiences and active learning

Standard 7 is about integrated learning experiences, which according to [2] should lead to *acquisition of disciplinary knowledge, as well as personal and interpersonal skills,* which implies that CBL is very much in line with this standard. Here interpersonal skills refer to Section 3 of the CDIO Syllabus, which includes Subsections 3.1 about *Teamwork* and 3.2 about *Communication*. Development of these skills are often referred to as motivating factors for the use of CBL, and in terms of intended learning outcomes the four C:s from the 21st Century skills are often used as reference, where *Communication* and *Collaboration* are tightly connected to 3.1 and 3.2. Standard 8 talks about *active and experiental learning methods*, and since CBL is a highly student centered and active learning approach, it aligns very well with also this standard. The conclusion is hence that CBL is an excellent alternative, among other learning approaches, in line with Standards 7 and 8.

3.3 Design-Implement Experiences

Design-implement experiences, i.e. Standard 5, are key components in engineering education programs. The purpose is to include learning activities that mimic the intended profession, and enable for the students to develop various skills related to this profession. Since more complex design-implement experiences require contributions from several participants, this type of activity is often carried out as team-based activity. The results of such team-based activities are often the most visual and spectactular outomes from a CDIO-based education, ans this has led to that the CDIO framework sometimes is seen as equivalent with PjBL, which is a somewhat limited view. It can be noted that neither the Description nor the Rationale of Standard 5 mention the word project, and that PjBL existed long before the CDIO Initiative was established. The purpose of the design-implement experience is to mimic the real profession, and for that purpose PjBL is a useful learning approach in engineering education. It is natural that PBL or CBL can have similar purposes in education programs aiming for other professions.

A key observation in [5] is that CBL has many different meanings, and similar observations have been reported for PBL and PjBL. For example, there are different version of how PjBL is carried out, depending on the discipline, how the work process is organized, the expected outcome of the project, assessment methods used, composition of the team, etc. Wikipedia's definition of a project reads: *A project consists of a concrete and organized effort motivated by a perceived opportunity when facing a problem, a need, a desire or a source of discomfort. It seeks the realization of a unique and innovative deliverable, such as a product, a service, a process, or in some cases, a scientific research.* In some interpreatations of CBL the process should start even earlier with a very open *Big Idea,* and from that define a challenge that is possible to treat given the available time and other resources. It gradually becomes a question about semantics, but starting from words *need*, *desire*, or *source of discomfort* in the definition of a project it is relatively straightforward to formulate a Big Idea.

Since there are many common aspects between CBL, PjBL and PBL it is desirable to focus on those and make use of the experiences that have been collected. These aspects include:

- Formulation of intended learning outcomes
- Characterization and choice of the Big Idea/challenge/project task/…
- Team formation, roles in the team, and team operation and development
- Structure and methods for the work process
- Methods and tools for continuous feedback and assessment
- The role of the teacher/coach/facilitator/mentor/…
- Interaction with externa stakeholders/challenge providers/…

The importance of these aspects can vary between the different learning approaches and different implementations of them, but it should be possible to extract common factors and enable transfer of experiences. See the illustration in Figure 1.

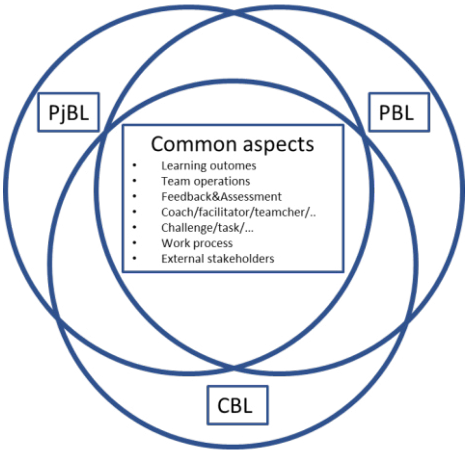

Fig. 1. Common aspects of PjBL, PBL, and CBL.

3.4 Learning outcomes

One of the main arguments behind both the CDIO framework and CBL is the necessity to develop the skills of the students, in addition to the subject knowledge. Within the CDIO framework, Standard 2 is focusing on this question. There are many important aspects of this that need to be discussed, and first it should be noted that there is a big variety concerning the vocabulary which is used when discussing skills. The words and expressions that are used in the literature include, for example, transversal skills, soft skills, transferable skills, generic attributes, and generic competencies. In addition, since there are no strict definitions of what is included in each of these expressions the discussion becomes somewhat vague. The CDIO Syllabus talks about *Personal and professional skills* in Section 2, and *Interpersonal skills* in Section 3, while it is more diversified in the literature about CBL. Second, and partly related to the question about the use of vocabulary, is the reference frame that is used when discussing and formulating learning outcomes. Within CDIO the Syllabus is the natural reference, but also here it is more diversified when it comes to CBL. As mentioned before, the 21st Century skills is one alternative, but there are several possible alternatives.

Via the principle of *constructive alignment* there is a direct link from learning outcomes, via the learning activities to the assessment. Assessment is even more challenging when it comes to assessment of skills. Since CBL, PjBL, and PBL often have related types of learning outcomes concerning skills, the question of assessment of this type of learning outcomes are of common interest. Some papers spend considerable effort on stressing the differences between these learning approaches, but it would be more fruitful to focus on the common aspects, where formulation of learning goals and related assessment for various skills is the most vital component.

3.5 Faculty development

Related to assessment but also teaching and learning in general is the need for faculty development. The literature about CBL stress the somewhat different role of the teacher in CBL, and there often is a need for faculty deveplopment. In the CDIO framework Standards 9 and 10 address the need for faculty development explicitly.

4 SUMMARY

The connections between the CBL and the CDIO framework have been studied, and the main messages of the paper are the following:

- The CDIO framework has a program perspective and hence a wider scope than CBL. The framework includes e.g. curriculum design, learning workspaces, faculty development, and program evaluation, and CDIO is not limited to one specific learning approach.
- CBL is a very good example of an active and integrated learning approach, and hence it fits very well as a compontent in the CDIO framework, where active and integrated learning are key components, as indicated by Standards 7 and 8.

As illustrated in Fig 1, there are many common aspects of CBL, PjBL, and PBL, and the potential for fruitful knowledge exchange concerning these aspects is very good. However, before considering which learning method to use, it is important to first reflect upon the learning goals, in terms of the knowledge and skills that are expected for the intended role of the graduate. Then, in a second step, one can choose a learning approach, including assessment methods, that is suitable in order to enable for the students to reaach the learning goals.

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EVERYTHING YOU WANT TO KNOW AND NEVER DARED TO ASK — A PRACTICAL APPROACH TO EMPLOYING CHALLENGE-BASED LEARNING IN ENGINEERING ETHICS

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ABSTRACT

Challenge-based learning (CBL) for engineering ethics tasks students with identifying ethical challenges in cooperation with an external partner, e.g., a technology company. As many best-practice parameters of such courses remain unclear, this contribution focuses on a teacher-centric introduction into deploying CBL for engineering ethics. Taking Goodlad's curriculum typology as a point of departure, we discuss practical issues in devising, maintaining and evaluating CBL courses for engineering ethics both in terms of the temporal dimension (before, during and after the course) as well as in terms of the people involved. We will discuss selecting learning objectives, forms of knowledge acquisition, supporting self-organization, and fostering discursive etiquette, as well as cooperative, yet critical attitudes. Additionally, we will delve into strategic

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matters, e.g., ways to approach potential external partners and maintain fruitful cooperations.

1 INTRODUCTION

Conceptualizing, establishing and maintaining courses that draw upon innovative educational concepts, such as problem- or challenge-based learning (PBL/CBL), requires a host of separate and intertwined decisions geared towards adapting all course parameters to local conditions, such as student clientele and resources available. At least to some degree, deciding upon appropriate learning objectives also often lies at the discretion of the teaching staff responsible. If desired learning outcomes are set, the primary guide behind particular decisions on course parameters usually focuses on how to aid students in reaching these objectives, typically in trade-offs concerning the efficient utilization of resources such as time available to teaching staff, facilities and technical equipment. However, while much is being reported on the educational concepts themselves, details on their implementation to accommodate and account for local conditions is rarely addressed. The present contribution tries to fill this gap based on experience obtained in implementing two challenge-based engineering ethics courses in different universities. Accordingly, we would like to contribute to the field of higher engineering ethics education utilizing CBL approaches by highlighting practical issues that one might face and how to possibly address them. We will offer arguments and experience-based insights from several iterations of and discussions about our courses. The remainder of this contribution is structured as follows. We will first briefly introduce the concept of CBL and its use in engineering ethics courses in higher education. In reference to Goodlad's curriculum topology [1] we will then proceed to tackle relevant aspects before, during and after the course.

2 BACKGROUND

2.1 Challenge-Based Learning

Challenge-based learning lets learners collaboratively define their own challenges based on real-life problems [2]. Students work on challenges under guidance of lecturers and external stakeholders, reflect on them and—if possible—solve them. The starting point is usually an overarching question, from which to derive more specific questions with regard to a self-imposed challenge. Challenge-based course designs typically incorporate public final presentations of student projects. This, e.g., achieves a multiplier effect, i.e., of conveying learnings, heightened awareness and the corresponding solution space also to the general public.

Challenge-based learning has mostly been deployed for teaching engineering development processes marking a shift away from pure knowledge acquisition towards focusing on application, cf. [3]. However, little experience has been gathered in different contexts. Especially its adoption to ethics is relatively new [4, 5]. The working hypothesis for the present contribution rests on the notion that—even though the activity takes place in a specific context, e.g., engineering—it also explicitly requires students to not exclusively identify solutions from a search space confined to the disciplinary context. Instead, students are encouraged to think in inter- and transdisciplinary ways. E.g, technological solutions often might involve accompanying socio-technical solutions concerning work processes, communication strategies as well as a gradual implementation via inclusive participatory processes. Hence, CBL for engineering ethics can be perceived as a way of encouraging transdisciplinary education rather than purporting a disciplinary focus.

2.2 Two Dimensions of Managing Challenge-Based Courses: Time and People

For the purpose of communicating and reflecting upon course design choices, we adapt the curriculum typology of Goodlad, Klein and Tye [1], which distinguishes the ideal, formal, perceived, operational and experienced curriculum. These five aspects can be broadly construed as the dimension of time, which we will more simply structure into phases of before (or intended, as referring to the ideal and the formal planning), during (or implemented as referring to the course as perceived and operated by all involved) and after (as referring to the experience reflected upon as a whole including deducting next steps). The following sections will traverse this temporal dimension and will iterate through relevant considerations of lecturers in their interaction with students and external stakeholders. Goodlad originally considered also the educational institution and external stakeholders, while the latter refered to citizens and policy-makers [1]. However, due to space limitations we will focus on students and external stakeholders more closely in terms of the companies involved in the CBL course scheme to limit the scope, while we do not deny the significance of the institutional and societal perspective. Further, we will add considerations of operationalization to the experiential post-implementation phase.

3 BEFORE THE COURSE

The preparatory and planning phases in CBL courses involve extensive commitments of both lecturers and external stakeholders, while the students' ability to engage themselves in and adapt to CBL needs to be taken into account.

3.1 Lecturers

When designing CBL courses, a crucial question rests on the role the lecturers should (ideally)—but also are willing and able to (formally and practically)—assume: The ideal choice of role should reflect the pedagogic goal pursued. Its matching with the realities of resources available as well as local study conditions and culture, in turn, should instruct the formal planning. In terms of an ideal CBL approach, lecturers should be facilitators by providing an overarching question that students refine, derive a concrete challenge from, and develop a solution for.

However, lecturers must ask themselves whether they will be comfortable guiding through challenge-based coursework ad-hoc, or whether they will want to restrict both the scope and topics to be able to either resort to existing knowledge (bases) or read up on the issues beforehand. Besides skill, this is also a question of the time available both before and during the term, and the extent to which lecturers may indulge in producing preparatory material or be available for frequent counseling. The nature of ethical inquiry in engineering makes these considerations central, as the case studies presented by the external stakeholders might incur vastly different socio-ethical and (socio-)technological aspects. Consequently, the amount and type of canonical knowledge to be presented to students during the term (if any) can—and probably will—largely influence the directions the student projects will take. To alleviate, one may develop an ever-increasing knowledge base and set of modules about specific ethical aspects to point out to student groups at an appropriate time.

A central question to consider is about student expectations and experience with both CBL course concepts and the subject matter of engineering ethics. If students are vastly unfamiliar with self-organized learning and CBL, significant overhead should be granted not only for conveying the general idea, but also for gaining familiarity with all modes of interaction, knowledge acquisition and handing in potential deliverables. If students are also unfamiliar with engineering ethics (which they most probably will, assuming there is only a single undergraduate engineering ethics course in the curriculum), they might be subjected to a doubly steep learning curve. Such general unfamiliarity might require lecturers to make significant concessions, e.g., by enveloping the CBL course concept within a more traditional lecture and exercise structure that might be more familiar to engineering students. For instance, the lecture material might consist of presentations with interactive discussions about a set of issues relevant to the stakeholder projects, traversing from the canonical to increasingly specific ones. Exercises could amount to weekly group meetings to reflect upon the lecture's content in relation to the project and to advance towards identifying a specific challenge. Furthermore, by adjusting the degree of freedom in identifying challenges, students could, e.g., be given initial pointers in varying degrees of specificity, or left with only a general explanation about the external stakeholders' technological case. In addition, by discussing both course organization and expected learning progress during the first few meetings of the course, the lecturers could, e.g., discuss previous case studies as examples from previous instances of the course.

Many more considerations need to be made, e.g., with respect to the number of lecturing staff available, and, hence, the attainable ratio between students and supervisors, lecturers' disciplinary specialties and modes of exchange among these.

3.2 External Stakeholders

The acquisition of external stakeholders willing to participate as real-world case studies in a CBL scheme is a delicate matter that involves a convincing communication strategy, expectation management, sensitivity regarding the stakeholders' corporate viewpoint and available resources as well as negotiations concerning the degree of influence exerted on the student projects. In terms of convincing stakeholders to participate, it may pay off to commit to a longer term partnership with a local business association that can lend its reputation for raising the interest of its members. Despite lacking the perspectives of larger enterprises, a start-up accelerator might make a good partner to regularly interest companies-in-the-making. In fact, the acquisition of start-ups as external stakeholders allows to perceive the interaction in CBL courses as a partnership, avoiding prejudicial tropes of enterprises focused solely on maximizing return-of-investment. Since a start-up will not yet have the resources to perform in-depth ethical analyses, students can step in as agents for constructive and friendly criticism. With product development still in its infancy, students' conceptual contributions could allow for meaningful pivoting.

However, even though acquiring the participation of external stakeholders via partnering with a start-up accelerator may be elegant and convenient, this does not mean that fewer efforts need to be taken to understand and respect each potential stakeholder's corporate identity, viewpoint and needs. For instance, while regular meetings between students and stakeholders may be preferable, flexibility is needed to accommodate a stakeholder's resources. Similarly, stakeholders should be given some room for expressing and realizing their expectations: While ideally deciding upon the students' degree of freedom in choosing a particular challenge is a pedagogical question, stakeholders might want to direct attention towards their most pressing issues. At the same time, lecturers should not give rise to exaggerated expectations with regard to the students' final results. An honest communication about what to expect, including the possibility that weaker students might opt for a particular stakeholder's project resulting in weak outcomes, lays groundwork for a trusting relationship between lecturers and stakeholders.

4 DURING THE COURSE

Key aspects during course implementation concern management, roles and modes of interaction and the coordination of the project work.

4.1 Students

A crucial question for course management is the right combination of knowledge transfer and the CBL-approach: How can the course's schedule ensure that students are exposed to the right material at the right time during their project work? Two basic approaches as well as intermediates are conceivable: One may allow access to all material from the beginning, opening up the possibility of getting an overview over general topics and identifying potentially interesting aspects regarding the "stakeholder project" already in an early stage. Alternatively, topics and access/presentation order are designed to approach ethics from general issues (e.g., basics of moral philosophy, responsible research and innovation) to specifics (e.g., trust, privacy, algorithmic bias), taking into consideration that the material might be very new to students and requires a careful progression. A mixture of both in the sense of allowing quick tabulated overviews (e.g., date, type of lecture/tutorial, building/room, topic, requirements) and making more advanced material available upon request would also be conceivable. It should be considered that not only ethics input is required, but also input for project management (e.g., planning, collaboration, group dynamics) to achieve proper and successful project work.

Ongoing student-student and student-lecturer interaction needs to be carefully fostered. Our experience here shows, e.g., that regular feedback (graded assignments or non-graded feedback sessions) maintains a high ratio of attendance and attention to the material. Interactions within student groups can be promoted by anticipating when lecturers may need to change roles from guiding instructor to accompanying affiliate and vice versa. Additionally, fostering an atmosphere of open exchange as well as cooperative and social learning, cf. [6], facilitates long-term motivation and commitment, e.g., by being upfront about etiquette or being inclusive by specifically encouraging students that tend to be silent[2]. Likewise, additional consulting to mitigate intermediate low motivation will likely be necessary. In addition to proposing creative methods to provide an enjoyable experience of ethical reflection, these may include highlighting the benefits of engineering ethics through real case studies and anecdotes, e.g., by demonstrating thought processes. It is also necessary to consider ways of ensuring a critical, yet friendly attitude of students towards external stakeholders. Continuous effort is needed to respond to attitudes and to encourage students to speak freely and not feel intimidated. Identifying challenges also may imply that stakeholders will (typically) develop defensive argumentation and—at first glance—they may often succeed. Students might need further encouragement to follow up on their early argumentation by highlighting that the stakeholder's initial deflection may only be valid from a business perspective.

During the course, efforts required to support the students' project work in terms of content, coordination and acquiring specific competences (argumentation, reflection, communication, presentation) should not be underestimated. This kind of support scaffolding is an open process, involving many supportive discussions and careful observations to determine what additional activities may help. While tasks such as developing posters to connect lecture contents with stakeholder projects seem to foster creative thinking, argumentative skills may be better developed via written exercises, or enacting debates in role-playing—but all of them require feedback and, ideally, educational material as a reference. It should be taken into account, however, that each student project group needs an individual level of supervision in its project management. Hence, the effort required for supervision can and will vary.

4.2 External Stakeholders

The interaction with external stakeholders requires constant attention for aligning business interests, student interests and capabilities as well as intended learning outcomes. Among other things, this requires to take into account and balance the desire of the external stakeholders to gain new insights within a solution-oriented frame for ethical analysis, at times highly inconsistent student motivation and capabilities as well as the pedagogical premise that ethical challenges need to be identified independently by the students. Additionally, stakeholders are usually short on time, but while students progress, they typically would like to inquire more frequently and more deeply. Primarily though, lecturers need to aid in converging perspectives by both pushing the envelope in terms of what businesses might assess

[2] *In addition, the experiences of CBL during the pandemic, such as diminished interaction, may be addressed. However, an exhaustive consideration goes beyond the scope of this paper.*

as responsibilities they might realistically assume as well as by asking the students to turn critical assessments into actionable plans for improvement.

For this purpose, the interaction of stakeholders and lecturers occurs on two levels: First, a bilateral dialog between lecturers and stakeholders allows the management of expectations and sharing assessments to inform the stakeholders about the actual progress of the project. This as well offers the option to personally intervene if there are any communicative misgivings and challenges, e.g., it may be appropriate to evoke sympathy for struggling students. Second, during the meetings that include all partners (stakeholders, students and lecturers), besides enabling the critical yet friendly attitude of the students, lecturers might need to assume the roles of arbiters, striking compromise between the students' theoretical demands and business realities. In that regard, concepts from ethics might also be novel to the stakeholders, which requires lecturers to support student explanations, but also to continuously argue for why ethics is relevant on a business and societal level.

5 AFTER THE COURSE

After the course, the lecturers' tasks are often strategic and need to focus on sustaining and perhaps even institutionalizing the CBL concept.

5.1 Students

A great strength of CBL is that the students' learning progress can be observed quite transparently. For instance, the quality of regular assignments (such as poster slides on the reflection of engineering ethics topics in the context of a stakeholder project) can be continually assessed in terms of learning outcomes, argumentative skills, etc.. In contrast to conventional teaching approaches such as lectures or seminars with discussion elements, here the steady progress of student work can be tracked.

In engineering ethics, grading is an act of balancing expectations given that this is typically the students' first encounter with ethics. This makes it crucial to clearly communicate requirements by providing grading rubrics, e.g., in terms of clarity and structure, showcasing comprehension and use of literature as well as critical independence and relevance. Detailed and structured feedback will contribute to student learning. Grading group work always carries the risk of allowing free-riding, but transparent grading schemes involving a weighted averaging of individual and group performances can keep the need for discretionary decisions at a minimum.

Student work is subject to privacy regulations, but if students allow, work can be forwarded to the external stakeholders. After completion of the course, further interactions between students and stakeholders may be encouraged, e.g., as a possible opportunity for employment. Students having shown particularly good performance may also continue to be involved as teaching assistants or ambassadors for the same course in the next academic year. To present the results of the students' work to the outside world, public events can be organized. However, it should be noted that the more time passes, the more difficult it can be to motivate students to participate actively. Hence, early on, plans should be communicated and an informal, or even formal, contact to a group of course graduates maintained.

5.2 External Stakeholders

Beyond university-wide platforms and support to engage with external stakeholders, individual lecturers in CBL must consider the steps they can take to ensure a sustained cooperation with stakeholders, or meta-organizations like, e.g., start-up accelerators. Extensive networking and forming a visibility of the group of lecturers committed to CBL appears to be of the essence. This way, stakeholders can pinpoint their partners from university by brand—such as a specific or collective of research groups. In addition, more personal relations should be fostered, with lecturers showing genuine interest into the effects student projects may have had on the external stakeholders' work. Ideally, a successful consideration of student output by a stakeholder is openly and clearly communicated to the students, lecturers and even higher-level university representatives. Such communication could be institutionalized by establishing a CBL course-specific “landing page” that features news and project results, both as a means to advertise, acknowledge and maintain relations. For such an instrument, agreements about the extent to which information on both student progress and case studies may be published need to be made.

A prospect for stakeholders to continue relations is viewing CBL courses as a pool for future talent. Ethics CBL courses may appear less suitable, as students are tasked to showcase their ethics more so than their engineering prowess. As the students' ethical analyses might well include highly critical stances, sustained relations are likely to only be possible with stakeholders that prioritize open discourse over managing reputation. However, economical success often appears to strongly benefit from the later, which makes managing relations a delicate task.

6 CONCLUSION

With this contribution, we have provided an extensive list of considerations for conceptualizing and establishing, maintaining and implementing as well as sustaining and further developing challenge-based courses in engineering ethics. We have been inspired by Goodlad's curriculum typology to structure our exposition according to the two dimensions of time and people under consideration, while we focused on what the lecturers responsible for the course need to take into account, may initiate and should act on. Since the prevailing circumstances at different institutions from higher education will vary significantly, we have formulated our contribution in terms of open-ended questions and considerations, highlighting exemplary choices and their corresponding reasoning where possible, but refrained from overly generalizing into a single or few correct choices. While our list of considerations may be extensive, it is by no means exhaustive and much more needs to be said about the potentialities of course design choices, management issues, an understanding of roles and means of interaction and stakeholder relations. We hope to have contributed to a discussion on these practical issues of conducting CBL engineering ethics courses.

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TEACHING ETHICS THROUGH THE BACK DOOR? – EMPLOYING IDEAS FROM ASSEMBLAGE THEORY TO FOSTER A RESPONSIBLE INNOVATION MINDSET

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ABSTRACT

Adding ethics courses to engineering curricula seeks to equip students with the critical mindset that enables careers committed to serving humanity. Yet, the knowledge of ethical theories is neither a necessary, let alone sufficient condition for being good [1]. There is no automatism that translates ethical knowledge into action, overriding attitudes that were developed during the enculturation of a student. However, we deem teaching assemblage theory a promising means to achieve a sustained commitment to responsible innovation practice. We base our argument on assemblage theory's (cf. [2, 3]) capacity to conceptualize the interplay of human actors and technological artefacts in terms of dynamic evolutionary systems. The notion of an assemblage as a collection of potentially heterogeneous elements that—despite displaying consistency—remains malleable through reorganization, interconnection and, (re-)attribution forms the ontological basis that guides a conceptual approach to thinking in-between the extremes of technological

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determinism and social constructivism. Information algorithms, e.g., can be regarded as having the power to facilitate ethical action as part of a larger assemblage [4] and artificial intelligence can arguably only be understood as “trustworthy” within socio-technological systems in which a shared responsibility realizes both epistemic and moral conditions for trust [5].

Ultimately, we intend engineering students to realize the extent of their influence on the world and, therefore, their responsibility for contributing to a prosperous community. Thus, ethics is not only taught by conveying its classical normative theories but rather explored by discovering the entangledness of technology and society.

1 INTRODUCTION—DRAWBACKS OF COURSES IN ETHICAL THEORY

Ethics has always been part of engineering and engineering education at universities and elsewhere—but mostly implicitly, to that extent that everyone who is involved, i.e., educators as well as students, is always endowed with an ethical configuration resulting from their respective socialization process. Our upbringing as well as the experiences we make have a further impact on how we assess moral questions and make judgments. So, if everybody already has an implicit understanding of what is right and wrong that reflects their personal views, why bother using a part of the already limited time for courses at university to add ethics education to an engineering curriculum? What difference can an ethics course make? And what difference would it make if it were based on assemblage theory, cf. [2, 3]?

First, we should look at how a course that teaches ethics by conveying ethical theory works, what assumptions it is based on, and what its (possible) drawbacks are. This will shed light on why we propose a different way which circumvents the pitfalls in ‹classical› ethics courses. Ethical theories, be they deontological (based on duties) or consequentialistic, provide normative frameworks. These start out at a moral problem and help its users to identify a path of action to take, which—according to the respective theory—is identified as either ‹good,› ‹right,› or ‹one's duty.› That is, an action is demonstrated as morally justified by outlining a sound argument.

On the other hand, ethical theory tends to be perceived as eluding the practical side of life. The criticisms voiced regarding the effectiveness of ethics education take place on (at least) two levels: (1) Skeptics of the teachability of ethics in general are claiming that one either is a moral person or not, as this is the result of a socialization process. (2) Skeptics of the knowledge of ethical theories being an asset to a person's ability to better deal with moral problems are claiming this knowledge does not contribute to the formation of moral judgments as it only serves as an *ex post* justification of decisions made without an ethical theory [6, p. 37–38].

Both, Johnson and Fischer, do not deny the teachability of ethics. Johnson thinks that skeptics in (1) have «oversimplistic notions of ethics and of human behavior» and declares «knowledge [of] codes and standards,» «skill,» «reasoning,» and «motivation» the core components of engineering ethics [1, p. 64]. Fischer pursues a different approach and points to evidence from courses in applied ethics for doctors and nurses, which were perceived as being disconnected from the needs of medical practice because the appeal to normative ethics fails by giving the justification of actions precedence over understanding the «morally significant situation». While according to Fischer we recognize such a situation and know what to do without going step by step through a (quasi-)algorithmic judgment process, Johnson regards it a teachable and thus learnable «skill» to «identify ethical issues» [1, p. 64].

Johnson is aware that ethics education will not automatically make people «good» in general but claims that this increased the probability that engineering students will be «better prepared to handle the ethical issues that arise in their professional lives» [1, p. 64]. Based on her assumptions that the knowledge of policies and professional ethics codes equips future engineers with a compass that suffices to handle ethical problems, hand back the verdicts of having «oversimplistic notions of ethics» back to her. Relying on such codes' results and their application is little different from relying on the knowledge of frameworks delivered in theories of ethics. Both are teachable, yet both represent a technical approach to ethics, meaning that a tool is provided to ‹solve› a problem. While theories of ethics are often employed this way, it is better to use them as concepts for analyses and approach real world problems differently. This however exposes a gap between ethical theory and moral practice.

2 AN ALTERNATIVE PROPOSAL—USING ASSEMBLAGE THEORY FOR ENGINEERING ETHICS EDUCATION

To fill this gap, we propose teach engineering in ethics not by ethical theories and their application to moral problems, but in a way that acknowledges the complexity of the world and society as socio-technical conglomerates, or *assemblages*.

2.1 A Brief Characterization of Assemblage Theory

We would like to precede a brief characterization of assemblage theory by disclaiming that our portrait may strike scholars of Deleuze and Guattari as overly simplistic. To the best of our knowledge, assemblage theory eludes a concise summary, perhaps with the exception of [7]. Scholars like Buchanan do, in fact, reject the very idea that something like this should even be pursued. At the core of Buchanan's argument lies a characterization of assemblage theory as an unfinished project whose principles can be extended [3, p. 6], but for which it is impossible to give an exhaustive and model-like description, because this would betray its very project of working against mechanistic ways of perceiving reality [3, p. 5].

If we accept these premises, then whatever we can sketch here will not do assemblage theory as originally conceived of by Deleuze and Guattari in *A Thousand Plateaus* proper justice. However, aware of this, we will try to sketch the general concept, hoping to evoke an idea of why it can be useful and how. In doing so, like Buchanan, we will try to remain true to the original idea that extends beyond—and rejects core tenets of-—the notion of assemblages-as-systems-of-things due to DeLanda [2]. DeLanda takes that properties of a given assemblage are generated by its components, whereas, according to Buchanan, «desire» is primary, i.e., it is giving selected things the properties they have in an assemblage [3, p. 56].

Crucial to understanding assemblages is to realize that assemblages are not defined by their components, but rather that they are defined by their products [3, p. 47]. The virtual (think, e.g., concept) is actualized by the elements' relations and agents. Assemblages are «alive» in the sense that they do not disappear, even if the material things they arrange are removed [3, p. 60]. What matters most are the ideas and notions that remain. In that sense, at the core of assemblage theory as per Buchanan (and hence as per Deleuze and Guattari) is a reversal of the «virtual» and the «actual», which can be exemplified in capitalism: Advertisements based on particular characters from, e.g., movies would only be *virtual*, because they are unaffecting without the stories that *actually* matter to prospective buyers [3, p. 60].

An *assemblage* (an unfortunate translation of *agencement*), then, is an «arrangement or layout of heterogeneous elements» [7, p. 22]. In contrast to portraying unity described by an essence, understanding assemblages as arrangements emphases multiplicity and events. While one cannot extract parts from unities without destroying them (e.g. a heart from a body), assemblages allow for recombinations or removals of parts and are defined by the relations between these. Hence, an assemblage «constructs or lays out a set of relations between self-subsisting fragments» [7, p. 23]. Instead of being about essence, presupposing a static, defining finality, assemblages are dynamic constructs of contingent features.

All assemblages are defined by three kinds of features: their *Abstract Machine* (or conditions, C), their *Concrete Assemblage* (or elements, E), and their *personae* (or agents, A) [7, p. 24–28]: *The Abstract Machine* are the external relations holding the elements together. While the conditions are not tangible objects and thus abstract, the external relations are real. *The Concrete Assemblage* are the actual elements from which the abstract machine is composed. The relation between the concrete assemblage and the abstract machine is reciprocal; they are mutually co-adapting to each other. *The Personae* are the agents that connect the concrete elements according to their abstract relations and are immanent to the assemblage [7, p. 27].

All assemblages are arranged as combinations of basic political types: *Territorial Assemblages (TAs)* are arranged to divide the world into coded segments that define the «natural» norms of life in terms of «this is how things are done, how they have always been done», [7, p. 28–29]. *State Assemblages (SAs)* are arranged to unify all concrete elements in the assemblage [7, p. 30]. *Capitalist Assemblages (CAs)* are arranged such that conditions, elements and agencies form abstract quantities [7, p. 31] that can be treated as globally exchangeable [7, p. 32]. *Nomadic Assemblages (NAs)* are arranged such that conditions, elements and agencies can recombine to allow qualitative transformation and expansion of the assemblage [7, p. 33]

In summary, territorial assemblages are based on essentialist meanings, state assemblages allow centralized command, capitalist assemblages allow exchange in terms of generic quantities and nomadic assemblages allow for participation and self-management. All assemblages constantly change according to different kinds of change (or «deterritorialization» as the way in which assemblages continuously transform and reproduce themselves [7, p. 34]): *Relative negative* processes maintain and reproduce an established assemblage. *Relative positive* processes do not maintain or create a new assemblage. *Absolute negative* processes undermine all assemblages. *Absolute positive* processes create new assemblages.

The above is a concise and ultimately incomplete terminology used in structuring concepts from assemblage theory. Its use will be exemplified next in the context of algorithmic accountability.

2.2 An Example — Algorithmic Accountability

Algorithms are generalizable descriptions of methods designed to accomplish certain well-defined tasks. Ananny frames algorithms as «unstable objects of study» [4, p.

109], which require a framework in which to address ethical implications that can keep track of the dynamic relations. Assemblage theory is a promising candidate.

Algorithms promote quantitative and oftentimes (deliberatively) reductive views that allow for efficacy or increasing the efficiency of various routines. Algorithms can hence be characterized as drivers of *absolute positive processes* that typically create *capitalist assemblages*. However, while not be wrong, this characterization may also be too limited [4, p. 97]. For instance, it fails to capture that algorithms also facilitate new forms of human interaction. Be it through, e.g., match-making, encryption or compression, algorithms have led to qualitative breakthroughs in the conditions under which humans can communicate, organize themselves and act together. Accordingly, they can be conceived of as drivers of *absolute positive processes* creating *nomadic assemblages* as well. Like institutions, algorithms have the power to structure and influence behaviour [4, p. 99] and an ethical analysis of questions of accountability needs to account for all elements, relations and agents involved.

The *concrete assemblages* of algorithms in social media, for instance, consist of actual code of both the social media-based algorithm as well as of systems interacting with it, human practices, i.e., those of the developing individuals, users of social media, policy, and regulatory bodies, etc., as well as norms. A particular *abstract machine* might be identified in the notion of «clout» as the power or influence an institution or individual might exert on social media. *Personae* connecting elements of the concrete assemblage are statistics, aggregations and other abstract means bringing about effects contingent on the abstract machine.

Algorithms working on data, e.g., influence associations by statistical means previously beyond the recognition of humans. More broadly, «[p]eople that fail to leave data that can be categorized are effectively invisible to the … algorithm» [4, p. 101], while those that share data may be viable targets for adverts but may also be offered interactions that induce opportunities. Accordingly, algorithms facilitate processes that maintain, undermine, or create associations and, hence, corresponding assemblages. Much of the effects of social media algorithms strongly depend on how users appropriate a particular platform, similar to, but perhaps far extending beyond the capacity of citizens appropriating urban infrastructure to their needs. In addition, the effects do seldom originate from the utilization of a single social media platform alone, but rather depend on the interaction with further platforms of, e.g., commerce, such as ad-targeting, aggregate news outlets and search engines. Hence, locating the origin of, e.g., the societal effects of a single post going viral, is difficult and can only be possibly understood or traced by examining interactions between the concrete elements of the assemblage. Furthermore, in case of machine learning algorithms, effects may also depend on past and present interactions encoded by various sources of data over time.

Assemblage theory may be a difficult concept to fully grasp. However, we believe that the above sketch outlines that it provokes a way of thinking about relations and events. In Buchanan's words «[t]he assemblage is intended to answer several types of question, ‹how?›, ‹why?›, ‹when?›, and not just a ‹what?› question,» [3, p. 13].

Ananny makes a point that more traditional perspectives from ethical theories, such as deontology, teleology and virtue ethics are at a loss for answering or critiquing algorithms appropriately. For instance, the effect of emerging categories would have to be assessed by outside standards in a deontological sense, by efficaciousness in a teleological sense, or by its alignment with virtue-based expectations in a virtue ethics sense. All of this is useful but overlooks that, e.g., an algorithm could bring about new collectives of ethical concern and that assemblages might incur transitions under which ethical assessments might alter. Ananny's argument for inquiring about the ethics of algorithms via assemblage theory, hence, hinges on a demand to go beyond lists of ethical guidelines requiring «transparency» [4, p. 109] or «justice», but to rather highlight the dynamics of relations and how these could bring about unethical states and conditions.

3 A PROPOSED COURSE DESIGN FOR HIGHER EDUCATION

Above we have elaborated on assemblage theory as a potential candidate for ethical analysis, whose use might mitigate the drawbacks of traditional ethical theory-based engineering ethics education. In the following, we will propose a course design rational and structure, arguing that using assemblage theory, it will be possible to educate engineers to routinely consider the ethical implications of their work «through the back door», i.e., implicitly through sensitizing for ethically relevant relations, conditions and events—in other words, through assemblages.

3.1 Rationale

To avoid any misunderstanding: by ‹employing assemblage theory› to foster a responsible innovation mindset, we do not seek to teach assemblage theory to create a fixed view on ethics. We also do not seek to teach assemblage theory as a kind of blueprint to be mapped onto any given situation, which would go against the intentions of its conceivers Deleuze and Guattari [3, p. 5]. Even though such an approach might be most familiar to engineering students, given the conceptual difficulties in providing for a concise and complete characterization of assemblage theory, it appears hardly possible to design a course that begins with outlining assemblage theory as such and then proceeds to apply it. Hence, to bring insights from assemblage theory to bear in an engineering course, lecturers might be best advised to keep explicit references to assemblage theory terminology to a minimum. In fact, even when scanning the (mostly sociological) literature covering aspects of the ethics of technology by means of assemblage theory, an explicit mentioning of assemblage theory-related terminology in terms of features such as *abstract machines* or political types such as *nomadic assemblages* is rarely found.

Accordingly, an approach to «teaching ethics through the back door» using assemblage theoretical concepts must succeed by conveying the relevance of socio-technical dynamics when addressing innovative technological disruption, the network of influences, responsibilities, and possibilities in flux as well as the interconnectedness of agents and the necessity of a shared sense of collective ethical action to achieve desired outcomes.

At times, conclusions might boil down to rather simple insights. E.g., when making «trustworthiness» the theme of discussion on artificial intelligence-based algorithms, a first realization may be that algorithms cannot be proper recipients of a moral account of trust because vulnerable trustors cannot attribute (well meaning) motivations to an artificial artefact, the trustee [5]. Algorithms may be reliable, but actual trust is to be lend to the socio-technical assemblage, in which conceiving, developing, marketing, auditing, competing, and regulating agents interact with, experience, challenge and support each other. Institutions are formed and categories (of algorithms) emerge that support trust by evoking expressions that portray algorithms—even though potentially opaque—as essentially based on good (or malicious) intentions, as trustworthy or not. Perhaps rarely will multiple agents consciously flog towards a common idea of advancing a specific product actively through the means of responsible innovation. But if this happens, an assemblage can be identified. Different from an indifferent, almost Kafkaesque, pursuit of an engineering career, acquiring a world view in terms of assemblages will hopefully spark the students' interest to contribute to the responsible innovation assemblage.

3.2 Course Structure

An actual engineering ethics course based on assemblage theory may obviously take many forms. We outline one possible concept of a structure that, admittedly, still needs to prove effective. Based on the above rationale, however, we believe it best to split the course into two parts: A first part is driven by case studies and works towards establishing the main concepts of assemblage theory one by one. A summary can then outline the theory itself and retrospectively link concepts and terminology to the case studies that were discussed in the first part. Its purpose lies in highlighting conceptual similarities and patterns as a concession to student expectations of take-away messages, which needs to be balanced with the open-ended nature of assemblage theory. A second part could task students to penetrate a new case study along the conceptual lines taught in the first part. More ideally than ready-made case studies as hand-outs even, a current situation from the news or reports could provide an analytical challenge a group of students could work on.

4 CONCLUSIONS

In this contribution, we have advocated the adoption of assemblage theory as a conceptual approach for ethical analyses in an engineering ethics educational context. We have outlined the limits of teaching ethical theory to increase commitment to responsible innovation practice in engineering students as a core motivation for approaching engineering ethics education differently. Instead, we believe that assemblage theory's focus on conditions, relations and events is well suited to shed light on the ethical challenges that innovative technologies, the perpetuated use of algorithms and artificial intelligence first and foremost, bring about. However, even though assemblage theory is a viable engine for ethics education, its conceptual intricacies may be best introduced in a step-by-step fashion without overbearing terminology.

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AUTHENTIC APPLICATION EXAMPLES IN MATH LECTURES THROUGH PEER TEACHING (CONCEPT)

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ABSTRACT

Engineering students often miss the connection between mathematics and the engineering disciplines. One solution to this problem is to integrate application examples into the math lectures. However, it is challenging for mathematicians to find adequate applications and to present them in an authentic manner.

We describe a concept of integrating application examples through peer teaching: A student who has already completed the mathematics course is involved in the preparation and presentation of such examples. As a result, the examples are very authentic since they are developed and presented by a person knowing the applications, the learners' motivation is high due to peer teaching, and the new

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material is high-quality owing to the supervision by the lecturer. Surveys conducted for each application example reveal that the concept is well accepted.

The paper describes the steps in the development of application examples of different length and mathematical depth and gives recommendations on how to implement the concept successfully into math lectures.

1 INTRODUCTION

Mathematics courses are important for the education of engineers at universities [1], but the link to the engineering disciplines is sometimes missing [2] and the course is seen as a hurdle [3]. This can lead to low motivation and interest in mathematics among engineering students [4].

1.1 Bringing different academic levels together (peer teaching)

Students' motivation and learning effects can generally be strengthened by peer teaching [5]. Several benefits have been documented across the literature for both tutors and tutees. Tutors benefit in particular from the intensive active engagement with the subject matter and from explaining it [6]. An advantage for tutees is a similar cultural and linguistic reference and a more direct speech and confidence between tutor and tutees [7].

In the following we use the term “peer teaching” in the sense that we engage major students as partners in the development and presentation of teaching material. Such concepts are applied in [8] and [9], for example. Croft et al. [8] describe a project where major students are involved as co-creators of screencasts for first-year math lectures. Bovill et al. [9] gives an overview of appoaches where students are involved as co-creators of teaching approaches, course design and curricula. Yet, these concepts encounters resistance from many lecturers as they fear that the quality of the resulting content may be insufficient [7].

1.2 Bringing different disciplines together (application examples)

There are various concepts to establish a closer connection between, amongst others, engineering and mathematics in engineering degree programmes [10]. One possibility is to integrate applications from the engineering disciplines into the mathematics courses. Such material should be as authentic as possible to create a link between mathematics and the engineering disciplines [4]. However, this idea includes the challenge for mathematicians to find appropriate applications [11] and to present them in an authentic manner [12].

1.3 Our concept

The concept presented in this paper combines both concepts, i.e. “Bringing different academic levels together” and “Bringing different disciplines together”: The lecturer and an advanced student together develop application examples, and the student presents them in the lecture. This leads to high-quality and authentic application examples as well as to authentic presentations. With this project we hope to create a stronger connection between the mathematical and the application topics within the given institutional and temporal conditions and in this way making the relevance of mathematics for the engineering programme more explicit.

1.4 Overview over the paper

The concept was conducted during a mathematics course for rescue engineers in the master's programme at a technical university in Germany. Students of this programme "obtain a specialized skill set allowing them to develop innovative and efficient concepts in hazard control and prevention as well as safety engineering" [13]. The mathematics course mainly includes topics in statistics and probability. It consists of a weekly lecture, in the form of seminar teaching using slides, and a weekly problem session.

In this paper we describe in detail all steps of the concept as it was carried out in that course in the winter term 2021 together with a major student (section 2). Then an accompanying evaluation of the intervention regarding the students' perspective on the application examples is described, and results are presented (section 3). Finally, the concept is discussed, and research perspectives and recommendations on how to implement the concept in other educational settings are given (section 4).

2 DESCRIPTION OF THE CONCEPT

In this section we explain in detail the steps that lead to the embedding of an example into the lecture. The steps are shown in Figure 1 and described afterwards. The fourth step sometimes made it necessary to return to the third step.

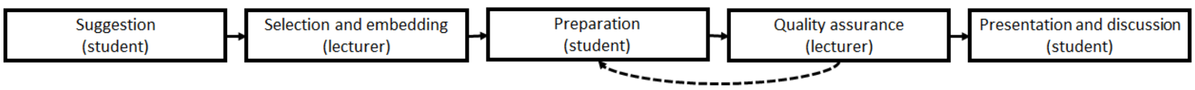

Fig. 1. Steps needed for the successful implementation of the concept

The project was realised with a (male) participant of the course of the previous semester who had achieved a very good grade and who had working experience in rescue engineering. We employed the student as an assistant for the project.

2.1 Suggestion (student)

Before the start of the semester, the student was assigned to search for applications of mathematics from the lectures of other engineering subjects, the related literature, and his work environment. He presented the results of his research to the lecturer.

2.2 Selection and embedding (lecturer)

The lecturer examined the collection of applications regarding the mathematical content and the fit with the lecture material. In the end, six examples were selected. We briefly describe two of the six examples, a short one and a long one, both receiving a very good evaluation by the students.

The example number 3 treated the mathematical topic of transformation of data (statistics). It consisted of a table with deployment data of twelve months for four fire stations, with a large accumulation of deployments in the month March (Figure 2). The task was to decide which of the four stations was unusually busy in March. For a meaningful comparison of the four stations the deployment data had to be transformed into standardised values. The student came up with the application himself based on his experience as a member of the volunteer fire brigade.

Fire station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	7	11	31	12	12	10	10	9	9	11	13	14
2	23	34	56	43	36	35	27	26	24	32	43	41
3	2	3	5	3	4	3	4	3	2	6	4	4
4	3	5	12	6	3	1	3	4	4	5	2	6

Fig. 2. Number of deployments for four fire stations

In another example (number 5), the use of various discrete probability distributions such as Poisson distribution, binomial distribution, geometric distribution and uniform distribution was needed. Deployment data from a rescue service location was provided (Figure 3), and it had to be estimated how many rescue resources had to be kept on hand at what time in order to ensure a high level of operational safety for the missions. The idea for this application came from a standard book for rescue engineers [14].

Total number of missions in 2020	12400
Rescue vehicles provided	3
Average duration of a mission (unit)	58 minutes

Fig. 3. Deployment data from a rescue service location

2.3 Preparation (student)

The student prepared the selected examples for a presentation. He was provided with the slides for the lecture in which the example had to be embedded so that he could fit the example well into the context. Furthermore, he was asked to build on the mathematical knowledge that had already been covered and to use matching notations. In addition, we explained to him in advance how to prepare an example in a good educational way. We used the modelling cycle according to Blum and Leiss [15] as a basis (Figure 4).

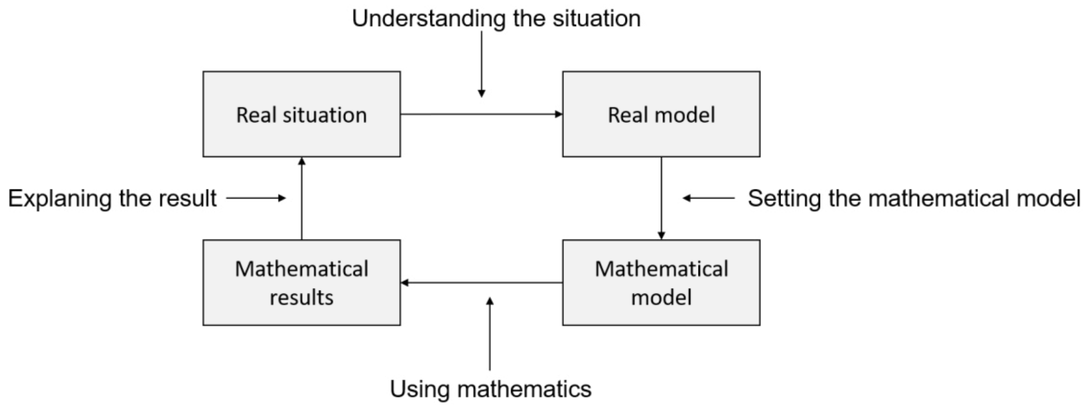

Fig. 4. Modelling cycle for the preparation of application examples ([15], modified)

The example number 3 was initially prepared by the student in a spreadsheet programme (Excel). The sheet included the number of deployments for four fire stations in twelve months (Figure 2) and the calculations for standardising the data. After quality assurance by the lecturer (see the next step), the student additionally prepared slides showing in detail the steps in the modelling cycle (Figure 4).

The example number 5 was also initially prepared exclusively in Excel. The student's approach first was very similar to the presentation in the literature [14]. He didn't show the simplifications and assumptions made for the setting of the model (steps from "Real situation" to "Mathematical model" in Figure 4) or which probability distributions were used ("Using mathematics" in Figure 4). In several cycles (see Figure 1 and see the next step), a number of slides were created that addressed the different steps in the modelling cycle (Figure 4).

2.4 Quality assurance (lecturer)

The student presented his material to the lecturer. The lecturer critically examined the preparation and the presentation, especially with regard to the setting and use of the mathematical model, the mathematical solution in the model, the fit to the course material and the quality of the presentation. In-depth questions by the lecturer on the application context improved the understanding of both and as a consequence also the student's presentation (see step 5). This discussion partly required the student to revise the preparation of the material (back to step 3).

The example number 3 required very little time on the part of the lecturer. The student supplemented his initial presentation via Excel sheet with teaching slides and he added a quiz to activate the students.

Example 5 was more elaborate in its preparation, on the part of the student as well as on the lecturer. All the modelling necessary for the mathematical solution was worked out very carefully. Hidden assumptions made in the applications were explicitely described and discussed and provided with a suitable discrete probability distribution. Several times, we returned to step 3.

2.5 Presentation and discussion (student)

The student explained and presented the examples in the lecture, sometimes with integrated quizzes or independent work phases in smaller groups, and he led the subsequent discussion. Questions concerning the application context could be answered directly by him, the 'expert' for the application. The lecturer was also available for questions (of a more mathematical nature) and for clarifications. The presentation of example 3 lasted about 10 minutes, whereas the presentation of example 5 filled a big part of the session (45 minutes).

3 EVALUATION OF THE CONCEPT

Our subjective impression was that the examples were very authentic and well received by the students who participated in the course. Nevertheless, we also wanted to systematically evaluate the examples in order to learn more about the acceptance of the concept, to better understand the students' perspective, and to obtain ideas for improvement from the students' perspective. In this section we explain the methodological tool of the evaluation and present the results.

3.1 The evaluation instrument

To measure the students' evaluation of the examples, the students answered a survey questionnaire after the presentation of each example. The examples should be evaluated regarding the criteria "motivational", "applicability" and "authenticity" which were developed in [4] and which we adapted to the setting of the examples. Respondents were given options using a six-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree) to measure their agreement on the statements of the questionnaire. Five items build the scale "motivational", one being for example "The reference to an application has aroused my interest." The scale "applicability" consisted of three items, one being for example "This example has improved my ability to work on tasks with an engineering context." The criterion "authenticity" is checked with one item, namely "The application reference is authentic: a real engineering problem is solved with the help of mathematics." (All sample items were translated by the authors.)

In addition, we had the following statement rated, on the same scale: "I liked that the example was presented by a student."

3.2 The sample

The study involved 7 to 18 students who were enrolled in the master's programme of rescue engineering. The six examples that were integrated into the lecture were evaluated by a different number of students: The first one was rated by n=18 students, the second by n=17, the third by n=11, the fourth by n=12, the fifth by n=7, and the last by n=10.

3.3 The results of the evaluation

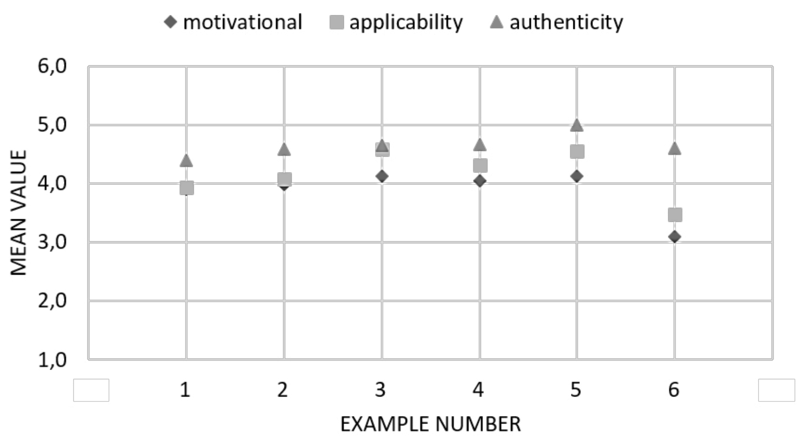

Fig. 5. Mean values of the three evaluation criteria in the six examples

Descriptive analysis for the evaluation criteria (Figure 5) reveals that all examples were evaluated as being very authentic (mean values ranging from 4.39 to 5.00), the one with the highest mean value is example 5. The examples 1 to 5 seem to be quite motivating (mean values between 3.90 an 4.12) and applicable (mean values between 3.93 and 4.58). In the example 6 the criteria “motivational” and “applicability” are rated weaker than in the other examples (3.10 and 3.47).

The mean scores for the examples in the item “I liked that the example was presented by a student” are 4.56, 4.88, 4.55, 4.33, 5.29, and 4.40, so they are consistently well above average (3.50).

4 DISCUSSION AND CONCLUSION

We summarize the concept and describe success factors and challenges, discuss the evaluation of the project and give recommendations on how to implement the concept in other courses.

4.1 The concept: summary, success factors and challenges

The concept successfully combines the ideas of “Bringing different academic levels together" and "Bringing different disciplines together" as explained in section 1, and additionally solves the disadvantages associated with the two approaches, namely the concern for the correctness of a student presentation [7] and the missing authenticity of the presentation by a mathematician [12].

Different levels are brought together by the collaboration with an advanced student during the development of the material and the presentation of the examples. The didactic and professional quality of the presentation is ensured by the the interplay between student and lecturer (in particular step 4, the quality assurance).

This close cooperation also brings together different disciplines: an engineering student and the mathematics lecturer. The involvement of advanced students with an engineering background makes the examples more convincing. The authenticity is reinforced by the fact that the student himself/herself presents the application and is directly available for discussions, especially on the context of the application. This is an important difference to the concept in [8], where screencast videos are developed together with students and then integrated into the course as video material.

The concept is a small intervention that can be easily accommodated within the given institutional framework and requires little time. The cooperation with the student is needed as the mathematician lacks the knowledge of the application context. Remark that short as well as long examples were successfully embedded into the course. A side effect of the project is the learning effect that the tutor has concerning the mathematics and the educational tools – the student’s presentations improved from example to example, and the student also confirmed an increase in understanding in an interview that concluded the project.

Central for a successful implementation of the concept was the collaboration with a student who was enrolled in the same study programme, had a good understanding of mathematics and who had experience in an engineering work environment, thus knowing the work place of engineers quite well.

Other important factors were the close cooperation between the lecturer and the student, the demand for a deep understanding of both the application and the mathematical content (on the part of both the student and the lecturer), the use of the modelling cycle in the preparation of the material and the attention to matching notations and a good fit with the lecture material.

A challenge even before the start of the project was to find a student with the mathematical and engineering background willing to develop teaching material and to present it. During the collaboration, it was challenging to develop mutual understanding, in particular to match the lecturer's 'mathematics language' and the student's 'engineering language'.

4.2 The evaluation: Summary, limitations and research perspectives

The results of the survey show that the examples were perceived by the students as very authentic and that they very much appreciated that a student had presented them. The example number 5 that took the most time to prepare, had the most mathematical input and took the longest to be presented was judged the most authentic. In addition, most of the examples were received as very motivating and applicable. Only the sixth examples was rated worse in these two criteria. A reason for this could be that the mathematical topic used in this example (hypothesis testing) is quite difficult for students.

Limitations of the evaluation result from the small size of the sample. Either the concept should be tested and evaluated in courses with a larger audience in order to gain better quantitative insight into the students' evaluation of the examples and the role of the student giving the presentation, or, with a similarily small sample as here, interviews should be conducted in order to obtain qualitative results.

In addition to a better methodological implementation of the study, it would be interesting to investigate if there is a difference in the evaluation of the examples when they are not presented by a student, whether the concept changes the students' motivation in the long term as a result of the intervention, and which value the tutor found in the intervention.

4.3 Recommendations

The concept can be transferred both to beginners' math lectures and to any other subject where connections between different disciplines can be created. The new material can be used beyond the specific implementation in one semester with a particular student, as the quality is good and the lecturer understands the application well after the implementation.

A challenging step is to find a student from a higher semester, ideally with work experience and good grades in the subject. We recommend asking students who have previously taken the subject.

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Bringing Visibility to Transversal Skills in Engineering Education: Towards an Organizing Framework

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ABSTRACT

Professional engineering work occurs in dynamic, complex contexts that require engineers to leverage various skills beyond their technical competencies to work productively with different stakeholders. Problem-solving is not merely a technical endeavor; educators and practitioners have long realized the synergistic connection between technical proficiency and complex personal and interpersonal competencies, such as critical thinking and communication skills.

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Since the 1990s, the topic of transversal or professional skills has been a common thread in engineering education literature. Engineering accreditation bodies such as Accreditation Board for Engineering Technology (ABET) and Commission des titres d'ingénieur (CTI), and engineering curriculum models such as the conceive-design-implement-operate (CDIO) have highlighted the importance of various transversal skills in professional engineering work. Today, there is a general agreement among engineering educators and scholars about the value and benefits of transversal skills. What is less clear is which specific skills should be considered transversal and how those skills can be categorized and defined. Efforts in settling these issues ultimately help engineering programs to have a clearer picture of which skills are (and are not) well integrated and assessed in their curricula.

This concept paper discusses a framework for categorizing transversal skills. We build on the relevant literature and the ongoing educational practices in prioritizing transversal skills at the École polytechnique fédérale de Lausanne (EPFL) to bring visibility to essential graduate skills and attributes, including those that are often underemphasized.

1. INTRODUCTION

Desired outcomes in engineering curricula for students' learning are often categorized into two groups: technical and transversal or professional competencies (we use the terms interchangeably in this paper). Broadly speaking, the technical competencies are among widely accepted desired attributes for engineering students. Accreditation bodies such as the Accreditation Board for Engineering Technology (ABET) and Commission des titres d'ingénieur (CTI), and popular models in engineering education, for instance the conceive-design-implement-operate (CDIO) approach, point out to outcomes that demonstrate more or less similar attributes regarding technical competencies, among them, emphasis on scientific and technical knowledge and ability to apply knowledge to solve engineering problems, or ability to plan and carry out experiments (ABET, 2021; Crawley et al. 2014; CTI, 2017). Despite engineering educators' familiarity with these competencies, defining specific outcomes, teaching strategies, and ways to assess the outcomes and their respective competencies are the focus of ongoing work in the scholarship of teaching and learning.

Our focus in this paper is on the second group of competencies, transversal skills, which has been a matter of debate. Since the 1990s, the topic of transversal skills has become a common thread in engineering education literature. The emphasis on these competencies in particular was motivated by reports calling for broader education and the observation of inadequate preparation of engineering graduates for work settings (Crawley et al. 2014; Shuman et al. 2005). In the U.S., for example, documentation of misalignment between the level of preparation of undergraduate students in attributes necessary for professional settings, such as communication and teamwork, led to the major changes in ABET requirements on students' outcomes, ABET Engineering Criteria 2000 (Prados et al. 2005; Shuman et al. 2005). Today, engineering programs are more intentional to incorporate various professional skills and competencies, often motivated by changes in student learning outcomes identified by accreditation bodies. Nevertheless, while there has been increasing attention to the importance of professional competencies within engineering education community, the lack of consensus about the breadth and depth of competencies addressed in educational settings as well as ambiguities in guidelines specified by accreditation bodies, for instance on ethics (Junaid et al. 2021), created a complex picture for building a common ground centered around transversal knowledge, skills, and attitudes.

Considering the diversity of the competencies and the complexities in defining them, we believe developing a framework for categorizing is critical for educators to have a clearer picture of which skills are (and are not) well-integrated and assessed in their curricula. This study was motivated by the recent strategic efforts and ongoing educational practices around transversal skills at the École polytechnique fédérale de Lausanne (EPFL) and aims to develop a framework that can bring visibility to essential graduate skills and attributes. This will also help to refine emerging approaches to teaching transversal skills, including the use of tangibles.

2. EFFORTS IN PRIORITIZING TRANSVERSAL SKILLS AT EPFL

With the recognition of the primacy of transversal skills for students, diverse educational initiatives have prioritized different skills in the curricula at EPFL. Notably, teachers are asked to select specific transversal skill learning objectives, for each course, from a list of 32 skills— adopted since 2013. These skills are categorized into five broad themes: (1) communicate, process, manage, and generate information; (2) personal effectiveness; (3) project management; (4) working in the society; and (5) working in groups and organizations; for more details see Kovacs et al. (2020). Some skills point out general statements that focus on behavior or performance, for instance, “write a scientific or technical report” or “collect data”; others emphasize specific processes, for instance, “communicate effectively with professionals from other disciplines”.

As thinking and experience within the EPFL community around transversal skills for engineering students evolved, a working group was set up in 2021 to review our current needs, objectives and resources in order to coordinate the teaching of transversal skills at different educational levels. The working group includes professors and members from several units, among them the Teaching Support Center (CAPE), the Language Center, and the representatives of the Student Association, and is led by Associate Vice President for Student Affairs (Hess, 2021). The working group envisions creating possibilities for EPFL students to develop the necessary skills for highly competent architects, scientists, and engineers.

In the first phase of their work, the group identified a list of competencies and the subjects that address those competencies, as well as a list of high-priority skills that should be taught at different educational levels (BA, MA, and PhD). Table 1 presents the list of transversal skills identified for bachelor students concerning five major themes: communication, interpersonal, intrapersonal, organizational, and enterprise. The group arrived at a consensus on some particular high-priority skills for bachelor level; for instance, giving oral presentation (communication skills), collaborating (interpersonal skills), and learning from feedback (intrapersonal skills).

In addition to the efforts described, there has been a growing interest and commitment to doing research and professional development with respect to transversal skills at EPFL. One such recent initiative is the 3T Play[1] (transversal skills, technical universities, tangible objects) that aims to design interventions for teaching transversal skills using tangibles. The project is a collaborative effort between several units at EPFL, including the College of Management of Technology (CdM), the Center for Learning Sciences (LEARN), CAPE, and the Discovery Learning Program (DLP). The current study is an initial attempt to converge the ongoing efforts and create a common framework for designing the 3T Play Project.

Table 1. List of transversal skills at bachelor level identified by the working group at EPFL

Broader categories	**Skills**
Communication	- Giving oral presentations - Writing reports - Listening actively - Mastering at least two foreign languages
Interpersonal	- Collaborating - Taking the perspective of others - Managing conflict
Intrapersonal	- Learning from feedback - Regulating emotion - Evaluating oneself - Planning learning goals - Managing priorities
Organizational	- Setting objectives - Managing time - Choosing appropriate methodology
Enterprise	- Working with other professionals - Determining relevant societal issues - Applying relevant ethical, legal, and safety goals

[1] https://learn.epfl.ch/wwd_learn/3tplay-tangible-objects-for-developing-transversal-skills-in-technical-universities/

3. TOWARDS AN ORGANIZING FRAMEWORK

There are some similarities among different lists of transversal skills proposed by accreditation bodies and/or adopted by various institutions. For example, they often highlight various communication and collaboration skills, which are widely recognized and frequently addressed in engineering education (Cruz et al. 2020). Such recognition implies that there is more emphasis on integrating these competencies. Importantly, there is less conceptual ambiguity in defining such skills and establishing evidence for their improvement. The differences, though, resonate with the diversity of attributes that have been addressed in the engineering education literature (Crawley et al. 2014; Passow and Passow, 2017; Rosén et al. 2019). They further speak to a degree of specificity in defining particular skills and competencies.

We picture a categorization on the basis of specific competencies rather than domains of competencies. That is defining domains of competencies, such as interpersonal skills, may in fact add another layer of complexity in developing a framework. Further, there are interrelationships among various competencies and as such, creating explicit boundaries around different groups of skills is not consistent with the reality of day-to-day practice, which is particularly problematic when considering interactions between personal and interpersonal knowledge, skills, and attitudes. For example, CDIO syllabus v.2 (Crawley et al. 2014) distinguishes between personal and professional attributes and interpersonal skills. The former includes categories such as “systems thinking” and “ethics, equity, and other responsibilities” and the latter includes “teamwork” and “communications”. While it would be perfectly reasonable to prioritize specific skills, within each category, in an educational setting, downplaying the importance of interactions between the two reproduces the predominant practices in engineering education that lacks consideration of broader social factors.

In addition, a useful framework of transversal skills should foreshadow criteria and indicators one could consider in addressing each group of competencies. There might be a diversity of interpretations about the specificity of particular skills; some point towards general descriptions and criteria for addressing the competencies, while others get to a more detailed description of each group of competencies. Moving towards a detailed description of skills and prescribing the attributes may, in fact, simplify the very nature of transversal skills and limit faculty members in operationalizing the skills in their classrooms. The goal is not to copy specific outcomes, as it is the case with learning outcomes identified by accreditation bodies. Here, it is important to distinguish between competencies and the primary emphasis of educational activities. One teacher may prioritize and assess critical thinking for a given intervention, while another may focus on collaboration and teamwork.

Now, the question is what skills and competencies should be considered in building a framework. Our goal is not to provide an exhaustive list of skills but to prioritize an initial list of broader themes and emphasize the interactions among them, which can help us identify specific criteria and indicators. There is a consensus about the importance of collaboration and communication skills for professional engineers. The abilities to effectively work and interact with stakeholders and individuals with different backgrounds are often integrated into engineering curricula. In addition, in agreement with theoretical and empirical works around transversal skills, we posit any set of proposed skills should prioritize fostering students' moral values. We use ethical reasoning as an umbrella term to describe skills for moral deliberation process, among them, considering and evaluating different perspectives, and insight into intended and unintended consequences of courses of action.

The last two broad categories we propose are thinking and management skills. By thinking skills, we mean reflective ways, cognitive, emotional, and social, by which we approach and engage in problem-solving and the process of inquiry. It emphasizes the skills needed to deal with ambiguity and uncertainty, which is the very nature of real-world problems. While different frameworks specifically address indicators of thinking skills, for instance, critical thinking, these competencies have remained underemphasized in engineering education. Not only is there less clarity about these skills, conceptually, but they are often treated fundamentally as problem-solving in ways that reinstate the status quo of technical rationality. Lastly, by management skills, we refer to the ability to organize taskwork or a change process individually and as part of a group.

As we move to spell out broader categories of transversal skills, it gets more clear that specific skills may interact. Considering such dynamics, we propose a different framework to organize various transversal competencies. We envision a more holistic representation of transversal skills considering overlapping relationships between five general themes: thinking skills, ethical reasoning, collaboration (teamwork), communication, and management skills. Readers may imagine a Venn diagram presenting relations between different themes. Such illustration emphasizes five broad themes of transversal skills that have been highlighted as critical graduate attributes for engineering students.

We intentionally avoid treating interpersonal and intrapersonal skills as broader categories to organize professional skills and therefore drawing boundaries between various skills on such a basis. We posit that competencies that are often defined at the individual level, such as critical thinking and ethical reasoning, interact with interpersonal communication and the dynamics of relationships between individuals. While this claim might seem obvious to the readers, its practical implication demands moving beyond the picture of thinkers as merely isolated individuals. Further, the interactions among the various skills, for example the overlap between ethical reasoning and thinking skills, demonstrate how interventions focusing on one may influence another. Treating imagination as the primary constituent of thinking skills and ethical reasoning, for instance, and providing opportunities for students to practice at imagining (Jalali and Matheis, 2017; Jalali et al. 2022) may work to simultaneously develop both. Put differently, the overlap between the themes can also be considered a guide for designing classroom interventions. The description of all reciprocal interactions is beyond the scope of this concept paper.

4. DISCUSSION AND CONCLUSION

This work-in-progress paper presented an initial work towards developing an organizing framework for transversal skills. While technical and transversal skills are important for professional engineering practice, transversal skills are often not adequately taught and learned (Graham, 2018; Kovacs et al. 2020; Sarrade et al. 2021). Kovacs et al.'s review identified that while some transversal skills are addressed relatively frequently, others are rarely addressed (Kovacs et al. 2020).

Our future work considers exploring the categories of transversal skills developed in other technical universities and next to the two lists developed at EPFL. In addition, we intend to examine the state-of-the-art in the categorization of transversal skills to clarify the discourse on differences among skills and categorizations. The outcomes help us reflect further and refine the initial framework of transversal skills proposed in this paper and define specific indicators. Further, there is an empirical component in working with teachers once we put forward the framework. It is essential to explore how it can be used in different settings and how its specificities, such as relationships between skills, are translated into practice.

The model proposed in this paper is an attempt to simplify the complexities around transversal skills and facilitate communication with a range of stakeholders, primarily engineering instructors. Our goal is ultimately to develop critical indicators for each theme, informed by the literature, and clarify the key synergies or overlaps between different groups of skills, which will improve understanding of what each attribute/competency is and what it entails. It also provides a springboard for successfully implementing these competencies in practice.

Recognizing the need to converge different approaches at EPFL into a coherent list for transversal skills, we aim to reduce the ambiguities around transversal skills and bring more visibility to these essential skills for faculty and students. We hope that the current study serves as an invitation to discuss how we can better communicate, further develop and implement a somewhat different model of transversal skills in our institution and potentially beyond.

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STRUGGLING AT THE CORE:

Multilingualism and multiculturalism in a European University Alliance

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ABSTRACT

With the ultimate aim of finding ways to improve the systematic integration of linguistic and cultural competencies in engineering education, this paper addresses how culture and language competency education is discussed within a technical European University Alliance and how this discourse is translated – or not – into educational initiatives and activities. By doing this, we aim to put focus on the gap between a certain European Union ideology – "united in diversity" – which is at the very heart of the EU project, and the everyday practices at technical universities, where linguistic and cultural competency education are often considered as marginal activities or elective add-ons compared to the hard core of technical subjects.

The paper is based on European University Alliance documents and the observations and experiences made within one alliance's working group on cultural and linguistic training during 2020-2022. We suggest that the gap between the

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rhetoric of multilingualism and multiculturalism and the reality of teaching and learning within the alliance has at least two sources: a tendency to engage in magical thinking where global competence develops “spontaneously” in international settings and a tendency to avoid addressing difficult questions, e.g., what multilingualism and multiculturalism actually mean in contemporary engineering education. This paper will provide some of the crucial questions that need addressing if we want to move beyond the empty rhetoric, as well as some practical suggestions for a systematic integration of cultural and linguistic competency education into engineering education.

1 INTRODUCTION

The European University alliances, exemplified in this paper by one of the first of its kind with an engineering profile, have the potential to systematically strengthen the integration of linguistic and cultural competencies in education, to the benefit of students, staff, educators and society at large. While the ambitious European University initiative in itself can be said to be in line with general trends of internationalisation in higher education [1] as well as older calls for comprehensive internationalisation [2], we would argue that the integrative training of global competence is – or at least should be – at the very heart of this educational endeavour, and also that this has a special relevance and importance for engineering education.

When the European Commission in 2019 announced the first selection of 17 European University alliances, representing more than 100 higher education institutions from all over Europe, this represented a qualitative change to the European educational area. The following year, the second call resulted in a total of 41 European University alliances, representing more than 280 institutions from 27 member states, and with further partner institutions from Iceland, Norway, Serbia, Turkey and the United Kingdom – the aim of the initiative was as ambitious as its scale .On a rather obvious level, the initiative aimed at strengthening the European Education Area, increasing the European Union’s international competitiveness and capacity to deliver the education and research needed to meet present and future economic, societal and environmental challenges. Equally important, however, and in line with earlier EU initiatives for the integration of European higher education, was the initiative’s role in the ideological work to promote official “European values” and strengthen the idea of the European identity – “united in diversity”, as the motto of the European Union has been since 2000.

When answering the call of the European Union, the motivation of individual universities to join and the perceived importance of the initiative and of its different aspects most likely varied from one alliance to another. Motivation and perceptions probably also varied between the different institutions within the alliances, and even within the individual institutions. As the motivation to work as part of a European University varies, so do the challenges involved, and the opportunities.

Engineering education has a special position in the educational landscape as a self-designated producer of "problem-solvers". It works at the interface between basic research and applied research and development, which is increasingly concerned with the grand challenges of our time, working towards a sustainable future while trying to balance the not necessarily aligned needs of the many stakeholders involved. Engineering graduates are increasingly expected, both by society and by industry, to possess the competence needed to effectively and appropriately communicate and work in environments characterised by cultural and social diversity, i.e., intercultural or global competence [3, 4]. The call for more socially skilled graduates is, however, a challenge for engineering universities, staffed foremostly by academics hired on the merits of often highly specialised technical knowledge, working in fields where ever more knowledge and specialised skills are seen as indispensable to already crammed curricula.

For educational leaders at these universities, internationalisation seems to be at least a partial answer to the question of how students can learn to work and communicate among people with backgrounds different from their own. Not only does internationalisation tend to help with the ubiquitous ranking lists, but also seems to be the answer to how students can acquire core competencies of a cultural and linguistic nature through international mobility. Furthermore, the scope of the European University alliances, like the other Erasmus programmes, also includes the mobility of teachers and staff. Given the challenge of many engineering universities to make room for global competence education or for languages beyond the local language and English, the European University alliance initiative holds much potential. This is true also of the alliance studied in this paper, Unite! – University Network for Innovation, Technology and Engineering, which we for the purpose of brevity will refer to as "the Alliance" [5].

The Alliance was created in 2019 between seven universities most of which had a long history of collaboration within the CLUSTER network. The official aim was to "be a model for a European University of innovation, technology and engineering addressing the Sustainable Development Goals through the twin digital and green transition." The member universities were located in Germany, Finland, France, Sweden, Italy, Portugal, and Spain.

In this paper, based on participant observation and document analysis, we explore how culture and language competency education has been discussed within the Alliance, and how this discourse has been translated – or not – into educational initiatives and activities. We will identify a gap between the Alliance's official rhetoric of multilingualism and multiculturalism, and the preparedness to see this translated into systematic and effective educational activities that could help individuals – students, staff and educators – acquire the competencies needed to work effectively with the cultural and linguistic diversity of our globalised world.

We argue that this gap has two likely sources. The first being the seemingly fact-resistant belief that global competence will spontaneously develop in an international work- or study environment. A second probable source is an avoidance strategy when it comes to addressing difficult questions such as what multilingualism and multiculturalism actually mean, or could mean, in engineering education today.

Finally, this paper outlines what we see as some crucial issues to address in order to move beyond the empty rhetoric. It also provides some practical suggestions to systematically integrate global and linguistic competency into a European University alliance such as the one discussed here.

2 METHODOLOGY

The data in this study come from multiple sources, both from official documents related to the EU project call and from observation notes and experiences of the members of the Multilingual and Multicultural Training Centre (henceforth M&M). The consulted texts include three official documents from three phases of the project: the first phase project proposal (2018), the progress report (2019), and the project proposal for the second phase of the project (2022). These documents serve similar purposes, addressed as they are to the grant giving organisation within the EU, and we believe that they can serve as good illustrations of how the concepts of multilingualism and multiculturalism have been framed, presented, and mobilised within the Alliance.

These documents are analysed in two stages: first a keyword search, then a text analysis to better understand how the keywords are used within the documents. In the first stage, a keyword search was performed across the three documents to track the evolution of the use of terms related to language, culture, diversity, internationalisation, skills and the like. In line with Dafouz's [6] study on another European University alliance, a keyword search related to the national languages of the members of the Alliance and English was also carried out. Table 1 includes a complete list of keywords for each document, the number of raw instances in each document, as well as the average times they appear per 1000 words in order to provide a means of comparison. Secondly, in order to investigate how the keywords were used, the passages of the documents including the keywords were analysed. This allowed us to understand the terms within the context of the document.

In addition to observing how the topics of multilingualism and multiculturalism are portrayed in the official documents for the EU grant, we also explore this question internally, based on the experience of members of the M&M-team working within the Alliance. An explanation of the group's goals and consequent experiences within the Alliance are developed in the next section of the paper.

3 FINDINGS

3.1 The Alliance's proposals

The official documentation reveals an evolution in how matters related to multilingualism and multiculturalism in the Alliance are presented within the context of the EU call.

Regarding the keywords *multilingual(ism)* and *multicultural(ism)*, we can clearly see their importance to the Alliance as there is a dedicated working group on this topic that is called the Multilingual and Multicultural Training Centre (M&M). Beyond this group, these terms have permeated the Alliance's communication, with an increase of the terms *multilingual(ism)* and, to a lesser extent, *multicultural(ism)* since the first proposal.

From the beginning, being multilingual and multicultural have been defined as "key to our mission to shape the mindsets of a new generation of European and global citizens and to educate the graduates that contribute to sustainable global Development" (1st phase project proposal, p. 158). Learning a language of one of the partner universities is seen as providing "better access to another European culture, increasing mutual cultural knowledge and understanding and helping students be part of the daily life of their host country" (1st phase project proposal, p. 109). Overall, this promotes "employability across Europe" (1st phase project proposal, p. 8, and 2nd phase project proposal, p. 38) Thereby, multilingualism and multiculturalism are seen to open doors and increase understanding, simply by being present. To acquire these competences, the Alliance intends to provide language courses and create opportunities for mobility and interaction. This communication around the benefits of immersing oneself into a multilingual and multicultural environment to increase linguistic and global competencies continues to be present in the 2nd phase project proposal.

Likewise, d*iversity* and *diversity and inclusion* are also terms that increased significantly throughout the project. A working group separate from M&M is devoted to "diversity, inclusion and well-being", and they have created a "Charter on Diversity and Inclusion". Diversity is understood to promote multilingualism, and as such, is integrated throughout the University Alliance: "Diversity, inclusion and well-being as well as transversal themes with clear goals and activities to promote multilingualism in our education are addressed in various work packages" (2nd phase project proposal, p. 5). Interestingly, the buzzword *cultural diversity* has been all but forgotten since the 1st phase project proposal, and is no longer highlighted as it once was earlier in the project. Yet, it is still referenced indirectly in the text: "The multicultural and inclusive alliance also promotes the diversity and cultural heritage of its countries and regions, thus also supporting visibility of the different institutions in it" (2nd phase project proposal, p. 36).

Also, the use of the term *English*, while almost forgotten in the progress report (2021), saw substantial increase in the second phase project proposal (2022).

English has always been recognized as the official working language of the University Alliance members. At the same time, the national or regional languages of the partner universities are mentioned less often. In fact, the specific languages are mentioned only once in the 2nd phase project proposal. In addition, the keyword *language* is used less in the 2nd project call, probably because the term *multilingual*(ism) is privileged.

Lastly, we also note that while *European* – unsurprisingly – has been used consistently throughout all documents, the use of the terms *international* and *global* have declined in comparison. The focus is placed on promoting European identity and common European values and “strengthening European Identity through Education and Culture” (1st phase project proposal, p. 6). By the 2nd phase project proposal, this has been clarified as “actively contribut[ing] to European citizenship as well as to European attractiveness, resilience and competitiveness on a global scale” (2nd phase project proposal, p. 4).

Table 1: Keywords found in official documents from different phases of the project

	1st Phase Project Proposal (2018) 164 pages 102 072 words		**1st Phase Progress Report** (2021) 49 pages 26 971 words		**2nd Phase Project Proposal** (2022) 123 pages 47 132 words	
	Raw instances (n=)	Normalised per 1000 words	Raw instances (n=)	Normalised per 1000 words	Raw instances (n=)	Normalised per 1000 words
Language(s)	158	1.55	10	0.37	44	0.93
Linguistic	19	0.19	0	0.00	1	0.02
Multilingual(ism)	44	0.43	12	0.44	27	0.57
Culture	34	0.33	7	0.26	14	0.30
Multicultural(ism)	21	0.21	10	0.37	15	0.32
Intercultural	14	0.14	8	0.30	11	0.23
Diversity	18	0.18	13	0.48	44	0.93
Differences	4	0.04	3	0.11	5	0.11

Cultural diversity	18	0.18	0	0.00	1	0.02
Diversity and inclusion	2	0.02	4	0.15	14	0.30
English	26	0.25	2	0.07	28	0.59
Catalan	4	0.04	1	0.04	1	0.02
Finnish	12	0.12	4	0.15	1	0.02
French	12	0.12	6	0.22	3	0.06
German	17	0.17	6	0.22	5	0.11
Italian	16	0.16	1	0.04	2	0.04
Portuguese	14	0.14	0	0.00	1	0.02
Spanish	7	0.07	2	0.07	1	0.02
Swedish	16	0.16	4	0.15	2	0.04
European	373	3.65	147	5.45	262	5.56
Global	81	0.79	10	0.37	27	0.57
International	312	3.06	48	1.78	57	1.21
Internationalisation	6	0.06	6	0.22	5	0.11
Interdisciplinary/ interdisciplinarity	30	0.29	12	0.44	10	0.21
Cross-disciplinary	5	0.05	0	0.00	2	0.04
Skills	115	1.13	1	0.04	27	0.57
Language skills	11	0.11	0	0.00	0	0.00

Intercultural skills	4	0.04	0	0.00	0	0.00
Competence(s)	26	0.25	5	0.19	9	0.19
(Inter)cultural/ global competence	0	0.00	2	0.07	2	0.04
Transversal	17	0.17	6	0.22	11	0.23
Communication	115	1.13	43	1.59	112	2.38
Intercultural communication	2	0.02	0	0.00	0	0.00

3.2 The Multilingual and Multicultural Training Centre (M&M)

During its first phase, the Alliance was organised into ten “task forces”. Matters related to language and culture were delegated to a sub-task force known as the Multilingual and Multicultural Training Centre (in everyday Alliance communications and henceforth in this paper referred to as “M&M”), which was associated as part of the task force in charge of “student services”. This positioning of language and culture issues, which caused some internal complaints, likely mirrored the non-academic position of some, but not all, of the language centres at the partner universities. Thus, already from this organisational design there appeared to be a mismatch – intentional or not – between the rather peripheral position of language and culture matters in the overall Alliance structure, and the centrality of the concepts of multiculturalism and multilingualism in the words and spirit of the proposal.

The M&M working group was set up from the start to be responsible for developing and supporting language and global competence offers inside the Alliance. The language training offer includes both language courses (i.e. structured, formal learning) and language tandems (i.e. informal, largely student-led learning), with a view to equipping engineering students for an increasingly internationalised, multilingual and multicultural job market and academic environment.

The M&M team is made up of language teachers, researchers and administrative staff from the seven member universities, with varying degrees of professional experience and training. The members of M&M are themselves multicultural and multilingual due to their personal and educational histories, and include a range of extra-European family backgrounds, expertise and experiences. As in the rest of the Alliance, the working language in M&M is English. A possibly unique feature of this group within the context of the Alliance is that English is also the first language of several task force members. With these professional, cultural and linguistic credentials, the M&M team seem ideally equipped to tackle the complex task of developing a multilingual and multicultural offer inside the Alliance.

The team took shape over the year 2019-2020, adapting quickly to the conditions imposed by the COVID-19 pandemic, and soon established a work approach based on weekly virtual meetings, with only some work done outside meetings. The points on the agenda are dealt with as a whole group or in smaller groups that report back to the team at the end of the meeting. The meetings typically develop through frank and open discussion of the issues, and virtual collaboration tools such as Google Docs are frequently used to produce documents and materials.

Although the team was mostly able to keep to the agreed deadlines, quite a bit of time was needed in the first year to become familiar with and understand the different work modes and local conditions and opportunities of the various universities represented by the team members. Engaging though also complex discussions often took place as a result of quite varying perspectives on the issues at hand. The M&M team very early on produced a joint list of language and culture courses that each partner university was willing to share with the Alliance. Slightly more slowly, the language tandem project was structured and defined, and a variety of global competence initiatives were outlined, including a course in global competence and a series of videos produced by students to present their local cultures to students from other partner universities.

It soon became clear that organisational differences between the partner universities, in terms of academic calendars, administrative processes and the structures of the chain of command, constituted a major challenge to the effective deployment of an M&M language and global competence offer. In the spring of 2022, a small offer of virtual language courses and activities was finally launched, covering the eight Alliance languages as well as English, intercultural competence and including one serious game as an Open Educational Resources (OER). This virtual offer represents only a small sampling of the full language and global competence training offer available at the different partner universities. Nonetheless, it was considered sufficiently varied to be attractive and of use to the Alliance student community, and, given the organisational complexity of providing even this relatively small offer, it seemed a good enough start. To date, however, the uptake of these courses has been quite limited, and enrolments have been fraught with administrative difficulties. A more precise picture of the possible reasons for the scant interest in the M&M course offer is yet to be gained, but it appears that effectively promoting multilingualism and multiculturalism in the Alliance is far more complex than what is suggested by the confidently positive wording of the project proposals and report.

Beyond the organisational challenges outlined above, what ultimately stymied the M&M team would seem to be the fundamental contradiction between the theory and the practice of the Alliance with regard to multilingualism and multiculturality. On the one hand the project proposals apparently support and encourage multilingualism and multiculturalism, to judge from the pervasive use of the terms throughout the documents, as shown in the Findings of this paper. The very fact that a specific task force has been assigned the responsibility for producing a language and culture offer inside the Alliance is a strong indication of intent. On the other hand, however, training in languages and global competence is glaringly absent from joint programmes and content course offers, and even on paper only 3 ECTS are reserved for language learning activities in any given joint programme or content course, obviously not enough to enable any teaching and learning of real substance. Clearly, a way to bridge the gap between the theory (e.g. the proposal rhetoric) and practice (e.g. the material inclusion of effective multilingualism and multiculturalism in the Alliance) needs to be found. Drawing up an alliance policy on language and global competence seems strongly advisable, as is discussed in the next section.

A clarification of the terms used should also be highly useful. It could be the case that “multilingualism” and “multiculturalism” may not be the most appropriate terms for the purposes of materially enacting the endeavours of the European University initiative. Using EU terminology, both terms simply describe the presence of different languages and cultures within a community [7], i.e. the de facto situation when more than two universities from different EU countries interact. It might be the case that the terms “plurilingualism” and “pluriculturalism” are more appropriate for the initiative, as these terms indicate the ability to use a repertoire of diverse linguistic and cultural resources to meet communication needs or interact with people from other backgrounds and contexts, and enrich that repertoire while doing so [7].

Even within M&M a mix of concepts has been used, likely reflecting the different backgrounds and expertise of the individuals involved. Early on, the group decided to do away with ideas found in the proposal and other texts that were seen as building on notions of cultural essentialism, especially in terms of national cultural stereotypes. Instead, the team preferred working with the non-essentialist notion of “small cultures” and proposed as a slogan for its work “the challenge of diversity”. The concept of global competence was also introduced at an early stage as being particularly fitting to an engineering endeavour working in the spirit of the European Union – united in diversity – while not forgetting the importance of connecting intercultural and plurilingual competence to the goal of “act[ing] for collective well-being and sustainable development” in the words used in the OECD definition of global competence [8].

Despite presenting these thoughts at several transnational Alliance meetings – so called Dialogues – and at full task force meetings, there is still a lack of formalised alliance-wide definitions put on print, and it remains highly unclear to what extent and in which way the understanding of central notions like these have been understood by other task forces in the Alliance. This lack of ready results, be it in educational activities or in the mindset of other colleagues working in the Alliance, was from time to time a source of great frustration within the M&M team.

Educational organisations, while sometimes able to respond very quickly to political steering and societal needs, are well known to find change difficult [9], and the frustration that was from time to time felt in the M&M team was most likely primarily related to the everyday red tape and inertia typical of higher education institutions general. In the case at hand, these standard difficulties were compounded due to the need to bridge the administrative gaps between different institutions in an alliance that subscribed to a model of simultaneous top-down and bottom-up agency.

4 CONCLUSION

In conclusion, we see a major gap between the idea of multiculturalism and multilingualism, despite the centrality of the notions in the original proposal, and the systematic integration of teaching aimed at fostering globally competent (or plurilingual/interculturally competent) individuals. As mentioned above, we see two main reasons for this. On the one hand, the “magical thinking” often found in internationalisation initiatives, where the mere fact that people in a group have different backgrounds should somehow spontaneously make them acquire these competencies, without the need for scaffolding and institutional support. On the other hand, the more or less tacit understanding that “English is enough”.

The tendency to engage in magical thinking as described here is as prevalent as it has scientifically been proven faulty, and should rightly be questioned, confronted and dealt with [10, 11]. The idea that English is enough is a more complex one. It should be noted here that this idea is not officially acknowledged but clearly discernible from the fact that the Alliance exclusively uses English as its *lingua franca,* and its learning offers are only provided in English (with the few virtual language courses described above as the sole exception to the rule). That English is enough is also mirrored in the language-related trends seen in the three documents analysed above. The issue of teaching, cooperating and studying using English is not a trivial matter for participants who primarily have English as their second (or third) language. As the Bologna process has set the stage of European education, it is also increasingly feasible for European students to go through higher education completely relying on a combination of their institution’s first language and English. For engineers, this may appear reasonable, seeing as their primary labour market would seem to be either local – using the local language – or in international organisations where English as a rule is the common working language. So is this a problem at all? After all, most of our students, teachers and staff would do well to become even better at using English. We would argue that it is a problem, primarily for three reasons:

- By not actively encouraging language learning beyond the local and national language through the integration in official curricula, the Alliance fails to work towards the EU ambition of all citizens being proficient in their national language plus two other EU languages.
- By ensuring only the language skills needed to complete their studies, the Alliance falls short of realising its potential for fostering true European citizens that can become part and parcel of the principle of free labour mobility. English may be enough to conduct official work duties abroad, but the EU ambition is to go beyond the creation of an “intra-European expat cohort” living in cultural bubbles isolated from the local society.

- The ability to understand the viewpoints of others is a vital part of global competence. Even as we agree that global competence training does not per se presuppose more than one lingua franca, the traditional role of foreign languages as the lenses through which we can experience the world from different angles is by no means outdated. On the contrary, the rise of world English is both an enabler of communication and an enabler of miscommunication, especially considering that this international form of English is not cultureless, but is influenced by the sociopragmatic assumptions and conversational expectations of the speaker [12]. Therefore, English-only education that lacks a focus on the cultural implications of its speakers contributes little or nothing to develop the capacity to function well in linguistically heterogeneous situations and organisations.

European University alliances run a clear risk of succumbing to an overly Eurocentric perspective when it comes to issues of language and culture, and we would like to critique this from the perspective of global citizenship, a concept embedded in the United Nations' Sustainable Development Goals. For the time being, we can only regret, and take part of the responsibility for, the failure of the Alliance in formulating any strong vision of how multiculturalism and multilingualism could be used as a resource for effective global competence education in the context of the Alliance, and to commit to systematically strive to achieve that goal. In combination with efforts to strengthen activities related to internationalisation at home, we believe the potential benefits of the Alliance go well beyond the activities of the Alliance itself, making a failure to act even more lamentable.

5 FINAL REMARKS

We hope that in its next phase the Alliance will manage to rise to the challenge of diversity, embrace a vision of what global and plurilingual competence could mean within the context of the European University, and commit to realising this vision. Should it fail to do so, it will not be for lack of ideas. Between the literature and the expertise in the M&M team, the list of activities and initiatives could easily be made very long. Some examples would be to tweak existing courses and learning activities to ensure they all include a global competence dimension; to initiate multilingual projects in line with higher education multidisciplinary project work; to provide earlier opportunities for mobility in order to increase language learning motivation; to enable bilingual courses; to ensure that students have room in their programmes to study language and culture [13, 14, 15].

First and foremost, however, the Alliance must make up its mind about how to view issues of multiculturalism and multilingualism, taking seriously the fact that global or intercultural competence, and plurilingualism, is not something that comes to people by magic just by being in diverse company, and that not acting is wasting a chance to contribute substantially to the future development of European engineering education.

Thus, the first point on the agenda during the second phase of the Alliance should be to draft an Alliance Policy for global competence, multilingualism and multiculturalism, defining key concepts, laying down the Alliance's overarching objectives and standards in these areas for faculty, staff and students, as well as for joint endeavours, and the means to reach these.

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THE POSITIVE START PROJECT: A PROACTIVE APPROACH TO PROMOTING WELLBEING IN THE NEWER ENGINEERING ACADEMIC COMMUNITY

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ABSTRACT

The Positive Start Project is a new initiative that is in the process of providing a series of workshops and events focused on academic wellbeing, career development and positive mental health within a large faculty of engineering and applied science in the UK. Aimed at building a scholarly and sustainable research and teaching community of early career academics (ECAs), the project has arisen out of a need to provide high quality professional development activities and frameworks for the ECA community whilst also combatting social and academic isolation left over from the two-year long period of 'lockdown'.

Adopting an Action Research Approach this paper addresses a little considered topic in academic circles, the need to nurture positive wellbeing amongst the Engineering Education academic community. Describing proposed plans for how the Positive Start Project will be developed, disseminated, and reviewed, attention is paid to how 'wellbeing' will be benchmarked at the beginning of the project. Following this a brief overview of some of the planned support and development activities is given whilst the conclusion reiterates the need for a positive and proactive approach to academic wellbeing whilst also noting why Early Career Academics are an important demographic group within our Engineering Education community.

1. INTRODUCTION

Set within one of the UK's largest applied Engineering Education Faculties, WMG employs almost 800 academic and professional support staff. In addition to this, it is home to around 350 postgraduate researchers and over 3,000 undergraduate and postgraduate students studying a range of different engineering, applied science and management disciplines. Tasked with rebuilding the academic community after two years of remote and hybrid working, the Positive Start Project aims to develop a unique Community of Practice for our Early Career Academics[2] [ECAs]. Starting with a two-day long professional development workshop in which the focus will be on colleagues' strengths and attributes (using the Clifton Strengths Tool[1])a fully licenced and fully experienced Clifton Strength Coach / Consultant has been employed to work alongside the academic team leading the project. Following this a series of 'live' face-to-face training workshops and upskilling events will be held alongside peer mentoring opportunities and coaching sessions. Underpinned and evidenced by an Action Research approach this short paper provides an insight into how the Positive Start Project will make a significant impact to the academic culture of WMG by targeting our large Early Career Academic (ECA) community.

[2] Early Career Academics (ECAs): *For the context of this project, the term ECAs refers to the following: PhD students: Colleagues in their first academic post, who have been employed five years or less as an academic, including those on research only, research & teaching or teaching only contracts: Colleagues within 5 years of beginning an academic career (this includes graduates as well as more senior colleagues who have entered academia after a career in industry); Colleagues who have worked in academia for some time but who have changed focus within the last five years (for example, colleagues whose whole career has been research-focused who have within the last five years changed to a teaching contract and colleagues who have previously been employed on a teaching contract who have, within the last five years, changed to a research or research / teaching contract).*

2. BACKGROUND & CONTEXT

One of WMG's key strengths within the University of Warwick is found in its longstanding links with industry. With a leading international reputation for cross-sectoral collaboration and cooperation, WMG has an established record of driving engineering innovation through cutting-edge research. At the same time, WMG's teaching portfolio is built upon a strong emphasis on scholarship and constructive alignment. Colleagues are supported to adopt an applied pedagogy whereby research, learning and teaching, student employability and the needs and expectations of wider society are contemporaneously considered.

Like the majority of academic institutions worldwide, the Covid19 Pandemic has had a marked impact on how WMG operates. Indeed, the past two years have seen a notable change in how the 'day-to-day' operationalisation of learning and teaching is managed and provided. From a teaching perspective there have been a number of changes in the make-up of the academic faculty, with many people leaving the organisation and newer colleagues joining. Many of the new arrivals are Early Career Academics [ECAs] at various stages of their own learning and teaching journey (from Graduate Teaching Assistants to post-doc academics and people new to teaching who are fresh out of employment). A significant number joined the organisation when the curriculum was only offered online, and no one permitted to visit the campus. Joining a large organisation during a global crisis, and then working in enforced isolation, without having an *a priori* relationship within an academic team, it is perhaps not surprising that some newer colleagues, most notably the ECAs have found themselves feeling somewhat isolated.

Yet, as we move towards what is becoming an 'emerging, reformed normality', so the impact of the Pandemic is becomes more evident. One notable issue that is increasingly being reported in the media, is a general increase in mental health problems across the population[2] . Already acknowledged to be a matter of some concern amongst the academic postgraduate research community[3,4], problems with poor mental health are augmented by low levels of individual wellbeing to impair promising academic careers[4,5].

It is in this unique 'reformed normality' that this paper is set. Within WMG itself there is a general recognition across the academic faculty that we need to rebuild and reboot our unique Academic Community of Practice. This is particularly the case for our ECAs, some of whom had limited or no opportunity to get to know their colleagues personally and so are struggling to feel part of an academic community. It is the impact of this 'lockdown gap' that this project will address over the next 12 months.

3. PROJECT OBJECTIVES

The Positive Start Project proactively addresses what is often perceived to be a 'taboo subject' in UK Higher Education, that of *collegial wellbeing.* Starting with a benchmarking survey aimed at gauging wellbeing across the faculty, a series of bespoke workshops and events are being put in place to help rebuild our academic community. To facilitate this the project has a single primary objective:

To provide the means by which WMG's Early Career Academic (ECA) colleagues can become part of a thriving Academic Community of Practice whilst developing their individual transferable professional competencies.

To support this, four sub-objectives have been developed:

- Conduct a detailed and critical literature review about collegial wellbeing in academia with a particular focus on Engineering Education.

- Undertake a benchmarking survey looking at academic wellbeing on which to ground ongoing interventions

- Starting with a number of two-day long 'kick-off' workshops, develop a series of developmental activities and events aimed at supporting the ECA community

- Disseminate knowledge across the university and beyond about how to better support ECAs from a professional development and wellbeing perspective

4. THE KICK-OFF WORKSHOPS

The kick-off workshops will take place over three days, offered in two distinctive themes:

1. **Academic Wellbeing: Balancing Professional 'Health' & Individual 'Wellbeing' (Workshop 1: Days 1 & 2):** *This theme emphasizes the link between academic wellbeing and professional development. Colleagues will be taught how to use tools such as a 'force field' analysis to build up persistence and research stamina*

2. **Academic Apprenticeship: Balancing Research, Teaching and Life (Workshop 2: Day 3):** *This workshop will occur 4 weeks after workshop 1 and will provide ECAs with the tools and strategies needed to move forward as part of a larger academic community of practice.*

In addition to the above, a programme of academic development workshops and events is being put together. This programme will provide colleagues with opportunities to share their experiences of learning and teaching in engineering whilst also providing opportunities for upskilling. Newer Career Academics will be encouraged to present their ideas and also to engage in scholarship; conducting research into their own teaching to identify areas for improvement and development.

5. BUILDING TOMORROW'S ACADEMIC COMMUNITY OF PRACTICE IN ENGINEERING

Whilst the generic benefits of developing an Academic Community of Practice are recorded in the literature[6], this project is distinctive in that it is focused very much on a relatively large single community of early career academics working within an applied Engineering Education setting. In addition to the ‘Kick-Off Workshops’ discussed above, the following activities and interventions will be rolled out of the next 12 months:

1. Peer Mentoring Network: Using an approach developed by two WMG colleagues[7] a Peer Mentoring Programme will be launched through the summer of 2022. It is anticipated that this will provide one-to-one and / or group support for all newer academic colleagues. In addition to the PGR community of 350 individuals, this intervention will be open for newly appointed researchers and teachers to join (those within the first three years of their first academic appointment initially).

2. Professional Development & Teacher Training: The need to train academics to teach has long been acknowledged in the literature[8,9]. Facilitated in partnership with WMG’S Education Innovation Group a series of learning and teaching focused workshops will be offered to all ECAs. Topics covered will vary, starting at a basic level for colleagues joining academia from industry or as graduate teaching assistants, with topics such as ‘An Introduction to Constructive Alignment’. Move advanced workshops will include ‘Curriculum Design’, ‘Developing a Successful MOOC’, and ‘PhD Supervision’. The professional development and teacher training activities will start in the summer of 2022 and continue.

3. Research Methods: WMG currently offers Research Methods training to all PGRs as part of their compulsory year 1 training. The Positive Start Project will expand on this and offer further specialised RM training workshops and events throughout the year open to all ECAs including colleagues who having moved to teaching directly from industry have little or no experience in conducting research.

5.1 Leading by Example: Scholarship in Action

In addition to the professional development focus described above, the Positive Start Project encapsulates an Action Research[10] strand. Adopting a mixed methodological approach, the project will begin with the administration of a survey aimed at gauging general wellbeing amongst the faculty as society begins to move out of the global Pandemic. Adapted from the NHS Staff Survey (2021)[11] the survey begins with a series of demographic and background questions. It is important to note that such questions are for analytical purposes only as all data collected in the survey will be anonymous. Ethical approval has been acquired and steps put in place so that should any sub-group be small enough to risk identifying individuals, the data will be aggregated into a larger classification.

The findings from the benchmarking survey will be used to guide and inform both the Positive Start Project whilst also being disseminated amongst the PGR team to enable future activity planning.

5.2 The Survey Tool: The main themes to be investigated.

In planning the benchmarking survey, a literature review has been conducted to identify the key factors underpinning wellbeing and mental health at work. Seven different themes are to be addressed by the survey:

i. **Number of hours per week spent at work / study:** Whilst occupational resilience is acknowledged to be linked to the ability to be flexible with regards to workload and other employment related demands[12], a small but important corpus of literature focuses on occupational burnout and excessive workload for colleagues working in Higher Education[13,14,15]. Given the focus on early-career academics, the need to gain an insight into the number of hours colleagues spend at work and / or studying is an important factor which will inform future decisions in respect of workload management and work-life balance.

ii. **Sleep:** There exists a considerable body of knowledge about sleep deprivation within younger people amongst university / college students and those in the early part of their (i.e., age 16-30 years)[16,17,18]. Whilst a different, but equally significant corpus of research has examined the impact of sleep deprivation on work performance of people of various ages[19]. In analysing this literature, the link between sleep deprivation, stress, poor work performance and general lower quality of life is evident making this an important variable within the study.

iii. **Exercise & Physical Activity:** Links between poor mental health, stress and a lack of physical activity are widely acknowledged[20,21]. The benchmarking survey will ask colleagues to gauge their level of activity and the nature of their role in terms of physical activity. Given the varied nature of WMG's ECA community this question is particularly relevant. A small handful of colleagues have physically demanding roles conducting primary engineering research, whilst others' time is generally spent conducting desk research. Over the Pandemic teaching has become a somewhat sedentary occupation, mainly taking place online. As we move back towards a more 'usual' pedagogic practice in which students will be taught in classrooms and laboratories the benchmarking survey will look at the physical nature of colleagues roles.

iv. **Individual Perceptions of Physical & Mental Health:** Connected to wellbeing these questions focus on the participants' perceptions of their own health.

v. **Social life / Leisure time:** The relationship between the amount of time spent on leisure or social activities and positive wellbeing and mental health on students and young people in particular has been well-researched[22,23]. In building an academic community of practice, particular amongst the postgraduate research community, the project team are aware of the need to support social activities. The benchmarking survey will look at what colleagues prefer to do outside of the academy.

vi. **Professional Development Activities:** The final quantitative question focuses on the proposed activities planned within the Positive Start Project asking participants to gauge the potential value of each activity. The responses to these questions will be used to guide and inform future activities in WMG.

vii. **Support within the Academy:** Three open questions are asked, one of which focuses on how WMG could better support ECAs professional and academic development. Whilst the second question asks about support for participant's overall wellbeing. The final 'catch all' question is intended to provide participants' with the opportunity to raise any issues pertinent to them.

5.3 Benchmarking Survey: Data Analysis

No identifying data will be collected. The data will be analysed using Qualtrics to produce descriptive statistics. A series of cross-tabulations will be undertaken with a view to gaining insight into any demographic differences in participants' perspectives and experiences. The three open questions will be analysed using an approach based on grounded theory methodologies in which the data will be conceptually analysed using simple and axial coding

5.4 Action Research Qualitative Research.

Following a typical Action Research methodological approach[10], the results of the wellbeing benchmarking survey will be to inform and underpin subsequent academic activities offered under the auspices of the wider project. Following this, the next stage of the research part of the project will be to critically analyse the impact and longer-term outcomes of the planned interventions. This will be undertaken using in-depth qualitative interviews and focus groups which will then be analysed, and the findings used to inform subsequent activities.

6. CONCLUSION

Purposefully designed as a holistic yet multifaceted approach to early academic career support, the Positive Start Project is still in its very early days. The intention in providing a range of opportunities from two-day-long workshops through to smaller professional development activities and workshops is to help the somewhat 'covid beleaguered academic community' to pick itself up and move forward.

In conclusion, the focus on the ECA community is important as newer academics, long expected to simply 'fit in' to the academy, are integral to the successful future of Engineering Education. Left alone to 'sink or swim' for far too long the Positive Start Project will make a significant difference across the faculty; building a cohesive, academic-focused, and supportive community will undoubtedly improve academic wellbeing amongst colleagues which will in-turn, enhance the student experience.

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CONTINUOUS ASSESSMENT WITH SELF-CHECKING TASKS

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ABSTRACT

This paper discusses the applicability and benefits of self-checking tasks in continuous assessment in an electrical engineering course. The method was implemented in the first-year online graduate course of Advanced Power Electronics. The method uses a two-week cycle, where during the first week a task is accomplished on the topic of that week. The tasks include working with data from

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component datasheets, reading and employing application notes, calculations, and simulations. During the second week, the students self-check their tasks using a rubric provided for them and then turn in a corrected version of the task. To keep the cycle going, during the second week, a new topic is also introduced, and a new task is given. The method was assessed based on a student questionnaire and teacher experiences. The method was new to all students. One of the main findings from the questionnaire was that correcting the original task submission supported student learning more than any other form of teaching on the course. However, there were different interpretations of how this support actually worked. The study also showed that there was significant variation between different types of tasks in how the students assessed the relevance of tasks and their difficulty level. Furthermore, students found that some tasks or their outcomes were more suitable for self-checking than others. This was confirmed by the teacher's insights on the course.

1 INTRODUCTION

The term 'continuous assessment' commonly refers to a practice where students' learning is assessed alongside their entire study process instead of merely at the end of the process. Continuous assessment can take many different forms depending on the nature of assessment tasks, timing of the assessment, formation of the final grade, and many other pedagogical design decisions that the teacher makes. Continuous assessment has been reported to have multiple benefits in various fields of engineering education. Previous studies have found that the use of continuous assessment leads to better grades, higher student satisfaction, a higher passing rate, and improved engagement with overall course activities. These studies were performed in chemical engineering [1], process engineering [2], and civil and mechanical engineering [3]. One of the benefits of continuous assessment compared with the end-of-course exam is that it provides students with information about their learning at the time when they still have a chance to adjust their learning methods, correct some misconceptions, or increase learning. However, the information received by the students relies rather heavily on the nature of the assessment tasks and the resources of the instructor for giving feedback.

Self-checking tasks have gained attention and popularity in engineering education in the past few years. Tasks of this kind have also been called flipped homework [4], self-corrected homework [5], dual-submission-with-reflection homework [6], and a self-evaluation and revision method for homework [7]. Such tasks commonly follow a procedure where the student first submits a solution to a task, then corrects it with the help of materials provided by the instructor, and finally submits the corrected version usually also containing reflection of the corrected mistakes and improved learning. Depending on the method, the instructor grades either both submissions or only the corrected version.

The method has been shown to make students take more ownership of their learning and thus also devote more time to solving the tasks [4], [5]. Students also have less stress about the mistakes in the first submission, leading to more honest attempts and less motivation to rely on solution manuals [8]. With instructor-assessed tasks, there is often a risk that students only pay attention to the grade of the task and do not review the feedback, thereby missing the opportunity to learn from their mistakes [7]. Self-correcting tasks, on the other hand, force the student to face their misunderstandings, thus enhancing their metacognitive skills and learning of the content matter [4], [5], [6], [7], [8].

The instructors also benefit from the self-corrected tasks. Despite the concerns expressed about the effects of continuous evaluation on the instructor workload [9], the users of self-corrected tasks have reported that it does not generate more work for the faculty [4] or even reduces the grading load [6], [8]. Nevertheless, the nature of the grading changes from pointing errors to providing feedback on students' conceptions and learning process, making the assessment process more fulfilling for the instructor [8]. The method also enables the instructor to follow the student understanding (and misunderstandings) of the topic without having to interpret the poorly conducted homework, which gives the instructor more emotional energy to invest in in-depth feedback [6] and the possibility to correct the misconceptions early on, thereby facilitating faster comprehension [7].

Self-checking tasks have been shown to be more effective than the traditional homework model [4]. The method is mostly preferred to the old ways of conducting homework by both the students and the instructors [6], [7]. With clear benefits for student learning and more meaningful use of the instructor's time, the approach appears to be a good choice to pair with continuous assessment practices.

2 DESCRIPTION OF THE METHOD

2.1 Course setting

The method of self-corrected tasks was implemented on a first-year master's level course of Advanced Power Electronics, which takes place during the spring semester. The course was organized for the first time during the academic year of 2020-2021, and it was implemented fully online. When the course was organized for the first time during the 2021 spring semester, continuously assessed weekly tasks were selected for the course. Continuous assessment has been found to be a versatile method, and it can be used with various types of tasks. For the course under scope, the continuous assessment accounted for 50% of the grade, combined with an assignment at the end of the course covering the other 50%.

The spring semester includes 14 teaching weeks, and for 13 of these, a weekly assessed task was given on the topic of that week. Out of the 13 weekly tasks, 11 were simulation tasks with Matlab Simulink. These tasks may require initial calculations or component dimensioning, and the simulation results are used for further analysis. After the weekly task deadline had passed, correct solutions, with at least one implementation method, were given to the students.

Even though a short report was turned in with the calculations and analysis of the simulation results, grading such tasks by the teacher was found burdensome and time-consuming due to the nature of the tasks. The initial calculations and further analysis can be browsed through rather fast, but detecting potential errors in a simulation model would usually require running the simulation in order to find the actual errors. Detailed assessment of the contents of the simulation model and trying to interpret the logic within the simulation is time-consuming, especially when the implementation can be done in various ways.

After the first time the course was organized, it was found that the original implementation was not applicable because of the increased workload for the teacher, and thus, the methodology had to be improved. Regardless of the extensive benefits of continuous assessment, previous studies have also found that the method leads to a significant increase in the workload of the instructors [9].

2.2 Improved method

When the course was organized for the second time in 2022, the approach to overcome the issue of increased workload was to involve the students in the assessment process. A computer-aided assessment process or adaptive homework has been found to decrease the workload of the teacher during the assessment, but may not enhance deeper learning [6]. Moreover, using such tools is not applicable with simulation tasks. Self-checking homework has been proposed previously with positive results [4], [5], [6]. The primary benefits that have been found with the method of self-checking homework are enhanced learning and self-reflecting skills.

Similar to the previous academic year, the weekly topic was accompanied with a task with a deadline by the end of the week. After the deadline for the weekly task, in the second part of the cycle (which overlaps with the topic of the next week), a grading rubric is given to the students. The rubric gives at least one implementation method for the task, and for the majority of the topics, a demonstration video is given to complement the instructions on the grading rubric. The students are instructed to turn in the grade and the corrected task, and the deadline is at the end of the second week. The two exceptions to the cycle used for the method are weeks one (W1) and 14 (W14). For W1, the task was a multiple-choice quiz with automated correction online, and for W14 there was no task, because of a visiting lecture from industry.

The grading of the tasks is split between the initial task and turning-in of the self-corrected task, similar to [6], where the self-assessment accounted for 30% of the grade. With the improved method, all the tasks are graded in the same way. The task that is turned in by the students during the original teaching week is assessed by themselves with a maximum of 8 points during the following week. All the weekly tasks have very different contents, regardless of the emphasis on simulations. For example, the grading is on dimensioning of components, designing circuit topologies, control logic, and analyzing the simulation results. Each week, the students are instructed to turn in a short report with answers to specific questions regarding the results. The corrected task, with the initial calculations file, simulation model, and the short report, are turned in by the end of the second week of the cycle. After the deadline, the corrected task is assessed by the teacher with a maximum of 2 points, leading to 10 points at the maximum per week.

The improved method was built on the tasks that were used during the previous academic year. The tasks were revised slightly based on the student feedback from the past year, but on a larger scale in order to fit the rubric and the 8-point grading system. Therefore, the number of questions or subtasks was increased, which also made it more straightforward for the students to implement the task.

2.3 Student questionnaire

The aim of the research was to find if the method was truly applicable with the task-based continuous assessment, especially with the tasks being simulations that are conducted independently. The feasibility of the method was assessed with a student questionnaire at the midpoint of the course. The timing of the questionnaire gives room for adjusting the method for the rest of the course. To motivate the students to submit answers, extra points were given upon a completed questionnaire. Out of the 34 active students at the time of the questionnaire, 33 answered the questions. The teacher gave the students feedback based on the questionnaire, and some key areas were emphasized for the remaining part of the course.

3 RESULTS

The first question in the questionnaire was: "*1. Continuous assessment with self-corrected tasks was a new form of learning for me.*" All of the 33 students answered this statement to be true. When a new teaching method is applied for the whole student body of the course, it will take some adjusting and effort from the students to orient themselves to the new practices.

The second question was: "*2. The teaching methods described below supported my learning. Use an average value over the first weeks of the course.*"[2] The subquestions and the mean and standard deviation (STD) values of the answers are given in Table 1. The two teaching methods that supported the students' learning most were the demonstration videos and correcting the original task. However, the differences were not statistically significant (two-way t-test, significance level $p<0.1$).

Table 1. Mean and standard deviation of the answers to question 2, n=33.

		Mean	STD
2.1	Video lectures and their lecture material	3.64	0.80
2.2	Demo videos on simulations	3.85	1.08
2.3	Weekly tasks	3.61	0.92
2.4	Self-assessing the weekly task with the rubric	3.66	0.95
2.5	Correcting the original submission of the task	3.88	0.88

[2] scale in questions 2.1-2.5: 1=Strongly disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly agree

Correcting the task is the most important part of the cycle of the method, and it was also acknowledged in terms of learning by the students, both in ratings given for question 2, and in open comments for question 3. These results are in line with the results found in [6].

The next question was: "*3. Briefly describe your learning process when using self-checking tasks.*" Students' answers confirmed many of the findings from prior research. A couple of students pointed out that without self-checking one would not necessarily go through the mistakes and correct ways of doing things at all, as suggested by [7]:

> *"You actually look into your task versus if the points just came by the teacher's evaluation it is possible that you wouldn't ever look the right answer and come back to the task to do it correctly."*

Also learning from mistakes [8] was mentioned often as a central feature of the learning process:

> *"There were "Exactly!" moments when fixing the task. These moments will be remembered."*

In this respect, the strength of the method is not only in that the mistakes reveal misunderstandings and unclear issues both to the students and the instructors, but also that the correction round reduces the pressures of getting things absolutely right in the first submission and thus encourages the students to solve the problems themselves instead of consulting solution manuals or other sources of ready-made solutions [8].

Many students emphasized the learning by doing aspect of the method, and some pointed out that seeing alternative ways of solving the problems develops one's thinking:

> *"It is interesting to compare your own output and task because there are so many different solutions. This is how you can change your thinking. Next time you can evaluate how to do it better."*

Students also perceived that this method takes up more time than traditional homework, but also linked it to learning more or better, as suggested in [4].

Probably the most common challenge in the learning process was related to situations where the student started to solve the problem very differently from the teacher. In these cases, the self-evaluation and correction were perceived difficult:

> *"Sometimes I opt for a different method if I am unable to perform in the suggested way, and in such circumstances it becomes difficult to self-grade the tasks."*

This became particularly evident from the answers to question 7, where students were asked to elaborate on the difficulties they met during the course.

In order to find out the perception that the students have on each weekly task, the following question was asked: "*4. Evaluate the relevance of each task.*"[3]. The follow-up question "*5. Elaborate on how relevant and/or rewarding you found the tasks.*" also provided insight on how the students assessed the relevance of each task. These questions are interesting for the teacher to assess the learning outcomes of the students reflecting on the lectures and the demonstration videos. The mean and STD values of the answers to question 4 are given in Table 2. Clear differences can be seen in the results, yet only the task for W6 stands out with a lower mean value. From the teacher's perspective, all of the tasks are relevant, but the task for W6 was clearly too difficult for the majority of the students. Based on the answers to question 5, the major issue was that the initial knowledge level and programming skills were insufficient for the completion of the task. As a result, a very thorough task demonstration video was given, but the task must be revised for the following year.

Table 2. Mean and standard deviation of the answers to question 4, n=33.

	W1	W2	W3	W4	W5	W6	W7
Mean	3.76	4.03	4.12	4.15	3.94	3.03	3.72
STD	0.91	0.65	0.76	0.71	0.81	1.42	0.91

The following two questions were used to evaluate how difficult the students found each part of the method: "*6. How difficult did you find the following (on average).*"[4] and "*7. If you found some of these difficult, please elaborate on.*" The mean and STD values to question 6 are shown in Table 3, and based on the answers, the most difficult part was doing the tasks. The comments in question 7 highlighted that there were difficulties with the new simulation environment, and certain tasks were found especially difficult. The procedures of self-checking and correcting the tasks were found slightly on the easier side, which can be interpreted in favor of the method. In question 7 there were a few comments on uncertainties with the rubric at places where it did not thoroughly specify certain parts of the task results. These rubrics will be revised for the next year.

Table 3. Mean and standard deviation of the answers to question 6, n=33.

		Mean	STD
6.1	Weekly tasks	3.97	0.63
6.2	Self-assessing the weekly task with the rubric	2.82	0.99
6.3	Correcting the original submission of the task	2.88	0.71

[3] scale: 1=Strongly irrelevant 2=Irrelevant 3=Neutral 4=Relevant 5=Strongly relevant

[4] scale: 1=Very easy 2=Easy 3=Neutral 4=Difficult 5=Very difficult

An interesting point relating to the development and importance of metacognitive skills was illustrated in one student's general comments about the course:

> *"It is not perhaps difficult but it is a bit scary to assign yourself the grade, so it can lead to unnecessary doubting of your own results."*

Although reflection skills are often emphasized with respect to situations in which the student needs to evaluate the soundness of their solution, one could argue that also reflection upon confidence in one's solution is a valuable skill in working life and thus something that should be developed during studies. The self-checking method seems to serve also this purpose and promote self-regulated learning [10].

A mismatch with the workload and grading between tasks can be unmotivating, and therefore, the following question was used to get the students' perception: "*8. Do you feel that the weekly grading principle of 8 points per task and 2 points for correcting and resubmitting the corrected task is fair.*" There were three alternatives:

a) Yes.
b) No, the original task should be weighted more.
c) No, the self-checking should be weighted more.

Out of 33 answers, 25 answered 'Yes', which is 75.8%, while the remaining 8 (24.2%) answered that the self-checking should be weighted more. Therefore, the grading can be found to be in line with student efforts, even though if the initial ratio had been 70% and 30%, the result to this question could have gained an even more positive response.

The final question was: "*9. The feedback provided by the grading rubric and the video feedback were sufficient to enhance my learning.*"[5] The mean value to the question was 3.58 and STD = 0.87. These values still leave room for improvement in the implementation of the method, especially with better rubrics.

4 SUMMARY

The results from the student questionnaire indicate that continuous assessment using self-checking tasks supports well both the learning of the content and the development of metacognitive skills and self-regulated learning. However, the suitability of self-checking depends to some extent on the nature of the primary task.

As for the amount of work effort by the teacher spent on revising the tasks, generating the rubric and the videos took approximately one working day each. This was approximately the same amount of work that was spent on checking the tasks during the previous year. The time spent on checking the short reports and the corrected tasks depends on the week, being nevertheless two hours at the maximum, which was significantly less than during the previous year. As a result, the time invested in modifying the teaching method will be beneficial in the future academic years.

[5] scale: 1=Strongly disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly agree

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DEVELOPING TEAMWORK SKILLS BEYOND CROSS-CULTURAL BARRIERS: A CASE STUDY FOR ENGINEERING STUDENTS IN HIGHER EDUCATION

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ABSTRACT

In 2013, our university has implemented a new educational model that puts team projects at the core of all BSc programmes, requiring that students develop teamwork skills. On top of this, in 2018, our Chemical Science & Engineering BSc has become an English-taught, international programme. In consideration of this challenging transition, we have developed additional training to facilitate students' acquisition of knowledge, skills, tools, and attitudes to aid conscientious intercultural teamwork. For this, it is paramount that students become aware of, and learn to appreciate, differences in the educational and cultural backgrounds of themselves and their peers. Concurrently, students should practice what they have learned and adjust their behaviour when appropriate.

In this paper, we share our experiences, best practices, and lessons learned. More specifically, our study: i) explores which factors are key to a successful intercultural team, ii) investigates how diversity in teams can be cherished and used for the benefit of the team, its members, and its goals, and iii) how these teamwork skills can effectively be taught in engineering programmes. Building on this, the paper

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describes how the new curricular education has been designed, what is taught, and how an inclusive, regardful, and pleasant atmosphere has been created for the intercultural project teams.

1 INTRODUCTION

1.1 Essential skills in engineering education

In this ever-changing society, higher education (HE) institutes should take on the responsibility of preparing students with the necessary skills in addition to their respective disciplines to face the world's greatest challenges. Among these skills, teamwork [1] has been identified as a key characteristic that employers seek in university graduates because workplaces demand interpersonal cooperation and high levels of interpersonal skills. In response to this, since 2013 all bachelor programmes at our university are designed based on a new educational model that enables students to create their development and learning experiences through a variety of projects that weave their way through the programme like a thread.

Furthermore, our Chemical Science & Engineering BSc has become an English-taught, international programme, and in today's globalised environment, intercultural skills are becoming increasingly important and desired [2]. Teamwork involves challenges that might be exacerbated when members come from diverse backgrounds but lack intercultural competence; students must be aware of their roles and of how to cooperate with different peers. Growing industrial interests also require the diverse population of engineering students to develop beyond traditional technical abilities. These challenges call for in-depth research to gain a better understanding of how to foster effective teamwork and intercultural skills in engineering education.

This study recognises the importance of intercultural skills and intends to provide means to train students to effectively work in teams with people from diverse backgrounds. More specifically, this study aims to (i) explore factors that are key in establishing success in intercultural teams, (ii) investigate how diversity in teams can be cherished and used for the benefit of the team, its members, and its goals, and (iii) develop an effective teaching method for these teamwork skills in engineering programmes.

1.2 Underpinning Theory

A team is here considered “a collection of individuals who classify, define and evaluate themselves in terms of a common social category membership” [3]. The core of a team is a shared responsibility for achieving common goals [4], which requires the commitment of each individual team member to work on assigned tasks.

In academic settings, simply getting individuals together is insufficient for effective teamwork. Students need guidance and mentorship to learn how to interact and work together and understand the team roles and responsibility of each member [5]. Teamwork competencies encompass a set of behaviours, knowledge, skills and attitudes from students that contribute to the team’s efforts [6]. Four dimensions of teamwork skills development [7] are identified: (i) identity (goals, sense of belonging, roles, adaptability, teamwork climate, commitment); (ii) communication (information, personal interaction); (iii) performance (planning, decision making, carrying out the tasks, monitoring performance); and (iv) regulation (collaborative problem solving, negotiation, making improvements). From this, one can conclude that the key components of teamwork skills development are:

- why the team exists (objectives),
- what a team does (activity), and
- who is on the team (roles) [8].

Furthermore, being able to work with diverse people is a prerequisite for successful teamwork, necessitating a comprehensive approach to incorporating intercultural skills into teamwork-skill training. Intercultural skills are "the ability to communicate effectively and appropriately in intercultural situations, to shift frames of reference appropriately and adapt behaviour to cultural context" [9]. Respect, openness and curiosity are the pillars [10] around which the competence is based.

From a pedagogical perspective, the development of teamwork skills is a process of learning involving strategies of (i) providing opportunities for the application of knowledge; (ii) structuring opportunities for collaboration and interaction with diverse peers; and (iii) providing opportunities for perspective-taking and reflection [11]. Based on this three-stage process, this study develops the teamwork skills training utilising the framework described in Figure 1.

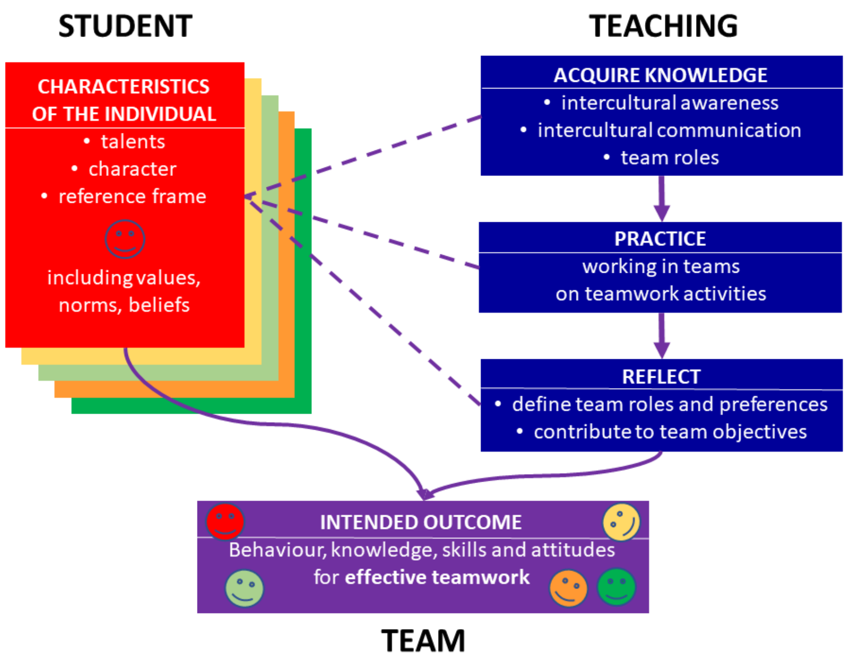

Fig. 1: Intercultural teamwork, from theory to practice in our programmes

2 METHODOLOGY

2.1 Programme context

Originally, our Chemical Science & Engineering programme was only offered to national (Dutch) students. The programme was converted into an international English-taught programme in 2018, with approximately 60% of the current students being international. This development is highly valued, yet a smooth transition from a national to an international classroom can be challenging. Therefore, the teamwork skills training was developed to prepare students to work effectively in project teams with their international peers.

2.2 Design of teamwork training

The training is designed as a four-stage process. Students acquire necessary knowledge and apply it through teamwork activities, while also reflecting on their experiences for future improvement (see Figure 1). The following section details the training setup for each stage.

Freshmen: When students enter our bachelor's programme, we teach them organisation skills, focusing on how to carry out effective meetings in a team of peers they hardly know. Some students have experience with group work, while others were used to working individually in their high school. In their first project, they experience what intercultural group work can be like in their studies. They take their successes and failures in this group work, as well as their individual questions, with them to the second project, where they receive the teamwork training with a new group of students (typically four-six students per team in the first and the second project).

Workshop on cultural diversity: We commence with a workshop on cultural and educational diversity, with the following learning goals: to (a) be more aware of each other's expectations; (b) be able to identify differences in (prior) education of their group mates; (c) devise ways to get the most out of their education at our institution; (d) empower effective teamwork in a (project) group of diverse people.

In a classroom setting, students sit with their new project team and work on assignments. First, they introduce themselves to their peers (with a focus on their name, its meaning, who named them; their upbringing; their high-school experiences; their affiliation with the project). Then, students collectively discuss given cases – situations where individuals have misunderstood each other – and try to identify what was the cause of the confusion. Students continue with collecting keywords that link to 'culture', and try to use these to constitute a definition of 'culture'. Additionally, students practise with an exercise about universal, cultural and personal characteristics, that they discuss with their team. At the end of the session, we teach students about conceptual knowledge on intercultural communication (emphasis on high vs. low context; perception of time as synchronic or sequential; affective or neutral emotions; relationship vs. deal orientation; and hierarchical vs. egalitarian cultures), with an exercise to highlight where on these axes students would position themselves and what the effects might be on the group or group process. After the workshop, the project groups work on an assignment about how they wish to work together, and how they will take into account each other's needs, norms, values, and beliefs, resulting in a project group agreement.

Workshop on team roles: We realise that, when they work in groups, students often define group roles by themselves, while they lack a theoretical background about roles in group processes. Hence, we introduced the Belbin model [12] to improve their understanding of team roles. The students fill out a self-perception inventory and ponder on its possible meanings. Then, they discuss the outcomes within their team, draw conclusions about missing or underrepresented roles in the team, and how to use these insights to the benefit of the team. Also, they are asked to decide who to work with in their next project (small groups of three students), taking into account the outcomes of the Belbin model.

Reflection: Lastly, we have reflection activities. Already early in the project, students give each other feedback on their perception of the leadership qualities, team-player behaviour, fitness for specific tasks and roles, and potential for interpersonal conflicts; students score themselves as well as all their peers from the project group. They discuss, in particular, discrepancies in the perceptions of themselves and the others; e.g., someone may consider her/himself a well-liked natural-born leader, whereas the other group members anticipate this person to induce problematic coacting and conflicts.

At the end of the project, we offer a reflection workshop. We look back at the original group agreement, what worked and what did not, why things did or did not work, and how a group might improve teamwork for the next project.

In the master's programme, we offer similar teaching activities, adapted to the fact that these students often have more experience in teamwork.

2.3 Evaluation

The evaluation input was gathered from multiple stakeholders:

- We asked the participating students after each workshop for feedback to improve the workshops and used that in the next year;
- The training is assessed as part of the regular course evaluation of the Chemical Science & Engineering programme to assure its quality;
- Additional input from teachers and programme management is requested to determine how the training is integrated into the programme's overall curriculum.

3 RESULTS

3.1 Acquire knowledge, practice, and reflect

The teamwork skills training is embedded in the existing programme. This implies that students have opportunities to apply their knowledge to concrete tasks through an engineering project: students have goals to achieve, technical issues to solve, and deadlines to meet while participating in a group process. Students focus on interpersonal qualities and relations in the team, which is separated from, yet in the context of the specific content and aims of the project. Additionally, students are encouraged to engage in meaningful and practical reflections.

The peer-review process revealed interesting insights, as students often have a different perception of their behaviour, strengths, and weaknesses than their peers do. They also needed time to reflect on their own performance for the group reflections to be successful. The introduction of the individual (peer and self) reflections has made the group reflections more meaningful and more thorough.

Students' perspective: Students' feedback provides input on how the training was perceived and what effects were obtained (see Figure 2). Below is a summary:

- The workshops validated that intercultural differences could be a cause of problems in a project group. For many students, working in an international project team at first was overwhelming. The workshops assist students in understanding how norms and values can differ and that there is no ‘wrong’ or ‘right’; just a different basis.
- Due to the workshops, differences among cultures were discussed, which would otherwise not happen automatically. Students claim that confusion and irritations were mitigated because of this approach. Often, groups immediately focus on the tasks they need to work on; now, they would start with the fundamentals of intercultural teamwork instead, and the workshops made it easier to address any teamwork issues.
- The workshops increase self-awareness in intercultural collaboration, especially when students need to decide on a project approach and agree on how they will work as a team (project group agreement).
- Students say that the workshops have massively impacted the way national and international students interact, and group bonding was increased – not just in this project but across the student cohort.
- The workshops were taught playfully, helping students to get to know each other better, on a personal level, increasing the groups’ ability to discuss possible issues.
- Groups were more aware of how they could improve the group atmosphere through better understanding and communication about expectations (from the project as well as from their peers). This also increased the likelihood of success. Success for a project group also was valued more by the students, because it was a true team effort.

Fig. 2: Word cloud of feedback from students after teamwork training: what did they learn?

Course teachers’ perspective: The course teachers of the project indicate that, due to the intercultural workshops, the teams perform and contribute better in their intercultural "Process Plant Design” project. The teams consist of 4-5 students and they sit together in a project room for 2-3 days a week. They need to collaborate intensively for five months to make their project successful. They are now much more aware of differences due to cultural backgrounds which makes it easier for them to discuss issues beyond their personal perspective, especially since this was addressed during the workshop. Potential conflicts are now discussed and solved within the team.

Programme director’s perspective: Although about 60% of our students has an international background, our national culture and norms tend to remain dominant in the classrooms. This workshop is of particular importance to broaden the perspective of international and national students and contribute to a truly international classroom culture. The workshop seems to have a lasting positive effect on mutual understanding and on formal and informal collaborations between students of different cultural backgrounds.

3.2 Future development

We shared our experiences with other programmes at our university. As a result, other engineering programmes also introduced workshops on cultural diversity in teams. On top, this implementation has become a stepping stone for the development of teaching methods for other essential skills in our programme (like academic writing, oral communication, critical thinking, conceptual modelling, and civic engagement including sustainability awareness). We couple these activities with existing courses or projects in the programme, and ensure that we assess students’ development in these essential skills.

The workshops also accomplish that students value and contribute more to global citizenship, as they learn to appreciate different perspectives.

We conclude that with this study, we found factors that are key in establishing success in intercultural teams. The main factor is awareness of the different backgrounds of students’ peers. Diversity in teams can be cherished and used for the benefit of the team, its members, and its goals, which became apparent to the students, who started their projects with more focus on what intercultural teamwork entails and requires, and with more awareness of the needs and backgrounds of their peers. Also, we have developed effective trainings to teach these teamwork skills in engineering programmes.

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Engaging leaders from students' perspective and the impact of professors as role models

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ABSTRACT

Preparing students for the labour market is an essential part of education, and academic personnel usually influence this process. Students' experiences with leading figures, like supervisors and other professors, can affect their expectations about future leaders. For this reason, our research aims to assess students' beliefs and expectations and make suggestions for higher education representatives who can serve as a leadership model for them.

We conducted focus group interviews mostly with engineering students at a Hungarian technical university in spring 2022. Thirty students participated in our research and were assigned to the focus groups according to their work experiences. After coding interviews, we categorized their answers into three groups: leadership qualities and professional and social expectations. According to them, a leader must be competent, socially active, and have a good personality. His or her behaviour must reflect these qualities to be engaging and a good role model.

Our results showed that school and university experiences are a critical starting point and reference when students formulate their expectations towards future leaders. Therefore, it is important to raise professors' awareness about their leadership roles and develop their leadership skills to be good role models for young people.

In our study, we discuss leadership requirements and suggest developmental methods, respectively, to the university's characteristics. In addition, we recommend integrating leadership development programs into engineering education, from which both professors and students could benefit.

1 INTRODUCTION

1.1 Academic professors as leaders and role models

Considering leaders as role models have been investigated for many years since transformational leadership and charismatic leadership influence leadership theories. They emphasize the leadership role and define it based on behaviour and the effect of leaders on subordinates [1], and even on the leader's capability to transmit goals and values [2]. Although it seems easy to draw a parallel between leaders' behaviour and role modelling, we have to define role models in the broader sense.

Role models are associated with influence coming from one's position and being an ideal person or example someone wants to identify with [3, in 4]. This definition combines two different aspects, one of the identification theories and one of the social learning theories [4]. Gibson [4] broadens the definition and emphasizes the cognitive construction within the modelling process. According to him, individuals want to be similar to those representing social roles and their perceived positive attributes. On the one hand, this construct of role models differs from the mentor definition in terms of development because mentors are usually described from career and developmental perspectives. The mentor helps to learn and develop through involvement. On the other hand, the similarity between the cognitive and behavioural models is that both are based on learning, but the latter focuses on observation and accessibility [4].

Uniting these developmental, behavioural, and cognitive aspects would be beneficial in leadership development since leaders are usually referred to as role models both in the business and the academic sectors [2, 5-8]. Therefore, it is important to raise professors' awareness about their modelling status because students learn from conscious activities where professors emphasize what to do and their observed behaviours, which students might unconsciously begin to copy and internalize [5].

In educational settings – especially in the academic sphere – leadership tends to be seen as a formal, managerial role, e.g., dean of faculty or head of the department. Still, leadership occurs informally, independently from designation [8]. We use the term "professor" in the broader sense, including academic personnel who teach and supervise without designation.

Academic leadership is "a process through which academic values and identities are constructed, promoted and maintained" [9, p. 3]. Educational leaders help colleagues or students to learn academic disciplines through empowering, mentoring, or even role modelling [9]. This form of leadership is usually associated with the work of supervisors because this leadership indicates that leaders guide and support colleagues to focus on research and develop professionally [8].

In his research, Macfarlane [6] summarized the qualities of intellectual leadership. Two main aspects among the six qualities have arisen, the interpersonal and the professional. From the interpersonal aspect, professors care and stand for younger colleagues and give protection and guidance to them. They even motivate students to take intellectual risks and use their hidden potential. Furthermore, they secure resources or other opportunities to facilitate research. From a professional or intellectual aspect, professors serve as role models because of their special expertise in one field and commitment to this discipline, inspiring others. They express their engagement in the way they promote their subject and contribute to scientific development through editorial work and reviewing or as a keynote speaker representing a university at a conference [6].

Both of the above-mentioned leadership forms reflect on a leader as a role model to some extent, which is not surprising since professors, as informal leaders, give a part of themselves to students. At the same time, they educate, inspire, support, and lead them [2] or just fulfil other duties [5]. This indicates that teachers and academic professors can be leaders and role models worth following [2]. This distinction is needed because role modelling is a two-sided phenomenon. Some people are motivated to identify themselves with the exemplar, and others are decided to avoid being like the modelling person. To be effective role models, academics need to demonstrate competence in the desired field, teaching, and good personal characteristics [5].

1.2 Student engagement and expectations

Even though academic professors are usually not identified as leaders or role models explicitly by students, they affect students and their engagement [10-12].

Wright, Wong, and Newill [10] found that role models and their personalities – sometimes different traits or values from other models – and students' relationship to them influence students' career choices. According to their research, students consider important the attitudes of the modelling person, his or her compassion and enthusiasm for work, the integrity of his or her personality, and the ability to be objective and use the power of humour if needed. Above this, students expect these role models to be socially active, have good leadership and communication skills, be patient, conscience, and aware of their capabilities [10].

The strong association between career choice and role model is also supported by examining the engagement and retention of STEM (science, technology, engineering, and mathematics) students in their selected major with the help of role modelling [12]. Shin and her colleagues [12] found that stereotypes can determine engagement, and these can be modified or replaced with the help of role models, in their case, role model biographies. The exposure to hard work and success of those typically underrepresented in STEM majors strengthened students' interest due to perceived compatibility with models. Students reframed their stereotypes because counter-role models were considered competent and inspiring. Their success based on effort and hard work showed another feasible way to be outstanding within these majors [12].

Competence and inspiration are essential factors in the case of university professors too. Tam and his colleagues [11] examined what makes a good teacher, and their participants formulated important aspects and requirements. They identified two main categories associated with expectations. Teacher quality includes caring for students, providing help and safety, having a democratic, humorous, open personality, and being competent, well-balanced, and knowledgeable. Appropriate use of assessment, student-centered and various teaching methods, openness to their opinion and feedback, and free choice in learning cover the category of teaching approaches. Favourited teachers served as role models thanks to their inspiring character and passion for teaching and learning. Students expect them to guide them and be available and open to the affective and social dimensions of education [11].

Cadwell and Anderson [2] highlighted seven factors influencing students' openness and willingness to learn from professors and achieve higher performance. Similar to Tam and his colleagues' results [11], if professors show inherent virtuousness and sincere feelings, they can reach students. Because students understand moral messages, realize how important it is to achieve more in life, appreciate support and care, and are aware of their role in changing the world and their moral responsibility [2].

All these results support that the influence of leaders is inescapable. Different leadership aspects brought different views and expectations. Still, they agreed that leaders – even teachers and professors – influence followers, which can result in identification with them as role models. Based on this influential relationship, our research aimed to understand the personal expectations towards leaders, especially how they can motivate and engage university students today.

2 METHODOLOGY

2.1 Participants

This research is part of doctoral research that aims to profile engaging leaders and the expectations of university students for leaders. We conducted focus group interviews in March and April 2022. Students mainly from a Hungarian technical university participated in focus groups. Some of them were offered to get extra points on a course for their contribution.

37 students applied for focus groups. From them, 30 students (20 women and 10 men) answered our questions. 17 are engineering students, and the others are studying economics, IT, or social studies. The youngest participant was 19 years old; the oldest one was 45, with an average of 23,9 years. 10 students are currently working for more than six months and spoke about their recent experiences with organizations, leaders, and work. Those with less than six months of experience or no experience answered our questions about ideal work, organizations, and leaders.

2.2 Procedure

Candidates were allowed to register on a Google Form after answering demographical questions. We assigned applicants into two groups based on their work experiences, considering whether they have been working for a company for more than six months or not. We decided to cut at this timepoint because it usually takes half a year to get acquainted with a new role, new group, and organization.

We worked with semi-structured interview questions. These questions were formulated considering the engagement influencing factors based on the results of Firouznia and her colleagues [13]. Our general questions were:

- What would you like to work in the future? In which position do you imagine yourself? or In which position and where do you work?
- What motivates you? What is your aim with this work or major you are learning now?
- What do you expect from work? How do you imagine your work, workload, and so on? (It was a question just for those who were currently not working.)
- What is your team like? How do you work together? or What kind of teams do you want to work in?
- What is your organization like? How do they motivate or engage you? or What kind of organization do you want to work at?
- What can or should the human resources department do for you to motivate and retain you for a longer period?
- What makes a good leader? How can they engage you? What characterizes them?

The personal interviews were recorded with a dictaphone, the online ones with the help of Microsoft Teams. We used online software to transcribe these interviews and corrected the transcripted text.

We used the desktop version of Atlas.ti 22 to analyse qualitative data. First, we generated a word list based on the interviews and listed words containing “leader” or “boss”. After this selection, we searched through the text and generated automatic codes for phrases including “leader” and “boss”. Second, we exported the labelled phrases into excel and categorized the answers into three categories based on the requirements of effective role models [5]. We also asked an independent leadership developer professional to assess and classify the responses from the focus group interviews. Finally, we compared the categorizations, and in case they were different, we consulted with the expert and decided on a category by common consent.

3 RESULTS

3.1 Frequency analysis

Frequency analysis showed that those with work experience used more words related to leadership.

The leadership code distribution of the documents is listed in Table 1.

Table 1. Distribution of “leader” and “boss” codes

Code	WE1	WE2	WE3	NWE1	NWE2	NWE3	NWE4	NWE5	TF
“boss”	4	8	42	10	3	18	2	8	95
“leader”	65	89	34	42	40	47	55	62	434
Total	69	97	76	52	43	65	57	70	529

Note: WE=group with work experiences, NWE=group with no or minimal work experiences, TF= total frequency

3.2 Text analysis

Our participants highlighted leadership, personal qualities, and professional and social aspects associated with leaders. Those expectations which appeared in more groups are marked in italic and presented in Figure 1.

The qualities of a leader should be: “a protecting wall”, *a good judge of character*, *accepting*, an *authority figure,* authentic, *available*, careful, *charismatic*, *confident*, *consistent*, *dedicated* to working and subordinates, democratic, *determined*, *direct*, *empathetic*, engaged, *exemplary*, fair, goal-oriented, *good communicator and mediator*, *good in problem-solving*, *helpful*, *honest*, *humane*, *human-oriented*, humble, humorous, in a *positive* mindset, motivated and able to motivate others, *open* to new ideas and people, resilient, *respectful*, straightforward, *supportive*, the one who not just speaks but does things, *the one who sets the course*, *trustful*.

The professional expectations towards leaders are that they must: *admit mistakes*, be clear about *what (s)he expects in work* and this should be the same as *what (s)he did or does also*, be *clear and realistic about expectations and articulate them*, be competent both vocationally and to leadership, be *good, skilled, and experienced at what (s)he does*, coordinate and *delegate* tasks, emphasize common plans, goals, and development, focus on realistic goals, have *earned the leadership position*, have good time management, keep his/her word, make decisions about workload based on the skills of subordinates, *organize regular meetings*, *participate* in projects, *plan and allocate work rationally*, qualified and up-to-date in his/her field, so one can trust in him/her, *share information and knowledge*, *show the added value of one’s work and its effect*.

The following criteria belong to the social expectations according to which leaders should: acknowledge and motivate team members, appreciate autonomy, ask and listen to the answers, be a *part of the team*, be an active participant who knows the inside jokes and stories, be like the team members, *be motivated to get to know better his/her colleagues*, be open to be friends and have programs together outside the workplace, be understanding and give comfort, *bring the team together*, *give feedback* and ask for it, give *individual attention* to everyone, have similar values and interests like the team, *involve* them and be open to ideas, *know the qualities and skills of team members*, organize programs and facilitate common experiences, protect and serve others, show *mutual trust and respect*, *stand for the team*, support learning and *development*, *treat everyone equally*.

Fig. 1. Students' expectations in a word cloud

Some groups mentioned experiences with teachers or professors in association with leadership experiences. We cite them:

"- And then I come to work and do the same as in elementary school and high school. (…) And the leader is similar to a class teacher in this way, and I think the class teacher has had five years to get to know the students, and I guess everyone gets along well with their class teacher in the fourth year and the fifth year. And I think it needs to develop with the time in a workplace too.

- I would say that my bosses are not class teachers but rather practicing teachers who come to us, who don't fully know what team dynamics are like, but they try to recognize it as well as possible, and they evolve with the team."

"When I went to college, and the teacher didn't even introduce herself, she was already telling me about an 80 percent dropout rate for a subject."

"It's even quite an interesting experience to go out with a professor for a beer outside of class and then get to know him from a completely different side. You see someone standing at the chair and just giving a lecture, and you are sitting at the table together. It is completely different when you are having a beer in the city and then talking about something completely different from the material in school. You get to know a completely new side of your professor."

"There should be no collective punishment. I always hated to get the punishment because others were stupid. (…) they're not motivating me by punishing me; they motivate me by acknowledging me for performing well. It's a problem going back to school. And it left a strong effect on me."

"Don't always stand behind me to see if I'm doing the job well. And stare. I don't know, for example, when you write an essay and then write and think. And then the teacher goes round and round. (…) So, I didn't like it that way, but the occasional feedback here is critical. But not by standing behind you and staring."

"…teachers have full power over students, so to speak, and expect full attention and full respect, and I don't think that's a good attitude. Of course, you need both, but I don't think so hard. For example, there has been no mutual respect in the teacher-student relationship, and I think this often happens in the workplace."

"And this attitude that the bell is ringing for me. So, if there is one thing that is true for everyone. Then why would it be true just for one person, regardless of whether he or she is in a leadership position? So that's so unfair."

4 SUMMARY

The role of education is to show students alternatives to thinking and views and teach them acceptable values and behaviours [14]. In this process, academics play an enormous role as leaders or role models. There has been little research on academic leadership. Still, some researchers have already emphasized the importance of leadership in education, independent of whether it is a formal position or an informal, supervisory relation [6, 8].

The expectations towards leaders, especially academics, were usually grouped into two categories, i.e., personality and relationships [10] or teacher quality and teaching approaches [11]. Macfarlane [6] brought the professional and interpersonal aspects together, and Cadwell and Anderson [2] highlighted the personality of a teacher and the responsibility and capacity of students. Our results indicate that three categories could describe better good and influential leaders and professors because personality, professionality, and even social skills and intentions are equally important for students, which are consonant with the criteria of effective role models [5].

The answers of university students from Hungary overlap to some extent with previous results [2, 6, 10-11]. Furthermore, they give new perspectives on these three categories. Appreciated leadership qualities are directive (e.g., determined, direct, the one who sets the course), practical (e.g., goal-oriented, exemplary), and emotional characteristics (e.g., empathetic, resilient, positive mindset). Rationality (e.g., rational plans, realistic goals and expectations), presence (e.g., participate, organize meetings), and experience in a broader sense (e.g., earned leadership position, expects what (s)he did or still does) are additional demands of students. Finally, university students wish leaders to be socially active (e.g., active participants, open to having programs outside the workplace), be team members and leaders or facilitators at the same time (e.g., part of a team, mutual trust, and respect, organize common programs), be good reading people (e.g., know better colleagues, know the qualities and skills) and be personal support (e.g., individual attention, give feedback, support learning and development).

Our results highlight that positive and negative role models can influence later expectations and relationships with leaders. Although they are congruent with previous results, we worked with a relatively small and diverse sample which does not allow us to draw an extensive conclusion. Even though we tried to ensure objective categorization, other independent raters could have secured a higher validity of our results. Additionally, more extensive research involving different universities, majors, and students could give us better insights into the expectations associated with leaders and let us understand better and compare the academic and business characteristics.

Taking everything into account, theory and practice are key elements to the successful education of young engineers or other professionals. But we should not neglect the influence of academics who support and guide them. For this reason, we recommend that universities promote leadership development which might be helpful and fit both professors and engineering students. Since role modelling can be experienced on formal, informal, and hidden, institutional levels, interventions would be needed not just on a personal but on an institutional level too to ensure leadership development and through this positive role modelling [5].

5 PRACTICAL IMPLICATIONS

There was a shift from basically research-oriented education to applied science and practical engineering [15]. It requires leadership skills from engineering students who can learn these from practicing those skills [16] and internalizing the behaviour of role models, mostly their professors. Professors are expected to be researchers and leaders simultaneously, which requires different skill sets [6]. Sometimes, their job description does not clarify the variety of tasks and emphasizes the managerial part of their work [8]. This entails that they do not usually get prepared or just too little for their career as an intellectual leader [17]. Because of this, we would suggest a complex developmental program that aims at all the three levels of modelling influence defined by Cruess and her colleagues [5] to raise professors' awareness about their influential power and modelling status and help them develop leadership skills.

First, academics need to acknowledge the importance of leadership development [15] on an institutional level and facilitate cooperation between faculties and departments to raise awareness about the importance of non-technical, interpersonal competencies [15-16]. A developmental program could effectively reach its goal in such a supportive culture with clear expectations about leadership.

Second, we suggest a reform of the curriculum too. Farr and his colleagues [16] emphasized that building in some new topics or methods is easier than creating a specified course for them. Engineering curricula and even Ph.D. curricula should be revised and extended to leadership theories and practice. Engineers at our university have mandatory psychology lectures without practicing social skills, which could be incorporated. The Doctoral Student Union provides optional workshops for Ph.D. students about academic, business, financial, and psychological topics. Professors are also allowed to participate in these workshops. This training could be built into the education regularly, not occasionally, and optionally.

If the university supports leadership development and the curricula are revised, then the informal level should be addressed intensively with the help of training and workshop series. Based on the developmental program of Rutgers Leadership

Academy, the series should cover organizational and leadership theories, the development of social skills and leadership competencies, and specifics of higher education [17]. The awareness of one's leadership function can increase with the help of projects, interactions, and reflections on teamwork [16-17]. These contribute to developing the most important engineering leadership skills (i.e., communication, teamwork, cultural awareness, and ethics) [15].

Although these suggestions are made on a theoretical basis and need to be tested and examined widely, they can contribute to the preparation and development of professors for formal and informal leadership roles. This is important because they can significantly influence students besides soft skill training and theoretical education. Professors should set an example that engages students, helps them internalize leadership skills, and prepares them consciously or unconsciously for their future leadership position, which usually comes fast in the case of successful graduate engineering students.

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Experiences from the First Implementation Round of Two Electronics Courses Utilizing Flipped Learning Method

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ABSTRACT

During the past years we have witnessed various development trends in learning. More and more the learning has moved online thus making it independent of time and place, students' responsibility of their own learning has increased, methods that promote active learning have gained more interest as they result in better learning results, and the role of a teacher has shifted towards a facilitator of learning. Consequently, the flipped learning pedagogical approach has become more common in recent years as it is one way to answer these trends.

This concept paper introduces two studies of practice in which flipped learning approach was implemented for the first time in a bachelor level university course of

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electronics at Tampere University (TU) during the academic year 2021 – 2022. The structure of the flipped courses consisted of online pre-class study materials and assignments, face-to-face learning events, various individual and group learning assignments and so-called prime time small group meetings with the teacher. Flexibility and versability of the learning experiences, both-way feedback possibilities as well as a combination of individual and collaborative face-to-face and online learning were emphasized in the course design.

According to the feedback many students felt that this flipped learning approach promoted learning and encouraged to study evenly throughout the entire course. Furthermore, the teachers' thoughts after the first implementation round are considered e.g., which parts and practices were successes, and which need further development. In addition, thoughts about teachers' workload and institute's support in utilizing flipped learning method are shared.

1 INTRODUCTION

In the flipped learning method (FLM) the students familiarize themselves with and learn the new course material first outside the face-to-face (F2F) learning events. Students can learn the new material at their own pace independent of time and place individually or in small informal groups. This is often referred as individual space meaning that students mainly work themselves and the work done is focused on the individual student’s efforts. In the F2F learning events, so called group space, students then learn with the entire class or in intentional small groups and the focus is on higher-level tasks and in active learning. [1] By creating such an autonomy-supportive learning environment in which the pre-class online materials meet students’ autonomy and competence needs and the interactive F2F learning events foster students’ competence and relatedness needs, active learning, self-regulation and engagement can be promoted, and students’ academic achievement may increase [2].

1.1 Designing Flipped Learning in Engineering Education

When designing flipped classroom, it is important to include there two components that can be seen in Figure 1: human interaction component (in-class activities) and computer-automated component (outside activities) [3]. Video lectures are a typical example of the outside activities and them being mainly teacher-centered they can be automated through computer technology. The in-class activities, on the other hand, should be designed based on student-centered learning theories, such as problem-based learning, active learning and collaborative learning to foster the success of the flipped classroom [3].

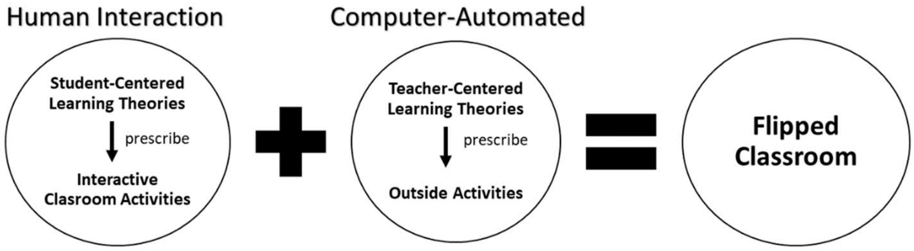

Fig. 1. Components of the Flipped Classroom [3]

It has been shown that the problem-based learning can offer students learning experiences in real world context and thus help them learn how to approach and solve challenging problems and improve students' ability to work in a team [4]. When designing flipped learning it's important to consider the collaborative learning as well as the collaborative environment of F2F learning events can strengthen students' critical thinking and problem-solving skills [5]. These higher order thinking skills, critical thinking, problem-solving skills and teamwork skills are core competencies that engineers need in the work life. The flipped learning setting of pre-class videos, in-class discussions and hands-on activities can furthermore contribute to a deeper synthesis of concepts and it enables more course content to be covered in addition of students learning more efficiently. Carefully designed flipped learning method has the potential to result in better learning outcomes, increase student engagement and enhance students' interest in engineering. [5]

2 FLIPPED LEARNING IN ELECTRONICS EDUCATION AT TU

Two electronics courses, Electronics and Circuit Theory and Product Design of Electronic Device, were designed and implemented using the FLM based on the above-mentioned components. Outside activities utilized the Moodle learning management system and the parts of the courses that required human interaction were designed to reflect student-centered learning theories. The target group of both these courses are bachelor students of the second and third years respectively, and both courses were implemented as seven-week implementations during the academic year 2021 – 2022. In addition to the technical core subjects, the target of these courses is to develop students' work life skills, such as documentation, presentation, critical thinking, argumentation, problem-solving and team work skills.

Both the courses had the same task and session types: pre-class materials and assignments, face-to-face learning events, and prime time meetings. Even though there were some differences between the course implementations, the basic idea in the design and implementation was similar.

With the online pre-class study materials that included short video lectures (duration 3,5 – 21 minutes) and online book materials the students learned the new topic and were able to work at their own pace independent of time and place. In both courses it was assumed that the students had studied the pre-class materials and completed the pre-class assignments before the F2F learning events. In this way the assignments to be done at the F2F learning events could be designed so that they promote students' higher order thinking skills, such as design, compare, analyze, estimate and choose.

The prime time meetings were an important feedback channel both ways, from teacher to student and vice versa. The feedback discussion on the meetings was based on the students' answers regarding questions like, how did you accomplish the learning outcomes of the module, what was the most interesting topic this week, what did you learn / didn't learn this week, what was the most difficult topic this week. At these prime time meetings students were thus able to furthermore deepen their understanding on the topic, make their learning process apparent, understand what they need to learn more and adjust their learning process accordingly. Feedback from students also helps the teacher to visualize e.g., the weak points in students' learning and make possible adjustments accordingly.

In both courses the final course grade was determined based on course points students gathered during the course. The pre-class assignments, or the F2F learning events were not compulsory, but by completing the assignments and taking part in the F2F learning events students were able to gather course points.

2.1 Electronics and Circuit Theory

The Electronics and Circuit Theory course is the very first course in electronics for the students to whom this course is targeted to. The students have some basic knowledge of basic circuit theory already from previous courses, but mostly the topics in this course are totally new to the students. The FLM in this course was designed to follow a weekly schedule which is presented in Figure 2.

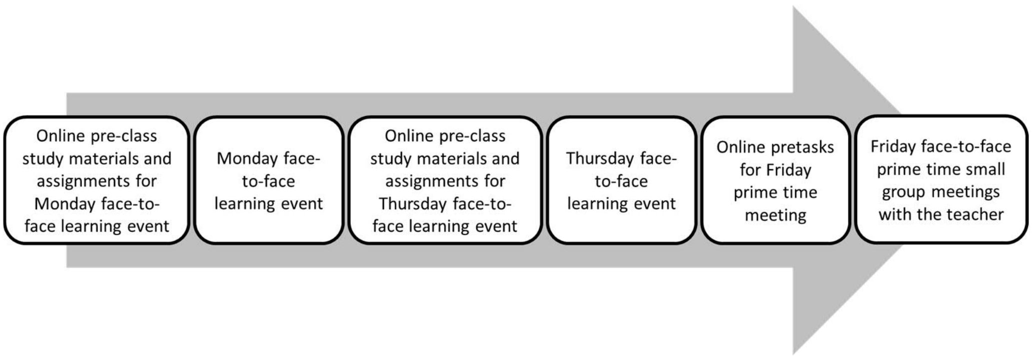

Fig. 2. Weekly schedule of Electronics and Circuit Theory

The assignments were Moodle tasks based on the pre-class study materials. Mostly the Moodle tasks needed teacher's checking, only some of them included automated checking. The future plan is to increase the amount of automatically checked assignments. The pre-assignments had a deadline, and the students had about two to three days to do them. The F2F sessions were for deepening the understanding of the issue at hand by doing various tasks, which mostly included paper and pen part, simulation part, and circuit prototyping part. The circuit prototyping in this case means that the student constructs circuits with through hole components on breadboards and measures and analyses them using a BYOD (bring you own device). Short mini lectures (about 5 to 15 minutes) were included to F2F sessions occasionally, especially when the topic was more demanding for the students.

The prime time meetings were mainly for feedback from the week, and also for clarifying the issues that needed further clarification.

The students gathered course points from all the course parts: pre-assignments, F2F sessions, prime time meetings, and four miniexams. The miniexams were small exams containing calculations, simuations and prototyping. Only the miniexams were compulsory, but for each grade the students needed a certain amount of course points.

2.2 Product Design of Electronic Device

The core contents of the Product Design of Electronic Device course are the different hierarchical levels, production processes and design perspectives of an electronic product. For the FLM implementation the course contents were divided into five flipping modules each of which lasted one to two weeks depending on the extent of the module. Each module followed the same structure presented in Figure 3.

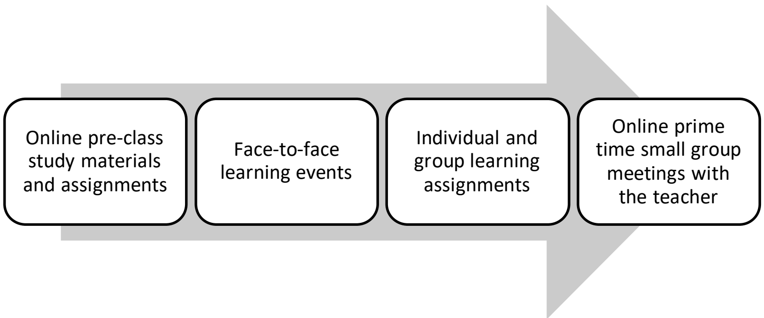

Fig. 3. Structure of one flipping module in the Product Design of Electronic Device course

The online pre-class assignments consisted of self-correcting multiple-choice tests that offered the students the possibility to test their learning and to make notes of questions or problems they may have.

The F2F learning events consisted of collaborative and active learning through various problem-solving and design exercises, calculations, presentations and group discussions in the classroom. In case of a difficult topic or questions from students the teacher explained the pre-class study material shortly anew. Students worked mainly in groups in order to enhance the collaborative aspect of learning as well.

The individual and group learning assignments were designed to deepen students' knowledge on the issue at hand, to promote collaborative learning and to increase students' work life skills. The individual assignments included a calculation exam in the Moodle and the group assignments included e.g., decibel meter construction work, a wiki assignment and a forum discussion assignment in the Moodle. The assignments were compulsory to complete the course and graded passed/failed or on a scale of 1 – 6 points.

The compulsory 30-minute prime time small group meetings after each flipping module were realized via Teams in groups of three students. In addition of the feedback discussion students' knowledge on the topic were tested via small group problem solving tasks. Points were assigned from an active participation.

3 RESULTS

During the academic year 2021 – 2022 a total of 28 students completed the Product Design of Electronic device course approvingly. At the end of the course student feedback was gathered with a questionnaire consisting of open questions. Although about ten students were expected, only one student completed the Electronics and Circuit Theory course. It seems that many students have postponed this course to the next academic year. Thus, we cannot draw any conclusions about this course from the student perspective.

3.1 Final Grade of the Product Design of Electronic Device

For the final grade of the Product Design of Electronic Device course the student was able to gather points from the self-correcting multiple-choice tests, F2F learning events, learning assignments and prime time small group meetings. The final grade scale was 0 – 5 and for a grade one student had to gather 27 points out of 56 points. Grade three required 39 points. Grade five required 51 points and in order to gather this amount of points, the student had to take part in a voluntary electronic exam of the course topics. The final grade distribution can be seen in Figure 4.

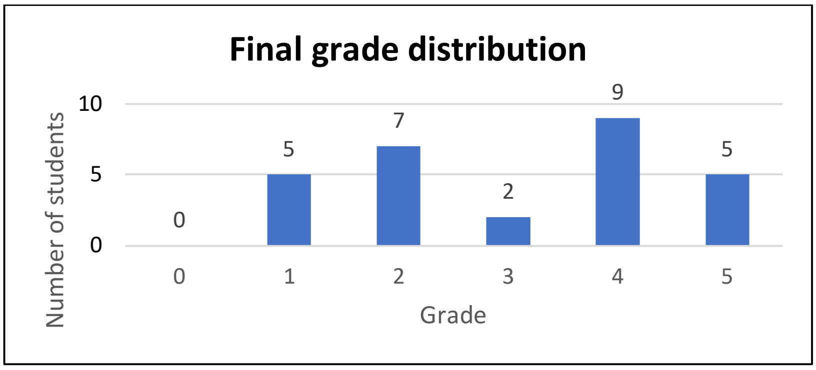

Fig. 4. Final grade distribution of the Product Design of Electronic Device course

As the Figure 4 shows many students (50%) performed very good (grade 4) or excellent (grade 5) at the course. This was expected as flipped learning often results in high student satisfaction and increased performance [5,6]. On the other hand, many students also received grade 1 (17,9%) or grade 2 (25%). There can be many reasons behind this, but these students might have lower self-regulation skills, as it has been shown that high self-regulation skills can be related to high learning achievement [7]. Overall, the grade distribution is consistent with other flipped courses [5].

3.2 Course Feedback of the Product Design of Electronic Device

The open questions in the feedback form asked students' experiences and opinions regarding the flipped classroom model, pre-study materials, learning assignments, F2F learning events, prime time group meetings and the grade formation. Many students believed the FLM promoted learning and made them learn throughout the entire course. This is indicated in Table 1 in the freely translated quotations regarding the question “What are your thoughts about implementing the course by the flipped learning method? Did the implementation method work? Did it promote your learning?”

Table 1. Student feedback on the flipped learning method

“The implementation method worked well ja promoted learning compared to traditionally implemented courses.”
“One had to out of necessity familiarize with the subject and (the method) encouraged to learn through the entire course.”
“In my opinion studying with the short videos and applying the knowledge in the learning events was a functional arrangement. The course didn’t feel too heavy, but one studied regularly during it.”
“I felt I learned well, but I’m not sure whether it was because of the implementation method or because of well and interesting materials.”

The short lecture videos used as online pre-class study material received very positive feedback and many students felt that the F2F learning events deepened their learning, although some students experienced the pace of the events too slow (see Table 2).

Table 2. Student feedback on the pre-class videos and F2F learning events

Pre-class videos	Face-to-face learning events
“The videos were excellent, the most important things were summed up to suitable packages.”	*“The assignments in the learning events visualized and deepened the topics.”*
“The videos were good and it was nice that one was able to watch them several times.”	*“The assignments in the learning events made one consider the topic at hand, and as the assignments were often applied, they were meaningful.”*
“The videos were of suitable length and of suitable amount.”	*“In the discussion assignments one was able to work on the subject together.”*
“Study materials were useful. The videos summarized the main points and from the e-books one could read more detailed facts.”	*“The learning events specified the topics in the videos. Although, if one had watched the videos, the learning events proceeded slowly.”*

There were also some comments in the course feedback about the workload of the flipped learning method being too heavy.

4 EXPERIENCES AFTER THE FIRST IMPLEMENTATION ROUND

In this paper we have introduced our way of implementing FLM to two BSc level electronics courses. The purpose of is to shear our experiences and thoughts about FLM, and this way boost the implementation of FLM also in other higher education institutes.

The design and implementation of the FLM requires time and careful design. Making and editing video lectures is really time consuming and the in-class activities and facilitation need to be planned so that they enhance students’ higher order thinking skills. Furthermore, the design and actual implementation of online self-correcting Moodle assignments were surprisingly time consuming. Teacher's workload is the highest during the first implementation year, but it is expected to be lower after that. Organisation's support for the teacher, such as time allocation, equipment acquisition, possibility to ask for help and peer support, are valuable assets and can greatly promote teacher's interest and success for the FLM implementation. In the structure of the flipped course flexibility, versatile learning experiences, feedback possibilities, individual and collaborative learning possibilities and learning of work life skills should also be considered. Skilled professional instructors are thus important in the FLM and the course content division between outside activities and interactive classroom activities need to be thoroughly planned [6].

The findings of the FLM studies of practise are encouraging for electronics teaching. The short video lectures accompanied with the self-correcting multiple choice tests worked very well as online pre-class study material offering students flexibility and possibility to work themselves mainly independent of time and place. The F2F learning events seem to have worked as well with the aim of learning actively together, deepen the learning and enhancing skills, like design, analyze and compare. Learning of the topic was further deepened with the versatile learning assignments that also offered students collaborative learning possibilities and taught work life skills. The prime time meetings wrapped up the topic and were an important feedback point. Some students felt that these prime time meetings were not useful and that there were too many of them, but from the teacher's point of view the meetings offered valuable information regarding students' learning and possible stumbling blocks. However, in future a prime time meeting after each module or every week it not absolutely necessary, fewer wrap-up and feedback points are adequate as the courses last only seven weeks.

When designing and implementing the FLM students' readiness and experience on working actively according to the method should also be taken into account. Students' readiness and self-regulation skills vary and this can result in disperse learning results as stated above. Course workload can also easily build up overloading or divide unevenly between the different modules or weeks. Careful design of the course workload and introduction to the teaching method are thus things to consider [6].

The findings of these studies are only preliminary since the FLM implementation of these courses were during the academic year 2021 – 2022 and the number of students attending the courses was 29. No absolute conclusions from the grade distribution or from the student feedback can thus be made, but these first implementations clearly showed that video lectures and self-correcting multiple choice tests as online pre-class study material can be automated them being mainly teacher centered. Carefully designed and facilitated student-centered F2F learning events and learning assignments are then needed to enhance students' higher level learning and work life skills not to forget important both-way feedback possibilities. In future the FLM structure of these courses will be continued and more experiences and feedback will be gathered in order to draw more conclusions on e.g., grades and students' self-regulation skills and to improve the courses accordingly.

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FACTORS OF ACCEPTANCE OF DIGITAL TOOLS: THE EXAMPLE OF THE 3DEXPERIENCE PLATFORM IN THE CONTEXT OF COLLABORATIVE PROJECTS

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ABSTRACT

In face of the omnipresence of digital technology in all aspects of life, education and training players are encouraged to adapt to digital tools. This should enable learners to grasp and take advantage of the potential it offers, while developing the various dimensions of digital skills. However, the introduction of digital tools in education and training environments still raises many challenges, especially because any new technology requires from all actors, teachers and learners in particular, a change in their habits and postures. This action research takes as a theoretical analysis framework the model of instrumental acceptance applied to information and communication technologies developed by Caron and Heutte (2017). It focuses on

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the factors of acceptance and use of a digital tool in general, in particular the 3DExperience platform, by learners involved in applied collaborative projects. It is based on several experiments carried out with students from ISAE-Supméca, a French engineering school, and other students from partner institutions as part of the EXAPP_3D educational research project. With a methodology that focuses on interpretative phenomenological analysis (Restivo et.al., 2018), it provides scientific support for the sometimes complex challenges of integrating new tools in engineering schools.

1 INTRODUCTION

ISAE-Supméca has been involved in educational research for a decade through concrete students' projects involving several stakeholders, from industrial partners to academic partners. In the global framework of the integration of technological tools in the world of education and training in order to improve the transversal skills of learners thanks to the opportunities offered by information and communication technologies, ISAE-Supméca has been introducing for years the 3DExperience platform (Dassault Systèmes).

Several students' projects use this tool as a support and learning tool for the management of collaborative engineering projects and gaining a feedback about their use is of concern and interest, especially in the framework of collaborative projects realized within the EXAPP_3D project[2].

It is therefore in this context of increased use in the process of training learners that this study is located. This work highlights the first results of a qualitative study carried out with ISAE-Supméca students. Our research is essentially focused on the use of the 3DExperience platform. This work with a comprehensive aim seeks to analyse the real uses of the tool and the conditions of its appropriation by the learners.

After a broad review of the theoretical frameworks, we present the context of the study, the characteristics of the target population and the methods of collecting and analysing data. Finally, we present the results of our analysis and conclude.

2 THEORITICAL FRAMEWORK

The explanatory factors for the successful use and integration of technological tools in an educational context have been the subject of many studies in recent decades. The scientific literature indicates the existence of a variety of models to account for the integration of digital tools in teaching (Fievez, 2017; Bauchet et al. 2020) [1] [2].

[2] EXAPP_3D (Experiment Learning by Problems and Projects via 3D Design) is an ongoing so-called e-FRAN project coordinated by ISAE-Supmeca and co-funded by the French Fund Deposits, from September 2016 to December 2022. Among other things, the project aims to promote active learning involving students from secondary school and/or high school and/or Bachelor's degree and/or engineering school in common dedicated projects.

Bobillier-Chaumon and Dubois (2009) [3] group them into three main categories, including theoretical models of the social acceptance of Information and Communications Technology (ICT).

Social acceptance basically refers to the way individuals behave when faced with the introduction of new technologies in both their professional and domestic lives.

Overall, we can distinguish four different approaches to the social acceptance of ICT. We will be particularly interested in the technology acceptance model (TAM) modelled by Davis (1986) [4] during his doctoral research at IBM. It has indeed its roots in social psychology and is inspired by Fishbein and Ajzen's Theory of Reasoned Action (TRA) (1975) [5].

2.1 Theory of Reasoned Action

The TRA rejects the idea that the actions of individuals are underpinned by unconscious, capricious and unpredictable motivations. Thus for Fishbein and Ajzen (1975) [5] human beings consider the implications of their actions before deciding whether or not to engage in them. "Behavioural intentions are indications of an individual's willingness to perform a behaviour" (Fishbein and Ajzen, 2010, p. 39) [6]. Therefore TRA is based on the assumption that behaviour (the adoption of new technology, for example) is under the total control of the individual (Giger, 2008) [7].

This theory analyses the intentions of using a tool based on three social determinants:

- the attitude, which refers to a set of values and beliefs, which leads a user to evaluate favourably or not the fact of adopting new technologies,
- the subjective norm corresponds to the social influence or the social pressure perceived by the individual to adopt the tools (perception of the expectations of others),
- the degree of motivation of the subject to comply, to follow or not the incentives for adopting the tool.

The theory of planned behaviour proposed by Ajzen (1991) [8] is an extension of the theory of reasoned action by adding a new component: perceived behavioural control (perceived self-efficacy, expectation of success).

Both of these theories hold that social behaviour is eminently voluntary, because it implies a choice based on deliberation (Ajzen & Fishbein, 1980) [9].

2.2 Technology Acceptance Model

The Technological Acceptance Model (TAM) of Davis (1986) [4] was inspired by the work of Fishbein and Ajzen (1975) [5] by taking up the variables of the Theory of Reasoned Action (TRA) to which he integrates new elements.

The TAM postulates that attitude in forming the intention to accept a technology is based on two fundamental determinants: perceived usefulness and perceived ease of use. Davis, Bagozzi and Warshaw (1989, p. 985) [10] state that the perceived usefulness refers to “the prospective user’s subjective probability that using a specific application system will increase his or her job performance within an organizational context" and the perceived ease of use refers to "the degree to which the prospective user expects the target system to be free of effort". Thus, according to this model, the perception that individuals have of usefulness and ease of use determines their attitudes and subsequently their behaviours in the use of technologies (Brangier, Hammes-Adelé & Bastien, 2010). [11]

The TAM had a resounding success and is even considered to be the dominant model for studies on the acceptability and adoption of ICT (Sanghee et al. 2013) [12].

Thanks to this success, other derivative models have been developed, integrating a multitude of external and moderating variables.

Faced with the diversity of enrichments to which the TAM has been subjected, Venkatesh et al. (2003) [13] proposed a "Unified Theory of Acceptance and Use of Technology (UTAUT)" from a synthesis of several behavioural models to explain the use of technology.

2.3 The instrumental acceptance model applied to ICT

The UTAUT has made it possible to identify four determinants on which the intention to accept a technology is based; namely the performance expectancy, the effort expectancy, the social influence, and facilitating conditions.

Caron and Heutte (2017) [14] adopted this model by necessarily adapting it to their context of study. The authors use therefore these four direct indicators of the intention to use (performance expectancy, effort expectancy, social influence, facilitating conditions). They match respectively the first two indicators (performance expectancy, effort expectancy) to the utility and usability dimensions. In order to understand the use of the prescribed tool, they propose that the perception of utility is broken down into the perception of general utility and projected utility. Their adaptation of the technology acceptance model is presented hereafter.

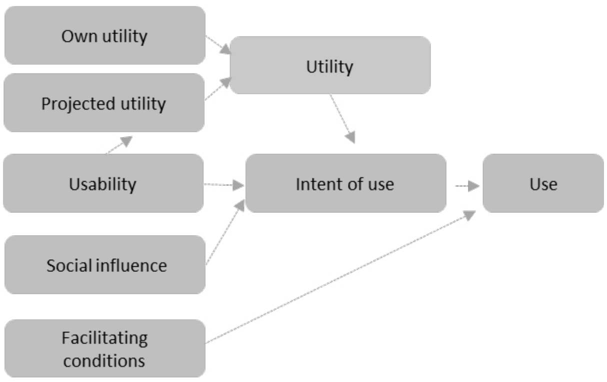

Fig. 1. The instrumental acceptance model applied to ICT (Caron and Heutte, 2017) [14]

The self-utility concerns the learner's assessment of the usefulness of the tool for him/herself. The projected usefulness concerns the learner's projection of the usefulness of the tool for his future, professional activities (in the context of this study, it is about the learners' perceptions of the requirement of mastery of the tool for professional issues). The usability is linked to design, efficiency and satisfaction. According to Davis (1986) [4], it influences utility. The social influence and the facilitating conditions are intended to address the use of the device in its context, by evaluating the social reasons and the conditions (institutional, environmental in the broad sense, etc.) pushing to use the tool.

3 OUR STUDY

3.1 The context

ISAE-Supméca being a French engineering school involved since many years in problem-and project-based learning (PBL) and in educational research, many issues emerged at the confluence of research and practice. Our study is therefore positioned at this confluence, in other words, in a space that meets “both the challenges of knowledge and those of action” (Carré, 1998) [15].

This work was carried out as part of an evaluation following the implementation of the EXAPP_3D project led by ISAE-Supméca and involving several academic and professional actors. This educational project uses the PBL approach in the training of engineers, based on the most innovative digital chain tools, in particular the systems and collaborative animation modules of the 3DExperience from Dassault Systèmes. 3DExperience is a platform that has the advantage of capturing all the activities of an organization and its partners in one place. The use of this tool aims on the one hand to promote greater interactivity and learning of collaborative work in project mode by using digital as an opening to new actors and new know-how for our learners. On the other hand, it promotes the development of monitoring strategies, methods and support tools by and for teachers using digital as a teaching tool.

The objective of our work is to assess the contribution of the project as a whole to pedagogy and its impact on the development of learners' skills.

We will only report here on part of this work: based on a qualitative study, we questioned the feelings of learners about the contribution of digital technology and mainly the use of the 3DExperience platform in the context of collective projects they had carried out.

3.2 Population of our study

We contacted the learners from the 2021-2022 class of ISAE-Supméca who worked on collaborative projects with partners and involving the use of the 3DExperience platform in order to obtain their active collaboration in this research work, through a personal interview. Among the people contacted, 6 showed their interest in participating in the project. We were finally able to interview 4 people, 3 men and 1 woman, from 22 to 24 years old. The concerned learners all used the 3DExperience platform for the first time during the project period, as this use is for the moment experimental for students within some PBL modules, especially in the framework of EXAPP_3D. So, our study is a first qualitative approach of students’ feedback and complements another study published in 2021 [16]. The limited number of people in the sample makes this study an example that cannot be generalized.

3.3 Data collection and methodology

Data collection began with a phase of observations in contexts. It aimed to better understand the overall portrait of learners and their training environment. This ethnographic approach, which consists of observing in contexts, was omnipresent throughout the investigation. Subsequently, a corpus of 6 semi-structured interviews was collected from ISAE-Supméca learners who had worked with the aforementioned platform. Proceeding with semi-directive interviews allowed us to give an orientation to the discussions with regard to the main themes of our research while leaving the necessary latitude to the interviewees for the nuance and explanation of their positions (Michelat, 1975) [17]. We were interested in analysing the conditions of use of a tool, the 3DExperience platform, among learners. The method that seemed suitable for capturing the observed phenomenon is induction.

For data processing, we used interpretative phenomenological analysis, a method proposed by Restivo et al. (2009) [18]. Thematic analysis was also used during this step. It consisted of identifying, story by story, the themes addressed, checking their recurrence from one interviewee to another. The thematic analysis was done using RQDA software. This tool allowed us to automate the identification and extraction of themes (coding) from each story. Coding facilitates the work of comparison because it allows the connection of passages dealing with the same subjects. Our corpus of texts was therefore imported into RQDA in order to carry out this thematic coding.

4 RESULTS

In this part, we present our results according to four categories: general utility, usability, social influence and digital environment of the institution.

4.1 General utility

The data analysis shows a positive perception of the usefulness of the 3DExperience from all the interviewees. They generally recognize the indispensability of this tool for certain aspects of their work, in particular the collaborative aspects given the geographical dispersion and the physical distance between all the actors involved. As a result, learners show a positive attitude to the use of the 3DExperience. For them, the tool is “very practical” and has an undeniable advantage because they can do everything with it: easy access to the work of each member of the group, communication with academic and professional tutors, etc.

The use of the tool for their projects determines the usefulness they perceive of it. The 3DExperience platform arouses their interest in view of the results of the analyses.

However, they use it very sparingly. For them, use is limited to the scope of collective projects. This is a relatively short period (even if each student works around 200 hours, only 2 months are almost full time) during which learners primarily use the tools they master and use with their teachers. Indeed, as already stated, these learners involved in the study used the 3DExperience platform for the first time during this PBL period. ISAE-Supméca students use it for the moment only during some projects modules, whereas all apprentices use it. So, one could argue that the use of this tool has a small impact on the general training of the learners of our study.

4.2 Usability

The 3DExperience is perceived as a complex tool because it brings together in a single place a set of 3D applications to which are added other functionalities that seem close to an educational platform. As a result, its usability is closely linked to it being used by our learners. The various functionalities of the platform are not mobilized in the same way according to the individual commitment of the students and their agency.

At the exception of students from one group, who used extensively the 3DExperience applications and used it for topology optimisation, our students mainly used it as file storage (access to resources) and communication (to a large extent) on the dashboard dedicated to the different groups and projects; to which only members have access. These uses are perceived as being very simple and intuitive. Thus, the majority of interviewees find the usability of the 3DExperience satisfactory. They then express a feeling of self-efficacy on these uses.

On the other hand, the design, optimization and simulation activities required self-training on the part of the students to improve their knowledge and have a greater mastery of the tool. It is here that the concept of agency used above finds its full meaning, insofar as it calls on the self-training activity of individuals as a self-directed learning process. Although all the learners expressed their training needs, the data show that only a few showed agency in implementing learning strategies to increase their effectiveness in using the tool through tutorials or other types of resources.

It could therefore be argued that the perception of the usability of the tool is variable and depends on the functionalities implemented, given the polymorphic nature and the richness of its functionalities.

4.3 Social influence

The social influence associated with the use of 3DExperience seems mainly linked to the injunctions received from academic and professional tutors and seems linked to a relative mastery of the tool on the part of the latter. The data analysis reveals that the interest given to the use of the platform was not the same in all the projects. In some cases, the use was perceived by the learners as an imposed or prescribed decision. The strategies for adopting the tool on the part of the interviewees were linked to their perception of the injunctions issued by the various tutors to use the tool. These learners perceive the first getting started tutorials provided by the tutors as a prescription for use. As a result, the deepening of the functionalities of the tool is nourished and supported by the connotations linked to the profile of the model learner, a determined individual-learner.

4.4 Digital environment of the institution

The analysis of the data brings out the theme of the institution's digital environment. It is present in the remarks of all the interviewees and concerns the digital tools used during their training. Their remarks are mainly structured around the determining elements put in place by the school in the training of students: the class, the courses, the modules.

The learners interviewed describe an environment that is not conducive to the full use of the tool set up for the projects. Indeed, as already stated, the 3DExperience tool provided for the projects is for the moment experimented only in several PBL modules and is not the subject of any training before the projects and is not used as a learning tool in any training module either (for the students, contrary to the apprentices in our institution). These results highlight the existence of a correlation between the discourse on the lived environment and the real practices of the learners during the projects. The use of the tool does not go beyond aspects perceived as intuitive and related to their digital skills. It could be argued that there is a strong correlation between the training received and the uses implemented. We note that the little training received in some groups thanks to tutorials from academic and/or professional tutors is positively correlated to the learners' feeling of self-efficacy and is the basis of the self-training strategies implemented.

5 CONCLUSION

At the end of this study, it appears that the 3DExperience platform is mainly used to access project resources, to store them and to provide access to them anywhere and at any time to other members of the work group. It is spontaneously used by all learners when it comes to communicating with other geographically distant actors and receiving feedback from their various tutors. On the other hand, it is often neglected when it comes to implementing more advanced functionalities such as design or simulation. In this sense, the functionalities that seem perceived as the most useful, even if more professional, are similar to that of an educational platform: space dedicated to each project where the project's resources are stored and are accessible, a space for coordination, mutual aid and communication between learners and between teaching staff/professional tutors and learners. It means that the real power of the tool was not really used during these projects.

The study highlights a discourse accounting for the uses of the platform and highlighting some components of instrumental acceptance (general utility, usability, social influence). It also makes it possible to understand that for learners, the in-depth use of a tool essentially involves institutional prescription, through training or the implementation of modules related to the skills for using the tool. Training in the perspective of supporting the appropriation of tools, even minimal, increases the sense of self-efficacy of learners and leads them to show agency.

Finally, we want to stress that we will use this feedback and then intend to conduct new studies like this one in the coming years, on broader samples, in order to be able to progressively implement more gradual changes.

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ENGINEERING SCHOOLS FACING THE THORNY ISSUE OF TRAINING STUDENTS IN COLLABORATIVE SKILLS: FEEDBACK FROM THE FIELD

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ABSTRACT

In a context of transformation and increasing complexity of work due to the development of information technologies, communication and digital networks, the question of the acquisition and development of collaborative skills of engineers in training arises with a particular sharpness. Achieving their acquisition in practice is a major challenge. In France, although included in the training programs for students, the world of training is struggling to find the teaching and learning adapted and capable of developing collaborative skills in engineering students. Thus, the practices and methods implemented are different from one institution to another. It

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goes without saying that the acquisition and development of collaborative skills that are highly sought after on the labor market are unequally distributed among graduates of the major engineering schools. Thanks to a recombination of theoretical approaches, a qualitative and quantitative study conducted at ISAE-Supméca, a French engineering school, in order to obtain an overview of the collaborative skills developed by the students during specific problem- and project-based learning modules, and also in order to provide a critical analysis and feedback about the development of collaborative skills into the students' training program through these applied professional projects that immerse them in work contexts close to the future professional realities. The results show a strong gap between skills development and a focus on the development of skills from the “Process – Deliberation” category.

1 INTRODUCTION

ISAE-Supméca has been involved in educational research for a decade through concrete students’ projects involving several stakeholders, from industrial partners to academic partners. Among other issues, skills is a topic of interest, especially collaborative skills.

Our study focuses on the feedback on collaborative skills from ISAE-Supméca’s students project realized in collaboration with students from other institutions. More specifically, the aim of the study was to obtain an overview of the collaborative skills developed by the students duting these projects.

Our paper is organized as following. Section 2 provides the theoretical framework in which the study took place. Section 3 presents the specific projects analyzed in-depth in order to provide the feedback. Section 4 exposes the methods. Finally, section 5 presents the results and section 6 concludes our paper.

2 COLLABORATIVE SKILLS: ESSENTIAL FEATURES AND ANALYSIS GRID

Although there is a lot of work in the scientific literature on cooperation and collaboration and a keen interest in exploring this concept, no single theory can help to understand the complexity of what is at stake in these dynamic. We will briefly present the theoretical contributions that make it possible to analyze collaboration and cooperation as a process evolving over time.

Collaborative skills result from a social construction within a formalized framework or not (D’Amour, 1997) [1]. We see it as the capacity for the subject to synergize with others by building links in order to achieve a common work (Dejours, 1993, Policard, 2014) [2] [3]. To understand the dynamic nature of the collaborative process, it is necessary to determine the main anchors in which the temporal perspective of the collaborative process is rooted. The approaches taken into account in this work make it possible to account for the dynamic dimension of the collaborative process.

The work of Mattessich and Monsey (1992) [4] offers an explanatory reading of collaboration phenomena. They identified 19 factors influencing the success of a collaboration, which they classified into six groups, related to six topics:

- Related to the environment,
- Related to group membership,
- Related to process,
- Related to communication,
- Related to purpose,
- Related to resources.

Thomson and Perry (2006) [5] present a similar classification. They propose a scale of the collaborative process that covers 5 key dimensions of collaboration, each involving activities related to this process:

- Governance,
- Administration,
- Organizational autonomy,
- Mutuality,
- Norms.

According to Thomson and Perry (2006) [5], the black box of the collaborative process includes three sequences whose structure resembles the models commonly used to illustrate the dynamics of the activity: antecedents – process – results.

The sequential analysis of collaboration proposed by Thomson and Perry (2006) [5] is close to the collaborative skills model of Morse and Stephens (2012) [6]. The latter maintain that the prior analysis of the type of activity carried out collectively by the actors involved in a collaboration makes it possible to identify the different phases of the collaborative action (Sanojca, 2018) [7]. They associate specific skills drawn from the literature with the different stages of the identified collaboration. The originality of their work was to consider that the type of skills used in the collaborative process stems from the very structure of the project. As a result, the authors argue that collaborative skills are skills that adapts to the dynamics of the process in which they are exercised.

According to Sanojca (2018) [7], the term "meta-competencies" (in which they include for example "collaborative mindset) given by Morse and Stephens (2012) [6] is not appropriate with regard to the constituent skills of this group, which are more akin to transversal skills. The "meta-competences" described here can rather be considered as attitudes or predispositions that can influence the choice to collaborate or not.

Sanojca (2018) [7] therefore proposes to establish a correspondence between them and the "antecedents" of the collaboration identified by Morse and Stephens (2012) [6].

By reorganizing all the skills identified in these approaches (Morse & Stephens, 2012; Mattessich & Monsey, 1992) [6] [4] according to the model of Thompson and Perry (2006) [5], Sanojca (2018) [7] obtains a scale of collaborative skills mobilized for the identification of the nature of the collaborative skills implemented by our students.

These three models constitute a theoretical framework of reference for the analysis of our data.

3 CASE STUDIES

For several years, ISAE-Supméca, a French public engineering school, has been offering its last-year students the possibility of carrying out a so-called “synthesis project”. These projects are done in a problem- and project- based learning (PBL) approach and are more precisely based on the socio-constructivist approach and give a central place to the individual in the co-construction of his knowledge from personal experiences and in his interactions with his environment (Vygotsky, 1978) [8]. Students work in teams of three (sometimes in teams of two), during around 200 hours (for a group total of around 400 to 600 hours) on a three-month period (and are almost full-time at the end of the period) on situations requiring the confrontation of points of view and the joint resolution of problems. The particularity of this PBL module is that it allows students to work on a subject proposed by companies on industrial issues, with all their complexity and richness. Some of these PBL include in these working groups at least two second-year BTS (French 2-year studies technician curricula) students, in the framework of the EXAPP_3D[2] project. These projects have run under the following collaborative projects model.

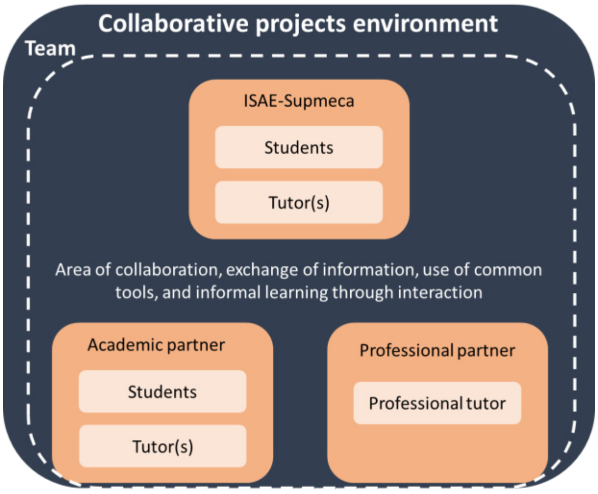

Fig. 1. ISAE-Supméca collaborative projects model [9]

Here, we study projects conducted with two partners: Lycée Voillaume and Lycée Louis Armand, both located in the same region (Ile-de-France) as ISAE-Supméca. As a result, these PBL involve many stakeholders and are focused on collaboration and 3D design and lead to concrete deliverables. A paper published in 2021 presented the frameworks of these projects and focused on academic and industrial tutors feedback in order to highlight some best practices [9].

[2] EXAPP_3D (Experiment Learning by Problems and Projects via 3D Design) is an ongoing so-called e-FRAN project coordinated by ISAE-Supmeca and co-funded by the French Fund Deposits, from September 2016 to December 2022. Among other things, the project aims to promote active learning involving students from secondary school and/or high school and/or Bachelor’s degree and/or engineering school in common dedicated projects.

The present works is a new block in the studies of these projects, especially their collaborative aspects.

4 RESEARCH METHODS

An exploration method appeared to be the best way to account for the social interactions between each student and actors involved in the projects, insofar as it induces the use of a qualitative data collection method (Fortin and Gagnon, 2016) [10].

The approach we have favored in this study is comprehensive and inductive. This inductive approach makes it possible to take what can be learned from the data as a starting point.

A collection of data by non-directive individual interview lasting an average of 30 minutes was conducted with eight students (five men and three women aged 21 to 23) contacted with regard to the activities they carried out in groups of two or three. Were excluded from our panel the groups in which we could not interview all the members.

Each of the participants was invited to express themself on the existing social interactions and the way of working during the project.

The qualitative data collected was analyzed using a computerized tool for processing textual data: RQDA (R package for Qualitative Data Analysis) from the items of our scale. It was a question of assigning to code the corpus when it was obvious to establish its correspondence with one of the items of the scale.

We have also opted for a mix of analysis methods, which combines quantitative and qualitative analyzes according to our progress in understanding the phenomenon studied.

5 RESULTS

The aim of our study was to understand a phenomenon: the acquisition and development of collaborative skills of students involved in collective projects, according to the point of view of students who experience it.

5.1 Overview of declared collaborative skills

In this part we present the action verbs and expressions used by ISAE-Supméca students, from the eight interviews conducted. The interviewees had to describe their collaborative practice based on a broad question: “What exactly do you do when you collaborate?”

The data collected was related to the different items of our scale, made up of skills rewritten and reorganized using the approaches of Morse & Stephens (2012) [6], Mattessich & Monsey (1992) [4] and Thompson and Perry (2006) [5].

These data, presented in Figure 1, are organized according to the different categories of our scale, highlight the average number of expressions listed in the verbatim statements and analysed as well as the number of people for each skill.

The general average occurency of the statements corresponding to the skills of the scale is just under 4. As a result, only the skills cumulating a number of statements greater than or equal to this threshold were considered significant. They are the lines in bold blue in Figure 1. Skills rarely or very rarely quoted by the students are the line in dark orange.

5.2 Data on the nature of the collaborative skills implemented

These data presented in Figure 2 allow some analysis on the nature of the skills the students pretend to develop through the occurency of the speech about them.

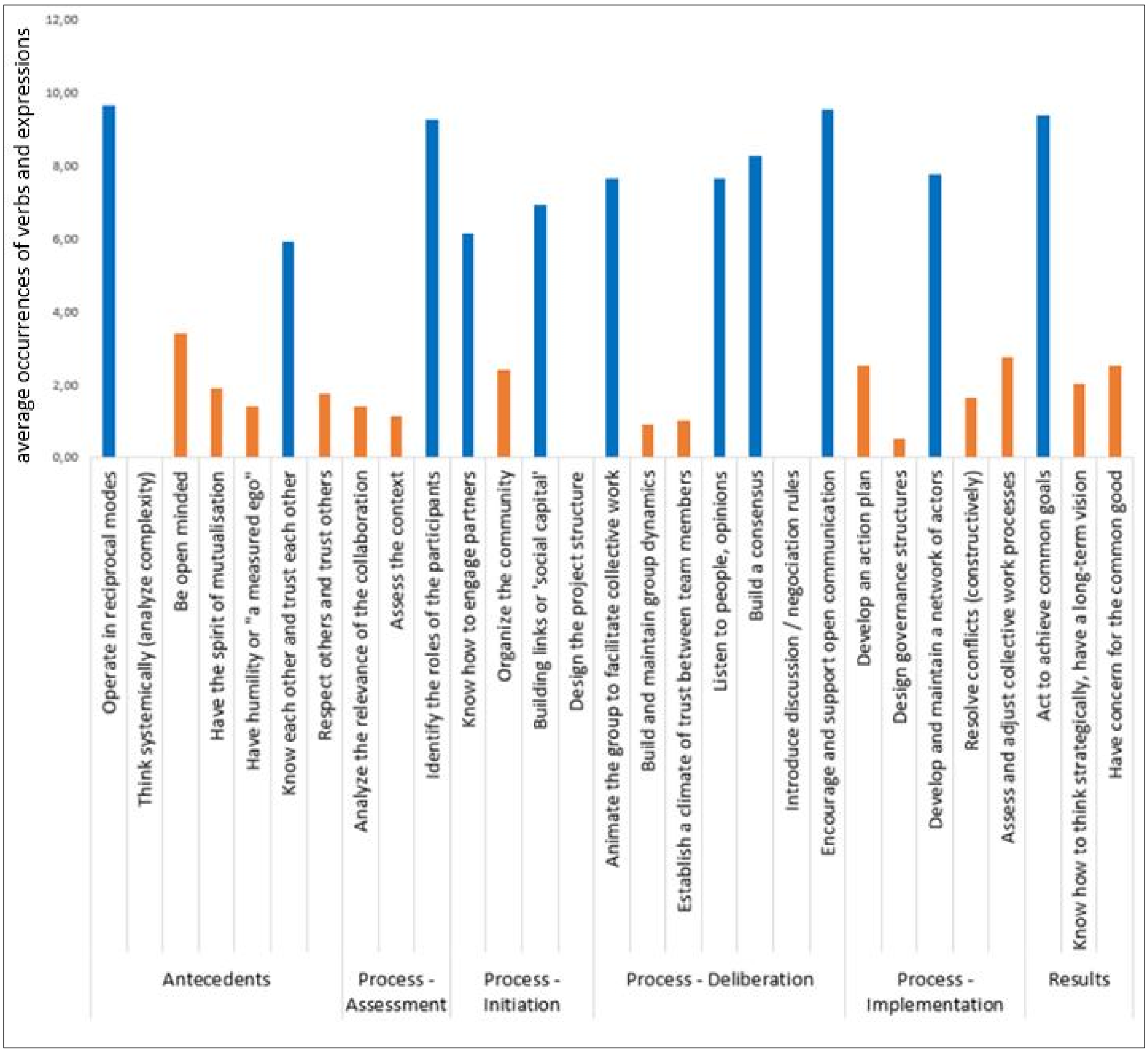

Fig. 2. Average occurencies of action verbs and expressions used by students in reference to each skill as re-written taking into account and reorganizing Morse & Stephens, Thomson & Perry, Mettessith & Monsey approaches

Among the skills with an average occurency over 4, four items have an average occurency over 9: these items are : “Operate in reciprocal modes”, “Identify the roles of the participants”, “Encouraging and supporting open communication” and “Act to achieve common goals”, all belonging to different categories. In terms of category, We note that the skills relating to “Process – Deliberation” are numerous to be considered developed (4 out of 7) and among them, “Encouraging and supporting open communication” stands out slightly, just above “Building a consensus”.

On the opposite, some skills are very rarely or even not quoted, but it should be highlighted that although these skills are rarely mentioned, the fact remains that they are the subject of development for some students.

We will now focus more on several significant data with regard to the threshold of 4 already explained. More precisely, we will highlight four other results of our study.

5.3 Development of attitudes related to the collaboration developed

Collective work is facilitated by the knowledge of the members of the group, which is acquired through interactions. This knowledge makes it possible to establish a balance within the group, based essentially on “trust”. In a context of collective work, knowing others is an undeniable asset. Indeed, knowing the members of your group means having knowledge of their skills, the way they work and the soft skills that characterize them. “I knew that we didn't have the same skills at all,” underlined one of the interviewees. So, even if the “Know each other and trust each other” skill received an average occurency of less than 6, it was quoted by all students and seems important for them.

5.4 Skills related to the implementation process and the achievement of goals

These collaborative attitudes are necessary to enter into collaboration and prove to be very judicious for the collective mode of work. To know is also to adopt a collective work organization which consists of a sharing of tasks by identifying the roles of each. This knowledge of others makes it possible above all to accommodate diverse personalities, accept other points of view and be attentive to each other: to listen to people and opinions.

Consensus building emerges also in parts of students statements; that is, the fact that the members of the group must succeed in converging their ideas to reach an agreement that satisfies everyone, when they discuss the activity.

To reach a consensus, everyone must speak up and communicate. Here the notion of communication refers on the one hand to the interactions relating to the task which are aroused during collective work and the confrontation of points of view and on the other hand to the fact that everyone is encouraged to freely express their ideas without embarrassment.

The items "Know how to engage partners" and "Building links or ‘social capital’" in the category “Process – Initiation” see an average occurency above 6 and refer to the way students proceed to achieve the goals they have set themselves and which are linked to the concrete organization of collective activity on an equal distribution of tasks within the group. But even by following this modality, students are aware that they must establish links allowing a certain proximity between members of the same group. These goals emanate from a desire to “succeed” in collective activities and to rely on the strengths of the group to achieve them.

5.5 The emergence of a new attitude: benevolence

The analysis of the data also reveals skills acquired by the students and not appearing on our scale. This is the case of benevolence perceived through the expressions “listen”, “attention”, “comfortable”, “benevolent” used by the interviewees. They emphasize the idea that students strive to interact with members of their group in a respectful and caring way and expect reciprocity from them. Benevolence is a state of mind that promotes the establishment of a healthy work environment.

5.6 Skills not developed according to the students

The analysis of the data also show that 3 skills were not quoted at all by the students in their speeches. These are “Think systemically (analyze complexity)”, “Design the project structure” and “Introduce discussion / negociation rules”. If the latter could maybe seem not so surprising, the two first ones can be surprinsing, especially in an engineering school. Also, only 3 students quoted the item “Design governance structures”, making this skill far from a priority. This result about skills not or barely mentioned is a small matter of concern about the development of some of these skills in the kinds of PBL modules studied, even with an academic partner and with many situations close to the professional environment.

6 CONCLUSION

We mentioned the importance for training structures in general, engineering schools in particular, to develop the collaborative skills of students. Data from interviews with students show that the collective projects offered to students promote the development of collaborative skills in action.

The development of these skills in situations close to those experienced in a professional situation corroborates the idea that the work situation conveys knowledge and generates skills (Schön, 1983; Orlikowski, 2002) [11] [12].

As a result, by focusing on what students do during collective projects and how they do it, we have managed to highlight the skills constituted by their collaborative practices. Although the data analysis has made it possible to observe the emergence of new skills, it should be specified that it is also important to note the analysis of the data reveals new skills not present in our scale. Indeed, our semi-directive interviews brought a reflective posture from the learners towards their practices and it brought more student awareness of skills practiced and learned.

We can therefore argue with Sanojca (2018) [7] that “There is a strong link between the development of collaborative skills and activity” (p.355).

Also, we can propose the hypothesis, especially because the understanding of each other and their roles in the project was highlited, that the length is important. For this reason, in order to compare results, we intend to conduct a similar study on groups of students working on a shorter period and studying one grade earlier.

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Enhancing student communication skills via debating Engineering Ethics

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ABSTRACT

In Engineering, the construction of informed, persuasive and convincing arguments is at the very core of everyday practice. However, in taught postgraduate education there is often an excessive focus on assessment of these skills through written arguments or oral presentations that are usually in the form of long uninterrupted monologues, where the construction of the arguments themselves is almost never challenged. To change this status quo, we have successfully pioneered the use of oral debate as a dynamic and engaging mechanism to develop and assess this skill in our Chemical Engineering MSc students.

Debate is an ideal mechanism to assess our students' ability to construct arguments as it actively encourages them to (1) think about both sides of an argument, (2) consider how they can persuade others and (3) express their viewpoint

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professionally but with conviction. For this reason, the debates undertaken were linked to important engineering ethical dilemmas, by discussing topics such as "should developing countries prioritise the shift to clean energy over economic growth".

The development of this debate-based training and assessment has had numerous positive outcomes on the students' learning experience and vital skills development. Importantly students found the debates to be both an interesting and enjoyable method of assessment and noted that the skills learned would be useful in their future careers. In this concept paper we present our experiences in delivering debate assessments to engineering students along with recommendations for practitioners wishing to implement similar styles of performative assessments in their own pedagogy.

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1 INTRODUCTION

1.1 Problem

A core part of everyday practice as an engineer, whether in the classroom or in industry, is the ability to construct persuasive and convincing arguments [1]. Despite this, we very rarely see the skills being actively developed in taught undergraduate and postgraduate engineering courses. It is rarer still that they are directly assessed, and if they are there is commonly a major focus on written arguments within larger reports. Whilst oral presentations do appear to allow the assessment of spoken arguments, they are usually in the form of pre-prepared, long and uninterrupted monologues, in many cases read from text or bullet points, followed by technical questions. Although these methods do allow technical expertise to be demonstrated, the quality of the argument structure and its impact, i.e. its construction, is almost never appraised. Possibly more importantly, arguments are also rarely challenged, particularly in the spoken form, despite this being a common feature of an engineer's everyday professional experience.

It is clear that in engineering education we must develop teaching and assessment methods that promote team working and effective communication, actively engage the students and allow them to improve their ability to develop, present and adapt arguments. To achieve this we would ideally pair any new pedagogical practice with subjects that allow for nuanced, complex and two-sided thought and discussion, as this will help to meet the requirements of classroom assessment as presented by the National Research Council [2]: to "give students the opportunity to think critically as they apply their understanding under novel conditions to solve new problems or to explain novel phenomena."

1.2 Ethics in Engineering

Ethics is an area, unlike most others in engineering, where there is no 'right' or 'wrong' answer to a question, rather we must use ethical frameworks to form views on which is the optimal path to follow. Nonetheless, it is a topic that it vital that engineers both engage with and understand; It is mandatory that ethics is taught for IChemE [3] accreditation. When discussing ethics in practice we must persuade and convince others, within our team and more widely, that our choice is appropriate, potentially adapting and reframing our arguments based on their unique perspective. Although written essays may be utilised to assess these skills to some degree, they primarily assess slow cognitive argument formation and presentation. Yet, in a non-educational context (e.g., employment) making fast-paced decisions that must instantaneously be justified, and are frequently challenged, is a common, if not every day, occurrence. Performative assessment methods, like debate, are better placed to develop and assess these skills.

1.3 Debate as a form of assessment for engineering ethics

The term debate finds itself applied to describe a broad and diverse spectrum of activities, ranging all the way from formalised parliamentary proceedings to chaotic online forum threads. In the context of utilising debating as a pedagogical tool, leading practitioners have defined a debate as referring to, broadly, “an equitably structured communication event about some topic of interest, with opposing advocates alternating before a decision-making body” [4].

There are several published examples from higher education where in-class debates have been used successfully, both as formative and summative assessments, yet the majority of the cases have been within humanities subjects with only a few examples from STEM subjects [5]. Debates encourage students to focus less on the facts, but more on how they use them to construct robust arguments, by conducting thorough independent research to develop a deeper understanding of the technical knowledge in order to be able to present that information robustly [6]. The development of such argument construction skills, alongside having to consider alternative viewpoints, is particularly useful for students’ to be able to discuss ethical dilemmas [7]. Debate has been clearly shown to be a successful tool for building student’s confidence in handling ethical dilemmas, particularly in relation to the health care sector where debate has been shown to improve nurses moral judgement [7]. However it has yet to be shown that this will work in an engineering context.

For many students, a debate may be the first time that their ideas have been critically challenged and so students are encouraged to think critically about the material in order to actively engage with the other side and present dynamic and robust arguments. In the few examples of debate being used within STEM subjects [5], the studies that have been discussed have clearly shown that debate-based assessments are beneficial to the student experience. Hence in the 2019/2020 academic year we piloted the use of oral debate as a mechanism to assess our Chemical Engineering MSc students’ understanding of ethical issues – a vital part of Chemical Engineering education [3]. As per the definition earlier stated given by [4], in our assessments we made use of a style of formalised debating which is standard at many competitive debating tournaments in the UK, making a few minor adaptations to simplify the rules for our students’ benefit. Borrowing from competitive standards ensured that as a means of assessment our debates were suitably structured, equitably-balanced and involved direct communication towards the assessors as the adjudicating decision-making body.

1.4 Objectives

Given the clear benefits of debating as a form of assessment that have previously been discussed, in the 2019/2020 academic year we piloted the use of oral debate as a mechanism to assess our Chemical Engineering MSc students' understanding of ethical issues – a vital part of Chemical Engineering education [3].

The aims of this pilot were to: a) determine if debating would provide valuable skills to engineering students, b) determine the best way of assessing debating skills and c) provide a framework for debating in engineering education that can be implemented by other teaching practitioners

In this concept paper we will discuss how effective the pilot year was and what impact it had on our students. We will also discuss how we have since developed the debating assessment, with a view to providing recommendations and encouragement for other teaching practitioners who wish to implement similar assessment techniques in their own courses.

2 METHODOLOGY

2.1 Student Background

This study was undertaken in a Department of Chemical Engineering at University College London, as part of the development of a new MSc level module on 'Research Skills' with an annual enrolment of 22-40 students. The students taking this course all have an undergraduate degree in Chemical Engineering, Chemistry or similar, however come from institutions across the globe. This lecture course was designed to ensure that they all have the same training to successfully undertake their final research projects. Alongside more traditional skills topics including literature searching and academic writing, research ethics is taught. Ethics was a subject that had not been explicitly taught as part of either undergraduate or postgraduate courses prior to 'Research Skills', instead different aspects had been covered in various modules. 'Research Skills' is fully assessed via coursework (both written and oral), with no examination component. Prior to the conception of this course, any preparation for the MSc research project was presented via traditional didactic lectures or in written texts.

The debate assessments were piloted in the first term of the 2019/2020 academic year. After their success this was continued, despite the pandemic, through the subsequent two academic years. These debates have had remarkable success in both in person, and remote teaching environments.

2.2 Debate Assessments

As previously discussed, debate is an ideal mechanism to assess our students' ability to create strong arguments, a valuable skill for the workplace, and especially for discussing the numerous ethical issues we face as engineers. However, for the majority of students debating is a novel form of communication which they are unlikely to have any significant prior experience of. Hence, we recognised that we would first need to provide the students with debating skills training before we utilised debate in any assessment.

In the pilot year, 2019/2020, bespoke hands-on training workshops were developed, in collaboration with the leading UK debating charity Debate Mate [8], to teach debating skills to the students, as well as providing opportunities for cohort building and increasing student confidence in public speaking. This training included sessions of information transfer from Debate Mate mentors to students (direct teaching), student-led activities, and scenario based applied learning via mini-debates. They therefore developed the students' critical and creative thinking skills for problem solving and encouraged the students to think on their feet and build dynamic arguments. This debate training was vital in improving the communication skills of the students and enhancing their ability to influence others and create impact with their arguments.

The students were then split into small teams for the final assessment, participating in a structured debate on an ethical issue related to science and engineering. The students were given their motion and whether they would be for or against the motion, one week to prior to the assessment for them to adequately prepare background research. An example debate motion is:

"*This house would punish workers who do not blow the whistle on malpractice, corruption or negligence as if they had carried out those acts themselves*."

In the debate, students presented their arguments (and rebutted arguments from the opposing team) using techniques learned in the training sessions. Teams could interrupt each other through requests for 'points of information' (POIs) and questions could be asked by the audience, responses to these had to be integrated into the final speaker's summary. This meant students could not prepare a static speech, but instead needed to reactively adapt their argument as the debate progressed, in order to be more persuasive.

In the assessed debates our students were evaluated on three key areas. Firstly, Style, the extent to which they were communicating clearly, confidently and utilising the persuasive techniques covered in the training sessions. Secondly, Content, the strength of their argumentation and rebuttal in terms of logical construction and analytical sophistication. And thirdly, Strategy, which covered a broad range of criteria including role fulfilment, time management, teamwork and engagement with POI's and questions from the audience where relevant. A representative from Debate Mate with a background in adjudicating competitive debating tournaments moderated the debates and functioned as a second marker.

2.3 Remote Learning

The pilot year was a great success and so the teaching team were highly motivated to continue to develop and optimise debating as an important training and assessment tool for the 2020/2021 academic year. However, in the 2020/21 academic year debates and training were moved online due to the Covid-19 pandemic. All teaching and assessments were undertaken via an online platform (Zoom). Online debate training sessions had very similar content to that of the previous year, ensuring that the vital aspects of communication for leadership were still practiced. For the debates, functionalities of the platform helped to maintain the dynamic and high energy feeling for this highly engaging form of assessment. The whole class was present on the Zoom call, and they were encouraged to use the ‘reactions’ emojis (e.g. applause) to praise or support well-made arguments (in place of in-room applause). Participants could make POIs via the ‘raise hand’ function and the moderator ensured the speaker was aware.

3 RESULTS

3.1 Student Feedback

When implementing a new form of assessment, it is important to evaluate how the students perceived the task and whether they found it useful. Over the past years we have actively gathered feedback from students on how they found the debate assessment. We conducted a non-compulsory anonymous survey asking the students if they believe that the debating had a “positive impact on their learning experience”. The results of this survey for the past three years are shown in figure 1, with all students indicating that they agreed with the statement.

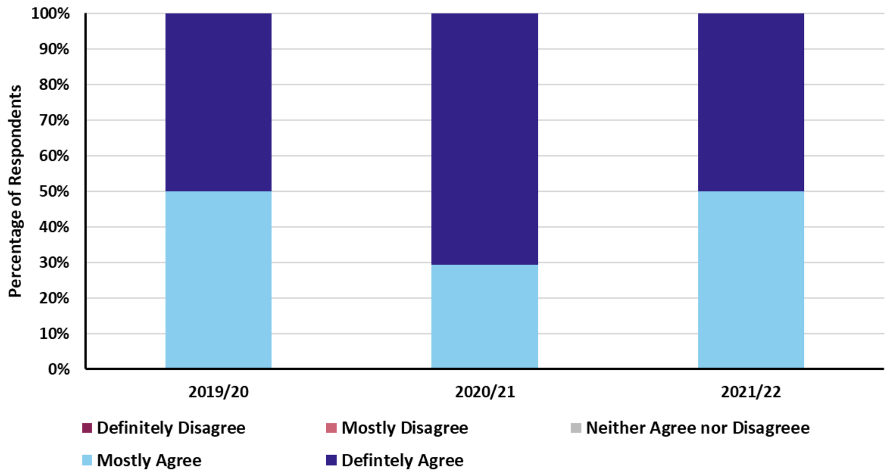

Fig. 1. Number of students surveyed as to whether debating had a “positive impact on their learning experience”

In addition to the survey, we also contacted students from the pilot year, 6 months after they graduated, to gain an insight into how the debating has helped them in their career. They were asked “Do you believe the debate skills you learned at UCL have been helpful for you in your career since your MSc finished? If so please briefly detail how?” All responses received were positive with key comments including:

- “I have now noticed that I am a lot more comfortable presenting to groups in my current graduate scheme”
- “During the interview, some interviewers gave a topic for interviewees to debate and then made a judgment from their performance in debating”

- "It has enhanced my ability to make a point sound convincing"
- "The debate class has improved my communication and presentation skills, in particular it inspired me the method to appropriately respond the challenging questions raised from the investors"

The final way we have received feedback from the students regarding the debates is through the national Postgraduate Taught Experience Survey (PTES). This is a general survey asking about their experience on their MSc, and as such none of the questions specifically focussed on the debates. One of the questions on this survey is "what was the most enjoyable part of the course" and multiple students highlighted the debates here with comments such as "it has improved my oral English and teamwork ability". This clearly shows that the students found the debate activity to be a highlight of their course.

3.2 Staff reflections

Whilst the pilot year was a resounding success, especially in terms of student feedback, the teaching staff discussed their reflections of how the assessment had gone from a pedagogical perspective and made some minor modifications to the way it was run to improve the experience.

The first observation was that whilst the requirement to form a rebuttal of the previous speaker's point and use of POIs meant that there was some element of students creating responsive arguments, it was still felt that this was done superficially, and students had overprepared speeches. In order to discourage this level of detailed preparation in the 2020/21 academic year, the students were given their motion one week before the assessment but were only told which side they were arguing for on the day of the assessment. They were then given 10 minutes to discuss their strategy as a group before the debate started. We saw that the quality of responsive engagement in these debates were much higher than those of the previous year.

The second key observation that we made was that the students were quite tentative about undertaking an assessment that involved such a high level of group work at the beginning of the academic year, when they were not quite comfortable working with each other. To address this we moved the debates from the first academic term to the second. This allowed the students to become more familiar with each other before being presented with a completely new style of assessment. We saw that this was effective as there was a greater interaction from all the students in the debates, with more POIs and more questions from the audience.

4 SUMMARY AND INSIGHTS

The development of this debate-based training and assessment has had several positive outcomes on the students' learning experience and vital skills development. Importantly students found the debates to be both an interesting and enjoyable method of assessment and noted that the skills learned would be useful as they look for jobs (e.g., at assessment centres). This can be attributed to the fact that, compared to typical technical presentations, the students are required to do more thorough research in order to consider both sides of the argument and work convincingly as a cohesive team, rather than a group of individuals, in order to strengthen their overall argument.

Not only were the debates high quality, but the practice of having to fully engage with what others are saying and being able to respond dynamically has enabled the students to improve their communication skills in other aspects of their learning. For example, in a subsequent presentation assessment the quality of the responses to questions was much higher than expected, with students providing well-reasoned responses rather than just rephrasing what has already been said. Students were also much more willing to ask their peers sensible questions, rather than it only being academics asking them.

The success of the pilot and onward implementation of debate training and assessment for MSc students has led the Chemical Engineering Department to begin work to expand this training across the other students across the postgraduate taught and undergraduate cohorts, as it has been seen that the communication skills that the students develop are invaluable for them in their future careers.

4.1 Recommendations

Due to the success of implementing this debate assessment we strongly encourage other engineering education practitioners to implement similar styles of assessment in their own teaching. Having run this assessment for the past three years we provide here a series of recommendations:

1. It is vital that there should be adequate training on how to construct arguments and particularly the structure of a debate as this will likely be completely unfamiliar to the majority of students.
2. How the assessments will be graded should be clearly communicated to the students from the beginning. It is important to be clear that their grades will not be directly related to whether or not their team win the debate, and also that the assigned debate topics are fair and balanced, to ensure that the students on both sides can reasonably be expected to offer strong arguments.
3. Having one student on the team in a non-speaking role helps students with lower confidence, especially those with a different native language. This student will still assist their group with their pre-debate preparation and will still have the opportunity to take an active role in the debate if they wish to offer points of information to the other side.
4. The quality of the arguments being presented is higher if students are only told the side which they are arguing 10 minutes before the debates occur, as this further limits the chances of students presenting pre-prepared speeches.

4.2 Acknowledgements

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Broadening personal competence profiles through transdisciplinary project modules

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ABSTRACT

Engineering education today is often organised in discipline-specific modules. Although it is essential to build up basic knowledge, cross-disciplinary knowledge is fundamental for solving complex problems. Transdisciplinary approaches can provide the necessary hard and soft skills, improve self-determination in education and broaden personal competence profiles.

The experience gained is conveyed using the example of project-based modules on the topics of a) AI applications to minimise racial biasing in medical technology and b) construction of microfluidic systems to avoid animal testing. These were developed over several semesters by interdisciplinary student groups involving industry and research partners. The concept was initially carried out online in an interdisciplinary project module focusing on individual learning objectives, composed of the disciplines "Mechanical Engineering", "Computational Engineering Science", "Physical Engineering Sciences" as well as "Biomedical Engineering" and is being expanded in a hybrid-transdisciplinary manner through gradual additions including systems engineering, philosophy and sustainability in technology, ergonomics and human-machine systems.

Through active participation in researching and solving real challenges, collaboration of transdisciplinary teams over several group generations and setting individual learning goals, profound knowledge and new methodological competences can be acquired beyond engineering disciplines. The integration of non-technical methods and approaches allows students to recognise complex problems and identify the necessary competences in order to realise a successful project. To further expand this approach, a new module concept for interdisciplinary cooperation in production engineering was developed. It takes up the aspects of individual, project-based learning and brings together all the competences of the institute in transdisciplinary exchange.

1 INTRODUCTION

1.1 Current situation

Constant technological change, the increasing acceleration of innovation, and changing work environments are changing the context in which science and teaching take place. However, adaptation to changes can be achieved through tailored teaching and dynamic teamwork. Higher education institutions should prepare students for lifelong learning and social interaction, involving those complex, rapidly changing social and socio-economic team structures. To meet these challenges, appropriate teaching concepts are needed that offer choice and flexibility, promote multi- and interdisciplinary learning, but also teach responsibility, methodological skills and ethical foundations. In an increasingly interconnected world, there is a need to provide the basis for taking global perspectives and experiences that go beyond the learning of engineering disciplines. Being prepared for career and the mixtures of disciplines that come along with it means having the capability of holistic thinking, initiative, self-confidence, creativity, lifelong learning, agility and corresponding methodological competences which should be taught as key components [1].

Transdisciplinary teaching formats represent one approach to this. The greatest challenge at present is to break down the prevailing, discipline-bound specialisation and, thus, fragmentation of thought and action. However, there is still a large gap between the advocacy of cross-disciplinary teaching and reality. Disciplines composed of specialist areas, disconnected modules and methods, each with its own concept of research and learning, have become the fundamental structures of modern universities giving only little space to different formats [2].

In the following, two examples demonstrate how interdisciplinary and transdisciplinary teaching approaches in small project groups of students that have been developed across different generations can look like. The work includes socially relevant problems, with focus on industry involvement.

1.2 Inter- and transdiciplinar teaching approaches: A way to strengthen individual learning goals?

In the 1970s, models have been postulated to promote measures to integrate research across different disciplines and sectors, with intensive collaboration between all participants. Transdisciplinarity has emerged as an approach best suited to enable the integration and implementation of research across disciplines and societal sectors, linking it to intensive participatory processes. Transdisciplinary work in teams is characterised by highly participatory, mixed methods involving science and industry from different disciplines and sectors of society, including those who are expected to benefit from the interventions. These stakeholders are brought into focus from the outset and on an ongoing basis. Although some interdisciplinary and transdisciplinary models overlap, transdisciplinary approaches typically go beyond an interdisciplinary contribution: they involve a transcendent approach, where students create a shared definition of a problem that goes beyond their own disciplines and even create new paradigms and methods for solving real-world problems [3]. For optimal collaboration, a synergistic combination of values, attitudes, skills, knowledge and behaviours must be communicated and taught to students. In particular, values are guiding principles that make team members want to participate, collaborate with others, and become comfortable with unfamiliar theories and methods. Attitudes include a willingness to invest time in learning as well as to adapt individual disciplinary thinking patterns to the demands of teamwork. Behaviours, in turn, include learning activities such as participation in team projects [4].

Further studies reveal what individuals need in order to work together successfully. Research on learning in psychology and education shows three main categories of competencies for successful outcomes: 1. Team knowledge (e.g. task understanding, shared mental models, role knowledge), 2. team skills (e.g. communication, assertiveness, situational awareness), 3. team attitudes (e.g. team orientation, trust, cohesion) [5]. These competences should be aligned with a cross-curricular approach. Furthermore, the approach of solving industry-related, real-life problems in joint teamwork has proven its effectiveness. It offers students the opportunity to experience how interdisciplinary knowledge can be integrated into practice, as well as the ability to challenge themselves to conduct industry-oriented research, giving them access to further postgraduate research.

2 METHODOLOGY: MULTI-GENERATIONAL PROJECTS FOSTERING CROSS-DISCIPLINARY METHODOLOGICAL COMPETENCES

2.1 Project organization procedure

A prerequisite for the interdisciplinary and hence self-determined tracking of individual learning goals is a high level of motivation to participate. For this reason, a broad spectrum of topics is offered, connectivity to current research projects or topics by industrial partners is given, and student co-determination in the setting of tasks is encouraged.

Below the procedure within the project modules is illustrated, adapted on the basis of experience. The currently preferred procedure is shown in Fig.1.

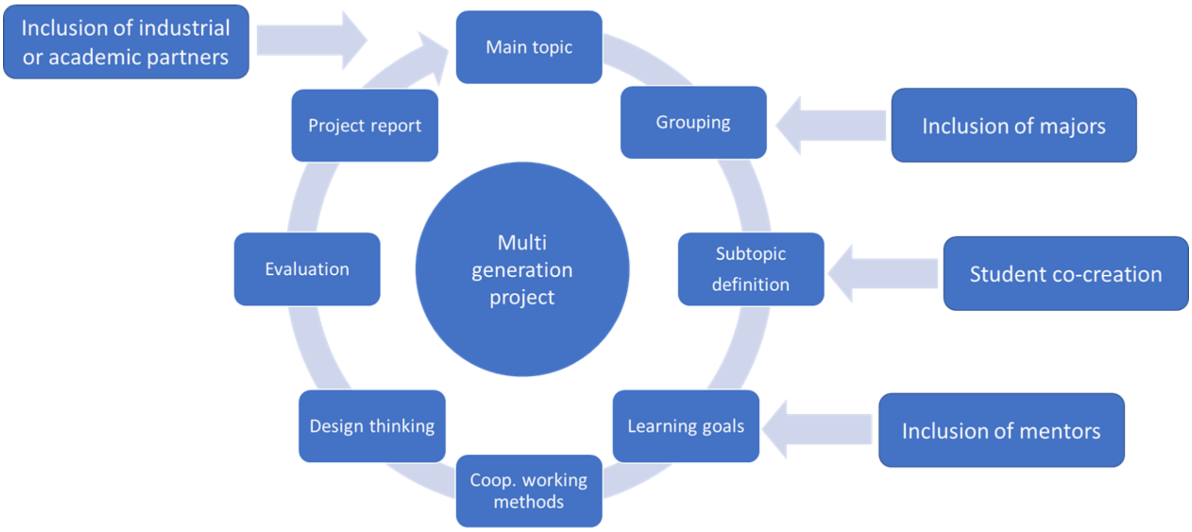

Fig. 1: Currently preferred procedure of the cross-disciplinary project module.

Students are recruited via the ISIS online portal of the TU Berlin. For each main theme, one-minute pitch videos are made available. The topics range from precision engineering, measurement technology, medical technology, micro-assembly, precision machining, micro fluidics, micro-optics, artificial intelligence to teaching topics by and for students. In individual cases, it is also possible for student groups to contribute their own topics. The fundamental requirement is that the task provides socially relevant and practical results that can be further worked on by other groups in subsequent semesters and that the solution requires different subject matter expertise to fulfil a transdisciplinary approach.

Within the limits of possibility, the project is offered to a variance of majors as wide as possible. Involved majors in the past were “Mechanical Engineering”, “Computational Engineering Science”, “Production Engineering”, “Physical Engineering Science”, “Transportation Engineering”, “Biomedical Engineering” and “Patent Engineering”. In the module under way, as well as in a planned expansion, there is involvement of the human factors science, technology assessment, and systems engineering.

On the online portal, students can assign themselves to the respective topic until a predefined group size is reached. The respective group supervisor defines the task in detail in cooperation with the students depending on their abilities, interests and individual learning goals. On this basis the students derive a working plan for the semester.

The following project work is done in regular consultation with the supervisor and progress is evaluated twice during the semester while the evaluation is based on interim presentations. The results of each group will be presented in the presence of the other groups and all supervisors. It is aimed that students actively and critically question their co-students and give hints on possible solutions that can be implemented in the further course. After the second evaluation, the final result is submitted in the form of a project report. This report forms the basis for further developments by subsequent generations of students. Depending on the project being theoretical or practical, the project team additionally presents and explains its results to students from lower semesters taking on a co-teaching part.

2.2 Examples of inter- and transciplinary project modules

The first exemplary student project was originally based on the development of a microfluidic set-up to demonstrate fluidic principles. The system was developed by an interdisciplinary group of students from the fields of biomedical science, production and mechanical engineering being intended to be used by students of lower semesters. The background was to encourage more experienced students to actively participate in preparing and imparting knowledge to other students. Since specific technical subcomponents were necessary for the realisation, industrial contacts to corresponding companies were established through the students' individual contributions. Based on these contacts, further socially relevant research ideas were derived.

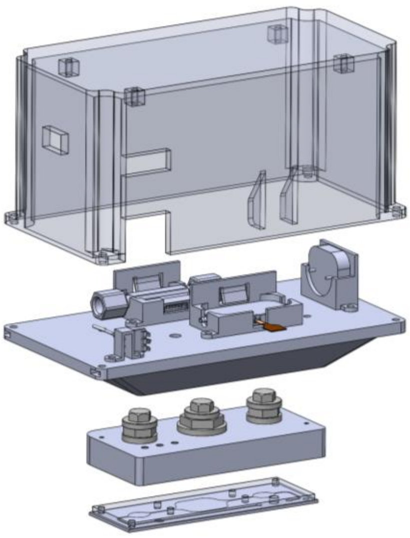

Fig. 2: CAD model of the micro fluidic setup (left) and physical model (right).

The project gave rise to the topic of a multi-organ chip with an integrated heartbeat. Background was to simulate the human body as close to nature as possible with the multi-organ chip, e.g. to determine the influence of drugs or other substances on the body. As part of the transdisciplinary approach, the ethical discussion of the avoidance of animal experiments was a driving motivation for the students. The properties of blood are difficult to reproduce using conventional reference fluids. Thus, experiments with fluids based on a newly developed 2-phase blood by medical and biomedical students of the Charité Berlin in the laboratory for Biofluid Mechanics were conducted. The blood model will further be improved by additional cross-universal investigations of multi-disciplinary groups with similar fluidic systems in the future.

The second project being presented was also developed over several generations of students. In the first iteration, an intelligent spectral measurement system based on low-cost filter sensors was to be built. Students from the fields of computer science and engineering initially collaborated. The students applied basic AI methods to the self-developed electronic system to analyse spectra. On this basis, the possibility of analysing skin pigmentation and vital data analysis was derived by other students' own initiative. The idea was raised to use spectral measurement to actively counteract racial biasing effects in the measurement of vital parameters which still poses a problem in applied systems as well as in consumer products like smart watches.

In addition, to the melanin content as an independent medical parameter, this also acts as a decisive influencing factor for other spectroscopically determined parameters, such as the oxygen content of the blood determined by pulse oximetry. Pulse oximeters are, however, very susceptible to error in heavily pigmented people. This example is frightening when the vital analysis decides on the medical necessity of inpatient or outpatient treatment. These are dramatic examples of racial bias in medicine - the fact that white patients are proportionally more represented in medical studies than people of colour, which leads to a structural disadvantage right from the development phase. This transdisciplinary project idea, thus, should contribute to being able to make statements regarding the melanin content of the skin on the basis of measured values from a non-invasive spectroscopic set-up.

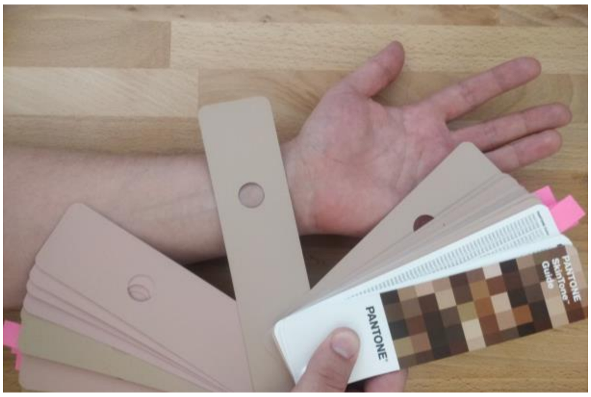

Fig. 3: Measurements of melanin content (left) and comparison with colour charts for the analysis of skin pigmentation (right).

3 RESULTS: LESSONS LEARNED FROM FIRST ITERATIONS

In general, it was observed that the intended motivation for interdisciplinary cooperation, self-determined learning and thematic co-determination could be achieved through the procedure. High-quality results could be derived from this, as well as further final theses, which deepened the students' own learning goal, initiated a self-motivated acquisition of students for subsequent generations by the students themselves and enabled matchmaking with the industry partners.

In the future, however, methodological adjustments will be necessary to promote the achievement of the learning objectives. It was recognized that basic skills for interdisciplinary cooperation are often still lacking and must be taught as part of the project. This is done in the new generation by integrating system engineering approaches. In particular, the continuation of the work over several generations is positively received by the students, as the work carried out forms a basis for future students. In addition, the connection to actual research projects and industry partners leads to an increased appreciation of the results achieved, which is perceived as motivating by students. In the survey mentioned below, students indicated that the interactive and interdisciplinary collaboration increased their motivation and personal and subject-specific development.

The findings formed the basis for several already funded research projects in collaboration with industry, medicine and engineering to address the problem of racial bias and questionable animal testing. The trans-industry and trans-university cooperation, thus, not only offered students the opportunity to gain new knowledge from other, related disciplines, but also enabled the departments to develop long-term research interests. Since its introduction, the module has seen a steady growth in the number of participants. A quantifiable evaluation of the development of the content and the achievement of the learning objectives of the students on the basis of a survey has already being conducted. In an anonymous survey, it became apparent that the students' motivation to learn has decreased due to the pandemic. 50% of the students reported being more demotivated, while 37.5% experienced no change. For the future, the larger proportion of students (61%) would prefer hybrid teaching models to classroom or online teaching. There is a desire to participate more actively with regard to the design of teaching, particularly with a stronger focus on interdisciplinary and socially relevant content. 75% of the participants wish to participate more individually in teaching according to their own learning goals, but currently do not see the capacity to do so in existing teaching concepts (28%). 39% report that they lack the time to pursue their own learning goals in current teaching models. The realisation of these needs through a transdisciplinary, hybrid platform that promotes interaction and individualism corresponds strongly with the initial survey results.

4 DISCUSSION AND FUTURE DIRECTIONS

Implementing transdisciplinary group work requires opening the modules to a range of curricula as wide as possible. In principle, this can be easily implemented with the procedure described. Supervision by several departments to support the individual learning objectives would be useful, but requires adaptation and synchronisation of the curricula as well as improved communication between the departments.

The combination of several disciplines requires a high level of self-motivation, as the high supervision ratio leads to a lower creditable individual teaching performance. The added value arises first and foremost for the students and only secondarily for the departments through better trained students. In addition, the respective disciplines must acquire a good knowledge of the contents of the other disciplines in order to synchronize the offered teaching contents, from which the students can derive their individual teaching paths. Experience shows that this can only be achieved through an intensive exchange of motivated and leading protagonists from the disciplines who actively involve other disciplines and convince them of the added value. In order to promote interdisciplinary and transdisciplinary teaching, administrative conditions must be created that adequately value this teaching performance - the current practice of only partial credit, i.e. proportional distribution between lecturers, sometimes restricts such projects.

The experiences of the ongoing project module will be implemented in a collaborative module of all departments of the Institute for Machine Tools and Factory Management-TU Berlin. The methodology for interdisciplinary collaboration is taught at the beginning of the seminar. In addition to the established evaluation, consultations are held with mentors from all disciplines providing subject-specific tips that are implemented by the respective responsible students according to their own learning goals. Part of the seminar is an initial and a final discussion on technology assessment and sustainability approaches, as well as an initial professionally guided design thinking seminar. In recent semesters, the students have worked together in a mixture of online and face-to-face sessions, which will continue to be used in the future. The creative process and the exchange with mentors and supervisors as well as the evaluation with all students took place online. On site labs, production capacities and a budget were made available for the realization of the project.

As described, the extended transdisciplinary expansion of the project module is an ongoing process. It is planned to expand the spectrum of disciplines in collaboration with other disciplines, also across universities. This will be implemented, in particular, on the basis of the transdisciplinary consortium of the Berlin University Alliance project GlobalRestist. In addition, the human factors science is to be integrated.

Particularly considering the resulting complexity of the disciplines, it is essential that the methodology for collaboration continues to be part of the module in the future. Cross-university collaboration also requires a platform on which transdisciplinary content can be made available and interactive collaboration of different disciplines is made possible online. The materials and technical competencies developed during the pandemic provide an excellent basis for this kind of implementation. The aim here is to create a virtual space that expands the students' individual learning goals to transdisciplinary subject areas by having various disciplines like ethics, gender studies or medicine offer their courses there as basic and in-depth courses.

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EVOLUTION OF GUIDED ACTIVITIES IN THE TEACHING OF ANALOG ELECTRONICS IN BACHELOR'S DEGREE IN INDUSTRIAL AND AUTOMATIC ELECTRONICS TO INCREASE THE STUDENTS' MOTIVATION

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ABSTRACT

Within the offer of core courses of the Bachelor's Degree in Industrial Electronics and Automation Engineering of the Technical University of Catalonia (UPC), which appeared as a result of the current undergraduate study program, within the European Higher Education Area (EHEA), there is a course, Analog Electronics (EAEIA), which allows the Electronic Engineering student to delve into the knowledge of this content. This paper exposes the philosophy of this course, in such a way that it analyzes the orientation that is intended to be given, especially within the new framework of courses offered at the EEBE where, in addition to the hours of lectures and laboratory sessions, there must be room for to the guided activities (GAs) that the current syllabus contemplates.

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1 INTRODUCTION

Despite the indisputable progress and development of electronics and digital systems, it is quite true that analog electronics, and especially that which directly affects the operational amplifier and its applications, is one of the fundamental pillars on which they establish the modern curricula for electronics students in different fields of engineering (industrial, telecommunications, etc.).

Within the offer of core courses of the Bachelor's Degree in Industrial Electronics and Automation Engineering (EIA) of the Eastern Barcelona School of Engineering (EEBE) of the Technical University of Catalonia (UPC), which appeared as a result of the current undergraduate study plan, within the EHEA framework, there is a course, Analog Electronics (EAEIA), which allows the Electronic Engineering student to delve into the knowledge of this content.

In this course's guided activities (GAs), the professor introduces a series of topics to the students (for example, audio amplifiers and equalizers, the control of a small DC motor, etc.). Then, the students, usually in groups of two or three people, work together, cooperatively, according to the puzzle technique, to design, simulate, assemble, solder and test in the laboratory the circuit proposed that fulfills the design specifications.

The current communication exposes the philosophy of this course, in such a way that it analyzes the orientation that is intended to be given, especially within the new framework of courses offered at the EEBE where, in addition to the hours of lectures, problem classes and laboratory sessions, there must be room for to the aforementioned 'guided activities' (GAs) that the current syllabus contemplates.

2 EVOLUTION OF THE TEACHING OF ANALOG ELECTRONICS WITHIN THE BACHELOR'S DEGREE IN INDUSTRIAL ELECTRONICS AT THE EEBE.

The student of Electronic Engineering, within the modern curricula, must not only acquire a solid base in the knowledge of electronics and digital systems for the control of industrial plants in its different fields (microprocessors and microcontrollers, programmable logic devices, automata programmable, etc). Indeed, he must also know those analog electronic systems that will allow him/her, in his subsequent professional career, the acquisition of data or information, the control of systems and industrial plants, and communications in said environments. Under this premise, and within the degree of Engineering in Industrial Electronics and Automation (EIA), offered at the Eastern Barcelona School of Engineering (EEBE) in its study program, in the framework of the European Higher Education Area (EHEA), the courses of the area of Analog Electronics, have a key importance for the training of the future Electronic Engineer [1].

In the now extinct Study Program 72, Analog Electronics was part of a compendium of compulsory courses within the study program that formed the electronic engineer (Industrial Electronics section, within the Electricity specialty). Basically these were two: On the one hand, Basic Electronics, and, on the other, Industrial Electronics.

Once the first year of the Degree with common courses had been passed ('***Linear Algebra***', '***Infinitesimal Calculus***', '***Physics***', '***Chemistry***' and '***Technical Drawing***'), '***Basic Electronics***' was an annual 2nd year compulsory course, formed by a total of 21 credits, simultaneously with '***Circuit Theory and Electrometry***', of 15 credits (Fig. 1). It developed the necessary knowledge that must be addressed in a university course on electronic engineering: Basic electrical laws (Kirchhoff's laws, Thévenin and Norton theorems, etc.), basic discrete components and their application circuits (diodes, transistors bipolar, and field effect transistors), the basic analog systems, around the voltage feedback operational amplifier (VFOA), the basic digital systems (simplification of functions, typical combinational and sequential circuits), and the static power converter structures basic (controlled and uncontrolled rectifiers, and voltage choppers).

In addition, '***Industrial Electronics***' was an annual 3rd year course, made up of a total of 18 credits, and where the horizons of Electronics were broadened in its different fields. In particular, topics related to microprogrammed digital electronics (microprocessors), analog and digital communication techniques, power electronics, and filtering techniques, mainly analog, were discussed.

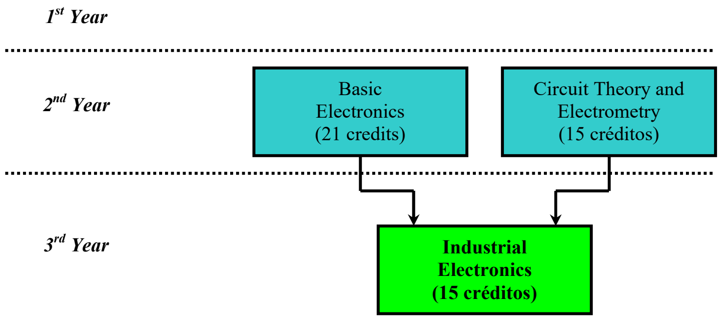

Fig 1. Teaching of electronic systems within Study Program 72 for the specialty of Industrial Electricity (Industrial Electronics section) at the EEBE.

This immense range of topics related to electronic science made that these two courses represent a difficult handicap for the student to overcome. In addition, the main teaching load was focused on lecture blackboard developments and not on practical or laboratory classes, generalizing the idea that, despite the interest aroused by the syllabus of the two courses, the knowledge of electronics taught in it was highly dense.

As a result of the implementation of the Study Program 95, a better rationalization was thought in the teaching of the courses related to Electronics. Indeed, the Electronics student, within an environment of four-month courses, was introduced to the world of Electronics with the compulsory course of 3 credits of the 1st semester '***Introduction to Electrical Circuits***' (Fig. 2.*a*), and '***Electronic Technology – 1***', this one of 6 credits. Once these courses were completed, the student's next encounter with the world of analog electronics was in the 2nd semester of the degree with the 6-credit four-month core course '***Analog Electronic Components and Circuits***', which was combined with the 6-credit courses '***Circuit Theory***' and '***Electronic Technology – 2***', this one of 3 credits. In this course, in addition to studying the basic discrete components and their application circuits (diodes, bipolar transistors, and field effect transistors), an introduction to systems based on operational amplifiers was made. Next, in the 3rd semester, the student faced the course of ‘***Analog and Filtering Techniques***’. In it, the knowledge related to the analog theme was expanded, such as topics related to the analysis and design of analog filters, power amplifier stages, sinusoidal oscillators and PLL (Phase–Locked Loops) systems.

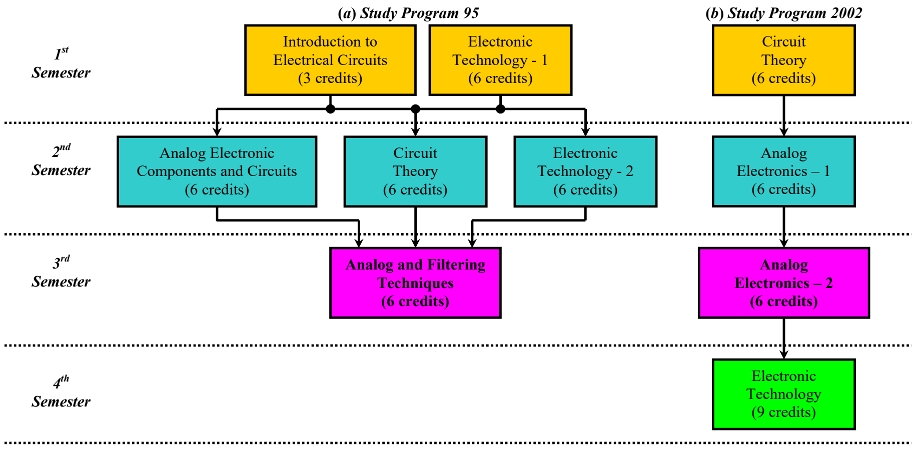

Fig 2. Teaching of analog electronic systems for the specialty of Industrial Electronics at the EEBE. (a) Within the Study Program 95. (b) Within the Study Program 2002.

In 2002, with the revision of the Study Program 95, the new Study Program 2002 was implemented in the old EEBE (the EUETIB), where an attempt was made to correct the most significant anomalies of the existing courses in the different degrees of the School. This revision also affected the courses related to Analog Electronics for the specialty of the Bachelor’s Degree in Electronic Engineering. One of the main anomalies detected in relation to them lay in a certain disorder in terms of the courses taught.

In this regard, and trying to correct this anomaly, in the new 2002 Study Program, the 6-credit compulsory course ‘***Analog Electronics – 1***’ was presented in the 2nd semester, once the course ‘***Circuit Theory***’ had been completed in the 1st semester, also from 6 credits (Fig. 2.*b*). In this course, in addition to delving into the basic laws (Kirchhoff's laws, Thévenin and Norton theorems, etc.), the behavior of passive RLC networks, the basic discrete components (diodes, bipolar transistors, and field effect transistors), as well as their application circuits (rectifiers, power supplies, amplifiers, etc.) were studied.

Once the course ‘*Analog Electronics – 1*’ was passed, in the 3rd semester the student studied the compulsory course, also of 6 credits, ‘***Analog Electronics – 2***’. This was focused on a course around the operational amplifier and its applications in different fields. Due to the course idiosyncrasy, its design was made to be approached from a highly practical point of view. This course was taken simultaneously with other courses of Electronic Engineering such as ‘***Power Electronics***’, ‘***Industrial Informatics***’ and ‘***Electronic Instrumentation***’.

3 CONTEXTUALIZATION OF THE TEACHING OF ANALOGUE ELECTRONICS WITHIN THE DEGREE OF ENGINEERING IN INDUSTRIAL AND AUTOMATIC ELECTRONICS AT THE EEBE.

With the new curricula within the European Higher Education Area (EHEA), the Bachelor's Degree in Engineering in Industrial Electronics and Automation appears in 2009. The course of '***Analog Electronics***', of 6 ECTS credits, is in the 6th semester (6Q) of the degree (see Fig. 3), coexisting with courses related to Analog Electronics such as '***Electronic Instrumentation***' and '***Industrial Informatics***' and other basic training for the electronic engineer, such as '***Power Electronics***' and '***Control Techniques***' [1].

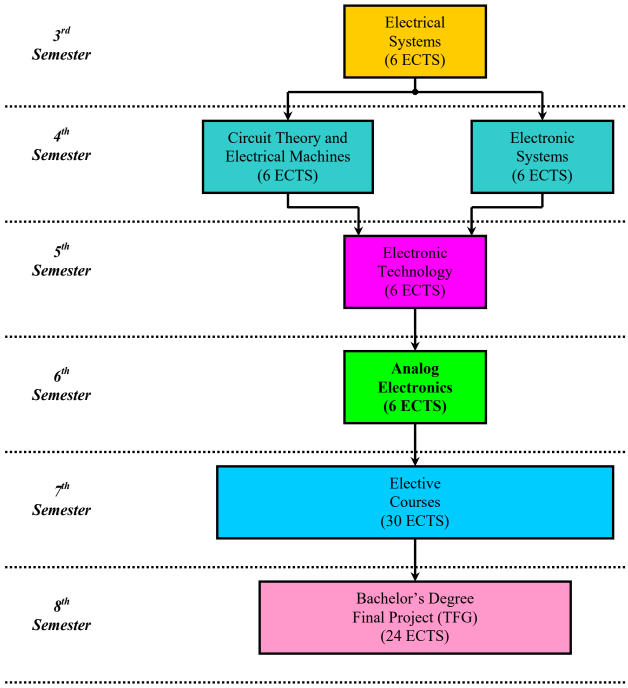

Fig. 3. Teaching of analog electronic systems for the Bachelor's Degree in Industrial Electronics and Automation Engineering at the EEBE within the current study program within the framework of the European Higher Education Area (EHEA).

4 KNOWLEDGE TO BE TEACHED IN THE COURSE 'ANALOG ELECTRONICS' WITHIN THE BACHELOR'S DEGREE IN INDUSTRIAL AND AUTOMATIC ELECTRONICS ENGINEERING AT THE EEBE.

Bearing in mind the idea mentioned in the previous section, the knowledge to be taught in this course has been divided into 5 large blocks, each with its own entity, but which together allow the student to obtain a clear idea of analog based systems based on operational amplifiers. These five blocks or chapters treated in this course are the following (Fig. 4):

1. The operational amplifier working with negative feedback.
2. The operational amplifier working with positive feedback.
3. The real operational amplifier.
4. Sinusoidal oscillators and signal generators.
5. Signal active analog filtering (continuous time and switched capacities).

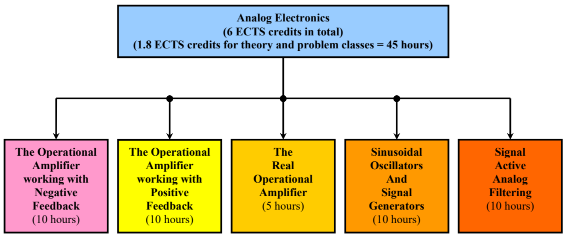

Fig. 4. Thematic distribution of the course 'Analog Electronics'. The indicated hours correspond to those of lectures and problem classes.

5 TEACHING METHOD: THE RIGHT BALANCE BETWEEN LECTURES, PROBLEM CLASSES, LABORATORY SESSIONS AND GUIDED ACTIVITIES.

With the implementation of the current Plan for undergraduate degrees within the EHEA at the EEBE, it is committed that a large part of the courses of the Bachelor's degree, especially those electives that lead the student to follow an intensification within a certain specialty, entail a percentage of credits referring to the so-called 'guided activities' (GAs). In them, it is proposed to carry out different activities (theoretical, practical or information search), in which the professor and student should not coincide in space or time. Of course, the professor tutors, guides and, if necessary, introduces elements of correction of these activities to finally assess them properly. The number of these credits is variable, depending on the course, but it ranges between 10 % and 25 % of the total credits of the course in most of them.

In particular, for the EAEIA course, of the 6 ECTS credits in total that the course has, 2.8 ECTS credits correspond to face-to-face activities in the classroom (70 total hours throughout the entire semester). Of these 2.8 credits, 0.4 ECTS (that is, 14.3 % of the face-to-face activity in the classroom) correspond to guided activities (10 face-to-face hours in the classroom throughout the semester). The other 85.7 % is divided between lectures and problem classes, with 1.8 ECTS credits (45 total hours throughout the semester), and 0.6 ECTS credits for laboratory sessions (15 total hours throughout the semester), always related to the lecture contents presented in the previous sessions of the course (Fig. 5).

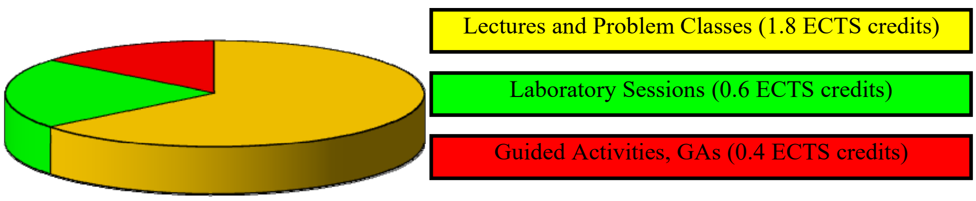

Fig. 5. Percentage distribution of face-to-face hours between lectures and problem classes (62.5 %), laboratory sessions (25 %) and guided activities (12.5 %) of the course 'Analog Electronics'.

This distribution of credits means that three hours of lectures and problem classes are taught weekly, and fortnightly laboratory sessions of two hours throughout the entire semester (considering semesters of fifteen weeks). Thus, there are available about 10 hours per week for each student to carry out the proposed guided activities during the semester.

In the guided activities of the course there is a first part of activities where the student, individually or in pairs, must analyze and simulate different circuits using the OrCAD-PSpice® program.

The second part of the guided activities proposes to the student the physical implementation of a project, using a cooperative work learning technique, in which an analog system is implemented using low-cost electronic circuitry. In effect, the teacher introduces a series of titles to the students (for example, audio amplifiers and equalizers, the control of a small DC motor, etc.) and the students, usually in groups of two or three people, ***work together, cooperatively according to the puzzle technique***. They must design, simulate, assemble, solder and test in the laboratory the circuit proposed by themselves on a test board that fulfills the task specified in the title of the work (Fig. 6).

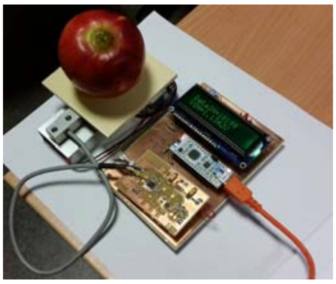

Fig. 6. Example of a prototype implemented in the Analog Electronics course as a part of the guided activities (GAs). In this case, an electronic scale.

In the 10 hours considered face-to-face of the guided activity (GA), the group of students is guided in the classroom by the professor so that the work is developed within the framework marked and scheduled in class. Now, outside the classroom, the group of students must continue working on the project, so that, in addition to the 10 “face-to-face” hours, a series of hours (around 30 more) are contemplated, where the group of students must continue with the guided activity outside the classroom (that is, “not in person”).

It has been seen in the last quarter of the course that the presentation of the prototype in front of the class as a whole is highly positive. The procedure consists of dedicating a few hours to this purpose at the end of the semester, so that for about ten or fifteen minutes the group exposes (we could even say ‘sell’) the design made by them, through the use of some slides. Once this explanation is finished, the rest of the students in the class and the teacher himself can ask the questions they deem appropriate in this regard. The evaluation can be done by the professor himself or even the students themselves can participate, personally issuing a note from the rest of the class groups. The interaction of the groups with the class as a whole, as well as the motivation due to the fact that it is the students themselves who have to defend 'their' design, are high.

6 DISCUSSION AND CONCLUSIONS

Although in general the students start the course with some reluctance regarding its content, it can be said that students’ satisfaction with the course is highly satisfactory. This is an important point despite the ambitious proposed syllabus, which entails an important work of study and assimilation of knowledge by the student, due to the relatively high load of content.

The introduction of software tools is also an important factor to consider. Especially, OrCAD-PSpice® is used for the simulation and analysis of the circuits studied both in the lecture and problem sessions as well as in the laboratory classes. However, the doors are left open for the use of different computer programs for specific course matters. This is the case, for example, of analog filters, where tools such as FilterPro, FilterLab or Filter Wiz PRO are incorporated for the synthesis of analog filters, without having to use the commonly cumbersome analytical methods or using tables for this purpose.

Regarding the guided activity (GA), and despite the considerable number of hours involved in making an electronic prototype that performs a certain task, practically all the students consider that it provides direct contact with the electronics laboratory and with the assembly, soldering and implementation of circuits, essential for future Electronic Engineers. The personal satisfaction of each of the members that make up the work groups is more than satisfied when they manage to make the prototype designed and implemented by themselves work.

With regard to what is indicated in the preceding paragraph, it should be noted and emphasized that, despite the fact that students dedicate 10 ‘face-to-face’ hours per semester to the GA, at home they dedicate a considerably greater number, in order to carry out the guided activity successfully.

As we have commented previously, let us think that these hours of “non-contact” activity of the GA outside the classroom are considered in the ECTS credits of the course. Specifically, of the 6 ECTS credits of the course, only 2.8 ECTS credits correspond to face-to-face activities in the classroom (70 total hours throughout the semester). As we have also previously mentioned, of these 2.8 credits, 0.4 ECTS correspond to guided activities (10 face-to-face hours in the classroom throughout the semester); 1.8 ECTS correspond to lectures and problem classes (45 total hours throughout the semester); and 0.6 ECTS credits for laboratory practices (15 total hours throughout the semester). The other 3.2 ECTS credits correspond to 80 hours of activity outside the classroom, divided between the study of the lecture material of the course, preparation of reports and previous laboratory questions, and the continuation of the guided activities.

Despite this workload for the student, the number of passes is highly satisfactory, thanks in large part to the completion of these guided activities. In the last calls of the course, the percentage of students approved in the course is around 75 % – 85 % of the total number of students enrolled.

Finally, it should be noted that the fact of carrying out the guided activities in groups entails putting into practice one of the objectives of the course and, in general, of all the courses of the Degree curriculum put into operation at the EEBE: Personal and student motivation for group work and cooperativism in learning.

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PBL ACTIVITY AS LINK ELEMENT IN THE BACHELOR'S DEGREE IN INDUSTRIAL ELECTRONICS AND AUTOMATION ENGINEERING

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Keywords: *project-based learning (PBL), Guided Activities, Student Engagement, Courses Coordination.*

ABSTRACT

This paper describes the experience carried out within the Bachelor's Degree in Industrial Electronics and Automation Engineering taught at the Eastern Barcelona School of Engineering (EEBE) of the Technical University of Catalonia–BarcelonaTech (UPC). Specifically, the experience is based on the realization of a cross project that is under the framework of the degree intensification named *Application Design in Electronics Engineering* (ADEE). This intensification, consisting of a block of two courses, taught in the Fall and Spring semesters, and offered for students in their final year, allows the fulfillment, for two semesters, of the aforementioned project. This includes the design, simulation, implementation (assembly), testing and experimental results (corroboration) of an electronic system or equipment within the field of Electronic Engineering.

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1 INTRODUCTION

As is well known, technical studies, especially those concerning engineering, require a highly recommended (and, indeed, almost necessary) practical aspect. It serves not only as main key from a practical point of view of this typology of University degrees, but also it can be used as a motivational tool to current students and future engineers. The idea of cooperative learning-based activity that is shown in this paper started as a result of the detection by course professors of a lack of students' motivation and academic level and ability the Bachelor's Degree in Industrial Electronics and Automation Eng. In particular, this degree, which started in September 2009, was launched along with the Bologna Process. It is offered at the Eastern Barcelona School of Engineering (EEBE) of the Technical University of Catalonia (UPC) in the European Higher Education Area (EHEA) framework.

This lack of students' motivation, stimulation, encouragement, academic level and ability was not only detected at first level courses, where sometimes the motivation is limited due to the large number of common courses to be taken, but also (and worse) in students that are finishing their studies in Industrial Electronics and Automation Engineering and courses related to their own specialty.

The detection of this problem led to Professors of elective courses (taught in 4th year) of this Bachelor's Degree to implement an experience object of this article. This experience covers the fourth last-year course of the aforementioned degree intensification, named *Application Design in Electronic Engineering* (ADEE), which has the current degree. Indeed, these low expectations have led professors of these intensification elective courses to carry out different activities in recent years, including those related to cooperative learning and project-based learning (PBL). These activities could motivate alumni and make them interested in the contents of the mentioned courses, including those of the aforementioned ADEE intensification.

2 GUIDED ACTIVITY (GA) AT THE EASTERN BARCELONA COLLEGE OF INDUSTRIAL ENGINEERING (EEBE)

At the EEBE, current curricula courses are divided into 6 ECTS biannual courses, except for some very particular courses. As a consequence, a 6 ECTS course, especially those that are part of the degree specialty (core or elective), has their structure divided into the following four blocks:

- 1.2 ECTS credits for lectures (corresponding to 2 h/week).
- 0.6 ECTS credits for classes concerning problems (corresponding to 1 h/week).
- 0.6 ECTS credits for laboratory sessions (also corresponding to 1 h/week, but grouped into fortnightly sessions of 2 h).
- 3.6 ECTS credits of non-presential off-site (NP, or non-classroom) activities, and guided activities (GA) (corresponding to 6 h/week).

It can be seen that good workload involved in a particular course, and that students must perform throughout the semester, is framed within 3.6 ECTS credits for non-presential off-site activities (NP), and guided activities (GA). In general, in these credits, course students must perform activities, tasks, works, etc., relating, among others, to the following points:

- Making activities, problems, etc., concerning topics explicitly explained or not by course professors in lectures, problems and/or laboratory session.
- Research, development and/or preparation of activities by students of some topics that are not explained in lectures by course professors.
- Writing laboratory reports.
- Implementation of physical prototypes of electronic circuits, systems or equipment within the field of industrial engineering that is being considered in the course throughout the semester.

Concerning undergraduate studies in Industrial Electronics and Automation Engineering, within this workload of guided activities, special emphasis is focused on the design, simulation, physical implementation and laboratory test of a prototype electronic circuit, system or equipment. Indeed, all this process involves different stages which refer to all the actual process of developing electronic systems or equipment in an industrial or professional environment that students will encounter in a near future in their professional career:

- Design of the different single blocks of the electronic circuit, system or equipment to be carried out.
- Simulation of the aforementioned blocks individually, and simulation of the complete set when they are interconnected.
- Physical implementation of the aforementioned individual blocks that form the system that should be implemented.
- Testing of these individual blocks and experimental corroboration of their operation.
- Assembly and installation of the blocks in order to obtain the complete system or equipment.
- Test, experimental corroboration and obtainment of experimental results of the complete system or equipment carried out.
- Creation of a technical report covering the entire process carried out, simulation results, experimental measures, cost estimation, etc.
- Oral dissertation, within a limited time, of the carried out cross project.

3 COURSES RELATED TO ELECTRONIC SYSTEMS IN THE BACHELOR'S DEGREE IN INDUSTRIAL ELECTRONICS AND AUTOMATION ENGINEERING AT THE EEBE

Within the Bachelor's Degree in Industrial Electronics and Automation Engineering at the EEBE, courses that refer to the study of electronic systems are shown in Fig. 1. Bachelor’s students begin in the Electronic Engineering area in the 3rd semester. In the 6th semester, the degree continues, among other subjects, with Analog Electronics, which allows delving, as similar to the previous one in the digital area, in this case into the analysis and design of analog electronic circuits, mainly based on the operational amplifier. Once passed this semester, in the 7th semester, students enter the phase of elective courses, in which they should choose five 6-ECTS subjects (the current curriculum includes a total of 30 ECTS credits for elective courses). Finally, for undergraduate student, the Bachelor's Degree in Industrial Electronics and Automation Engineering at the EEBE ends with the development of the Bachelor's Thesis (BT) during the 8th semester.

This paper focuses on one core (compulsory) course and one elective courses shown in Fig. 1: ***Analog Electronics*** (EA-EIA), and ***Implementation of Arduino-Based Acquisition Systems*** (ISABA). However, it is also important to highlight that each of the two courses are considered «self-contained». Therefore, the order in which students can take them is not significantly important.

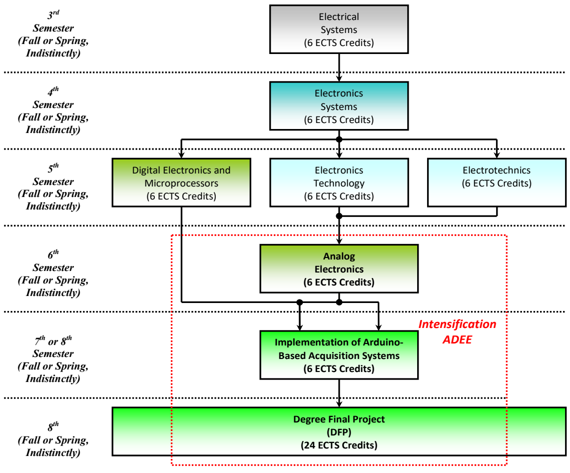

Fig. 1. Map of courses in the field of Electronic Engineering and degree intensification Application Design in Electronic Engineering (ADEE) for the current curriculum of the Bachelor's Degree in Industrial Electronics and Automation Engineering taught at the EEBE.

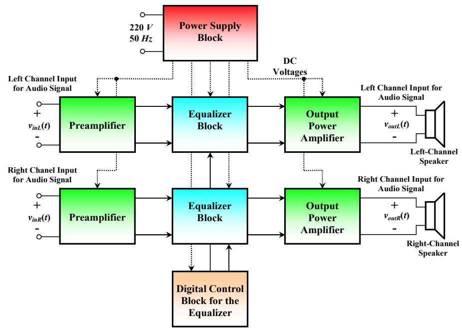

Fig. 2. Overall block diagram of the equipment to carry out in the cross project.

4 EXPERIENCE CARRIED OUT IN COURSES UNDER STUDY

As already mentioned, the idea of cooperative learning activity that is set out in this paper starts when low academic results are observed by degree staff since the introduction of the current curriculum level in September 2016. These course students' low academic results worry and even alarm lecturers, especially because they are in core courses of the Bachelor's Degree, just before ISABA course. Moreover, in recent years, these low expectations have led professors of different elective courses in Electronics area, to consider different activities, including those related to cooperative learning and project-based learning (PBL) to motivate alumni and make them interested in the contents of the mentioned courses, including the subjects included in the aforementioned intensification ADEE.

This paper focuses on what the authors have called "***cross project***" as part of the GA activity. This cross project is included in the two courses previously mentioned (and, obviously, their materials) that define such intensification. To carry out this cross project, it is required that mind-preferred (although not essential), undergraduate students enroll in these two 6-ECTS courses; compulsory course (EA-EIA) in the Fall semester, and the elective course (ISABA) in the Spring. Thus, they can obtain 6 ECTS credits of a total amount of 30 ECTS required to complete their Bachelor's Degree. The activity focuses on the development (which includes the design, simulation, implementation, testing and experimental corroboration) of an audio equipment based on the following five blocks (Fig. 2): Audio equalizer stage, audio preamplifier stage, audio power amplifier stage, digital control module for the equalizer stage and power supply subsystem.

In particular, focusing on the experience on which this paper deals, the activity under study mentioned before consisted of all the process (design, simulation, implementation, testing and experimental corroboration) conducted. To do this, this is carried out in face-to-face sessions, where lecture (2 hours/week) and problem (1 hour/week) sessions are merged in a single 3-hour weekly session. Thus, the cross project is divided into the two semesters (Fall and Spring) mentioned above.

5 PART I OF THE EXPERIENCE CARRIED OUT (COURSES IN FALL SEMESTER)

As a first step in the realization of the cross project during the Fall semester, advanced the course ***Analog Electronics*** (EA-EIA), detailed guidelines (that is, design specifications) of said equipment are presented in class (required output power, frequency bands working, input and output impedances, etc.). From these specifications, and from week 10 of the course (remember that the academic semester includes 15 weeks), in parallel with the progress of this first course, students also advance in the design of part of the different blocks that constitute the system. In particular:

- The design, simulation, assembly, testing and experimental corroboration of the equalizer stage. This process includes the design and calculation, simulation (by means of OrCAD-PSpice®), etc., of the different cells that form the required equalizer.
- The same process for the preamplifier stage is performed. This serves as a support for the student to do the transistor level simulation of such blocks based on the initial design specifications (simulation of the operational amplifier used in different sub-blocks, simulating the preamplifier stage performed around this operational amplifier, etc.). In addition, the student implement theoretical knowledge explained in theory classes.

During the final five sessions of the course, they (considering 3-hour classes) were divided into different parts:

- The first session (that never exceeds 50-55 minutes) has been devoted to explaining (through lecture) those theoretical contents that the course professor must develop so that students can delve into the different topics required for the proper development of the cross project. Students, in this first hour, had a passive role, listening and note-taking or, where appropriate, monitoring the corresponding transparencies previously delivered to them.

- Then, in the next two hours of the session, students, in groups of three, worked on the stages design, simulation or/and assembly directly linked with the theoretical stage explained by the professor in the 1st hour of the session.

In general, the time available in the last five weeks of the course is insufficient to carry out all the process design in class. However, it is important to highlight that this cross project is framed within the non-attendance of the course workload. Therefore, course students should continue working in it outside the classroom, as part of the 3.6 ECTS credits that correspond to non-presential off-site activities and guided activities (corresponding to 6 h/week) referred to both courses. This Fall course ends with two full prototypes developed by the working group (Fig. 3):

- First, the design, simulation, implementation, and testing of the experimental audio equalizer stage.
- In addition, the design, simulation, implementation, and testing of experimental preamplifier stage.

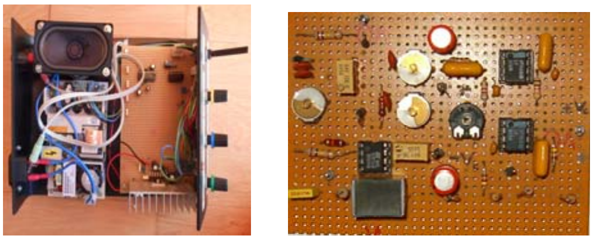

Fig. 3. Examples of different prototypes of some of the partial blocks implemented by students.

In addition, depending on the number of students enrolled in the course, some semester, course professors have also opted for a 15-minute oral presentation. With this presentation, every group can present the work they carried out to course professors, and their classmates.

The project ends this semester transiently with a numerical score which is incorporated into the course EA-EIA of this semester. The weight of this part in both courses is 30% of the total.

Note that each block of the implementation could be self-contained (an amplifier stage, for example, is already a system that allows to be used in many applications). However, the student should keep the key idea that this block is part of a more complete system, whose objective goes beyond that one of these single courses. Notice that here, the idea of globalization, content integration and course coordination are key.

6 PART II OF THE CARRIED OUT EXPERIENCE (COURSES IN SPRING SEMESTER)

In this case, the courses where it continues with the realization of the cross project consist of the elective course of the ADEE intensification taught in the Spring semester: ***Implementation of Arduino-Based Acquisition Systems*** (ISABA).

The mechanism, procedure and routine of the courses are similar to the first one taught in the Fall semester: In the first sessions of each course, the cross project remains stopped, and theoretical and practical elements and contents of both courses evolve. Then, from week 10 on, approximately, students pick up the project with the realization of the missing blocks to complete the overall system:

- The design, simulation and assembly of the digital control stage for tuning the audio equalizer is performed. It serves as support for the student to perform the design, simulation and implementation of control system for the equalizer stage implemented in the previous semester.

- The design, simulation and assembly of the power amplifier stage, and the power supply subsystem of all equipment is made. It serves as support for the student to perform the design, simulation and implementation of the power amplifier stage and power supply that provides power for the entire equipment.

Thus, when optional ISABA course ends, in a similar way that in the compulsory course EA-EIA, with two full prototypes made by the working group:

- On the one, the design, simulation, implementation and test stage of a digital control sub-block for the audio equalizer, developed in the course EA-EIA.
- In addition, the design, simulation, implementation and testing of the power amplifier stage and power supply subsystem carried out in the course EA-EIA.

7 PART III OF THE CARRIED OUT EXPERIENCE (COURSES IN SPRING SEMESTER)

Completed the two semesters (Fall and Spring) and, therefore, having made the student group's cross project framed in the two courses under study (EA-EIA, and ISABA), finally, to overcome the activity and finish it, the students' groups must:

- Assemble the different circuit blocks that make up the complete prototype of the overall project.
- Test of the global equipment in the course laboratory, taking appropriate experimental measurements of the whole, corroborating the proper functioning of the whole system.
- Submit a technical report that highlights everything done in relation to the cross project along the four courses (detailed explanation of the project, process design, simulation and experimental results, etc.).
- Present the project to the group of professors of the four courses as well as the set of classmates.

The project ends with a numerical score. This mark is incorporated into the ISABA course. The weight of this part in the subject is 60% of the total.

8 EVALUATION AND CONCLUSIONS OF THE CARRIED OUT EXPERIENCE

Regardless of qualifications, to assess the activity, information reported by the ‘affected’ people (i.e., course students) was used. It is important to highlight, after several detailed talks subsequent to the presentation and defense of the cross project, the good reception of the experience by students. For the article authors, this aspect is very important, even though, in some groups, results and marks were not fully satisfactory (marks below 7 on a total of 10 points).

For most students, it was not the first time that they performed an evaluation experience of this kind. In fact, in different core courses exposed in Fig. 1 (e.g., Analog Electronics), a part of the course includes the design, simulation, implementation, and experimental corroboration of the operation for a more limited circuit. In them, the goal is that the circuit has a well defined purpose, within the scope of the course itself, but its magnitude is generally dimensioned so that the same dedication from the student is limited. In this case, however, the cross project has a much larger dimension. In addition, it is contained in different courses that, although they are in the same area, they deal with different topics within the field of Electronic Engineering.

However, despite the difficulty and great dedication that students said in their opinion of the course, they expressed a number of strengths of the activity. From these collected opinions, three should be emphasized:

- For students, the proposal of the cross project resembles projects that would take place in a company by a group of engineers. This put the involved courses, and their contents (and, of course, especially, the degree) closer to the imminent actual professional world for these students.
- The *cross project* removes the «tightness» that currently have many courses taught in Spanish University. Our undergraduate students often see the degree courses as separate from other courses. This separation is perceived not only for courses in different semesters, but even for courses taught simultaneously in the same semester. They find it difficult to integrate and globalize different degree courses (core or not) in a common framework of the degree. According to students, the cross project largely eliminates this sealing. As mentioned here before, the idea of globalization, content integration and coordination in the cross project is key point.
- It allows students to focus their Bachelor's Thesis (BT) on a topic close to the cross project or close to contents of the courses included in the intensification that serves as framework for the transversal project. This idea is also a key point to many students who are intensifying as a way to focus their careers in a certain area within the wide field of Electronic Engineering.

Finally, as future research by part of the coauthors of this study, we want to make a series of progressive improvements in the carried out procedure, which involves the following points:

- Mount the cross project as a learning system based on project-based learning (PBL) by technical puzzle. This will imply considering a greater time commitment within the course to carry out the project (sessions will be needed to make the expert meetings, to take time for explanation of an expert to the other members forming the group, etc.). However, in the article authors' opinion, it will result in an improvement from the point of view of learning.
- Conduct a peer assessment set by the students enrolled in the course. Until now, assessment has been carry out by the course professors involved in the project. It is not excluded, however, that part of the final grade of the cross project is carried out by course students themselves.
- Open the project presentation to students of previous semesters, in order to see what advanced students of the same degree have done. This would undoubtedly incentive and motivate these students less advanced, who would firsthand see the «applicability» of their Bachelor's Degree.

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FIRST RESULTS OF COMPUTERIZED ADAPTIVE TESTING FOR AN ONLINE PHYSICS TEST

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ABSTRACT

Tests are an essential tool to assess students' ability. In online education these tests are mostly of static nature with the same items for each student. In contrast computerized adaptive testing concepts take into account the information about the test user automatically collected in an online test. The aim is a comparably precise test result with fewer test items (questions). An implementation of such a computerized adaptive test (CAT) is presented here. The adaptation process is based on the precise knowledge of the item parameters, e.g. difficulty, in the item pool. An estimation of the knowledge level of the test user has to be performed in real time after each answer. With this information the next item can be selected accordingly. This leads to a highly individualized test for each test user. For all items the parameters were determined with methods of the item response theory (IRT) in the framework of the probabilistic test theory. For that real test results of former first year students in engineering science had been analyzed. The prototype of such a CAT has been developed. It focusses on a physics test for prospective students in the STEM fields. In fall 2021 the pilot phase was conducted with first year students in engineering science. The CAT shows that the same precision can be achieved with a mean of 9.3 items compared to 12 in the static test. The acceptance among the students is high. The correlation between the static test and the CAT is satisfactory.

1 INTRODUCTION

1.1 Starting Point

At the transition from school to university the knowledge level of prospective students in STEM – which stands for the academic disciplines "science, technology, engineering and mathematics" – is very heterogenous. In Germany about one-third of all STEM students (one in two in mathematics) drop out of university or change the subject before graduation [1]. The lack of basic knowledge is one of the most important reasons for dropouts. As one of the primary goals of current German education policy is to increase the number of graduates in the STEM fields, not only the number of beginners has to be increased but also the number of dropouts has to be reduced. As the first year at university is crucial, support offers should start as early as possible guaranteeing a smooth start.

1.2 The Project MINTFIT Hamburg

In 2014 the project "MINTFIT Hamburg" [2, 3] started to give support with a free-of-charge online service. The MINTFIT platform aims at prospective students who are interested in independently reviewing their knowledge in mathematics, physics, chemistry and computer science. One can check if the current level of knowledge fits the basic requirements of a STEM study in Germany and at the same time receive information about which gaps need to be filled. MINTFIT focuses specifically on the transition from school to higher education, since there are good opportunities to identify and fill knowledge gaps before problems occur in the first year. Within the MINTFIT learning platform an online test is always the starting point. That far all tests have a static character. For three tests (physics, chemistry and computer science) the questions do not have any variation whereas the math test randomly chooses questions from an item pool or varies values within one test item.

1.3 The Static MINTFIT Physics Test

For the CAT development, described in the following, the physics test was chosen from all MINTFIT tests. The static MINTFIT physics test, that is the current standard, consists of 40 basic test items in the subdomains mechanics, electricity, energy, and optics. While the contents correspond to the intermediate school level, the (re)presentation as well as the mathematical methods (e.g. vector analysis or integral calculus) are oriented to the university level and serve therefore as a well fitted preparation for higher education.

Based on the main topics and subtopics in school about 200 items had been developed. Different question types are used: multiple choice, drop down menu, cloze, short answer, and algebraic questions. For the final test 40 out of these 200 items have been selected to accommodate the test total length to about 60 minutes. The selection was done in several iterations. The items were tested in target-group schools and with first-year students. The final test has been adjusted to allow an optimal assessment of the level of knowledge as well as to offer suitable learning recommendations.

For the comparison to the CAT development described in the following only the mechanics part of the static test was used.

1.4 Alternative Test Ideas for the MINTFIT Physics Test

As the physics test is voluntary, the duration time of 60 minutes is quite long and seems to be one of the reasons for the high dropout rate. It shows up that only one third of the started tests are finished regularly. In about 20 % of the finished tests users stop answering after the first 10 out of 40 questions. The aim for a new test type is therefore to significantly reduce the number of questions or the test duration while maintaining the quality of competence assessment at the same time. To accomplish this, MINTFIT experiments with so called computerized adaptive testing methods [4]. This approach resembles more an oral than a written exam and is related to the expectation to achieve a better or equivalent assessment of participants' competences with fewer questions.

2 METHODOLOGY COMPUTERIZED ADAPTIVE TESTING

Computerized adaptive testing (CAT) is a form of testing, where the next administered question (item) depends on the answer of the already administered items. If, for example, a student answers an item correctly, the next item could be more difficult. Here CAT is used within the framework of the item response theory (IRT) [5]. More precisely the Rasch model [6] is used. The Rasch model defines every item with a single parameter, the difficulty b, and also every student with a single parameter, the ability θ. The probability of answering an item correctly is then determined by:

$$P(x = 1|\theta) = \frac{\exp(\theta - \mathrm{b})}{1 + \exp(\theta - \mathrm{b})} \tag{1}$$

One of the advantages of this model is, that ability and difficulty are measured on the same scale and can therefore be compared. Note that in this model, if a person has the same ability as an item's difficulty, the probability of solving this item is only 50%. The maximum of the slope is at exact this point, where θ and b are equal. The slope is of special interest. The higher the slope is, the better an item can differentiate at this point between higher ability and lower ability students. To make this point clearer, imagine an item with difficulty 0, and four students with abilities of -0.5, 0.5, 1.5, and 2.5. The Rasch model then yields the following probabilities of solving the item: 0.38, 0.62, 0.82 and 0.92. See how the differences between the students shrink: From 0.24 between the first two students, to 0.1 between the last two students. It can be seen therefore, that the most information can be gained from an item, when the student has the same ability as the item difficulty. CAT tries to make the most efficient test by re-estimating the student's ability after every answer and presenting the best fitting item. There are different stopping criteria possible. A stopping criterion that relies on the precision of the measurement is used. This means, the test ends as soon as a certain precision is reached and a statement about the student's ability can be made with sufficient certainty. The precision of a test is also called the test information. It is defined as the sum of the item information. The item information for an item i is defined as the product of the probability of solving the item (p_i) and the probability of not solving the item (q_i). The standard error of estimation SE is then defined as the square root of the inverse of the test information, or as a formula:

$$SE = \frac{1}{\sqrt{\sum p_i q_i}} \tag{2}$$

As many people are more familiar with the term standard error, it will be used throughout this paper. Note, that the Rasch model is a rather simple model. More complex models, like the 2PL model [5], describe an item not just with a difficulty parameter b, but with a second parameter a that has an influence on the slope. This parameter is called the discrimination parameter. The Rasch model can be seen as a special case of the 2 PL model, where the discrimination parameter is fixed to 1 for every item.

3 CAT PROTOTYPE

3.1 Concept

For the CAT prototype an algorithm is implemented that is based on the 2 PL model considering the difficulty and the discrimination parameter for every item. For the pilot phase described here the discrimination power of all items was set to 1. This is equivalent to using the Rasch model.

Initially, a test user's ability is estimated with the value 0. A new question is always added to the test based on the current estimate. For the selection of the next question the item information of all unanswered questions is calculated. One of the questions with (almost) maximum (> 99% of the maximum value) item information is randomly chosen next. Questions are excluded from which it can already be predicted with a probability of 95% or more whether they will be answered correctly or incorrectly.
Always after a question has been answered, an estimate of the ability is calculated for the respective test user and the standard error is determined. For this purpose, the highest maximum a-posteriori probability is taken. This is done by multiplying the discrete standard normal distribution between the minimum and maximum possible ability (-3 and 3) by the respective probabilities that a person with that ability answers the question in that way. The maximum value is the estimated ability. The algorithm terminates if, after answering a question, the standard error falls below the specified threshold. The determined ability after the last question gives the score for the whole test. For better understanding and consistency with the other MINTFIT tests, this value is converted into a scale from 0 to 3 stars and is given as feedback to the test user.

3.2 Realisation

The adaptive test is implemented as a Moodle plugin [7]. The implemented plugin borrows some ideas from a publicly available Moodle plugin for adaptive tests [8], but is not based on that, as a more general approach is used for the ability estimate and the selection of the questions.

A test can be configured with multiple subdomains, but in our test run the CAT was limited to mechanics. For each subdomain a question pool must be specified and a minimum number of questions has to be configured. Each question in the question pool needs a corresponding question difficulty and discrimination power (here set to 1), which are specified using tags in Moodle. The termination threshold for the standard error has to be specified and a maximum number of questions is also set as an alternative termination criterion for the entire test.

From a test user's point of view, the CAT has the appearance of a regular Moodle test. Due to the adaptive concept, the questions have to be answered in the given order and it is not visible in advance how many questions the test will contain.

3.3 Question Parameters

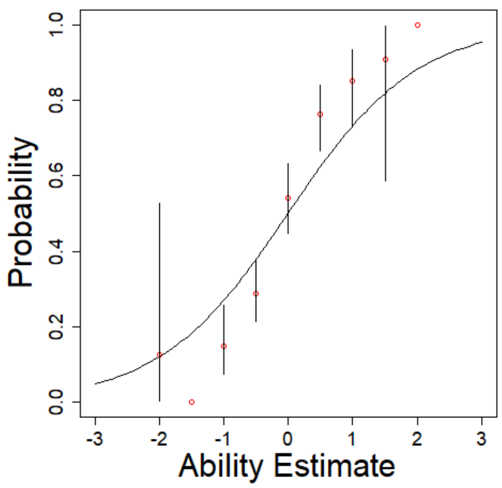

Fig. 1. Excellent fit to Rasch model

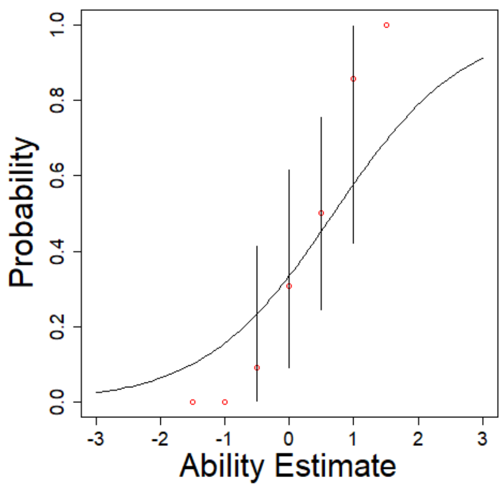

Fig. 2. Acceptable fit to Rasch model

As described above, for the physics test an item pool of 200 items had been developed. To determine the parameters as e.g. difficulty all items were investigated in the winter term 17/18 in a pretest with approx. 350 first-year students at the Hamburg University of Technology (TUHH) and the Universität Hamburg (UHH). The items were split into 8 test sets. 12 so-called anchor items (3 from each subdomain) were included in each test. Afterwards an IRT analysis of the items was performed. As the number of given answers for some items was quite limited the fit of the 2 PL model did not satisfactorily converge. Therefore, the discrimination power was fixed to 1 for all items and the fit was performed within the framework of the Rasch model. An important quality criterion for the procedure is the empiric match between data and Rasch model. Two examples of the model agreement after the fit are shown in figures 1 and 2.

From the complete question pool 72 questions are in the mechanics subdomain and have been used in the CAT.

4 PILOT PHASE

The test setup for the pilot phase consisted of two tests, the mechanics part of the static MINTFIT physics test and the new CAT. Two questionnaires, one after each test, evaluate the respective tests. Also, in the second questionnaire personal information of the test user is included, e.g. the final grades in math and physics before university as these had been identified as important predictors for academic success [1, 9]. The idea is that each test user starts with the static test followed by the first questionnaire. Next is the CAT followed by the second questionnaire (see figure 3). The test feedback and example solutions for the CAT are given right after the test whereas the feedback of the static test is only available after the whole procedure not to give any support for solving the questions in the IRT-CAT test.

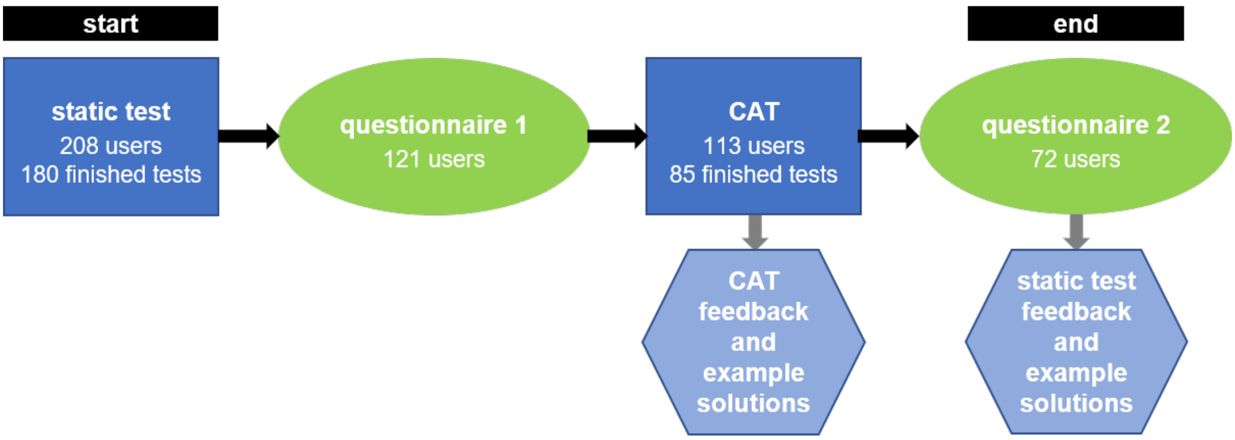

Fig. 3. Overview of test setup

In November 2021, 208 first year students in engineering science took part in the pilot phase. The students worked individually during a 90 minutes presence exercise session that complements the module in mechanics.

Out of the 208 test users that started the static test, 85 users got a converging result for the CAT. Finally, 72 test users also filled in the two questionnaires and thus completed all 4 stages.

To get an impression on how the IRT-CAT-test works in practice for a single user the development of the difficulty of the questions and the estimate of the personal ability and confidence intervals are shown in figure 4.

The items of the static test were not excluded from the item pool for the CAT. 70 % of the converged CAT runs had no overlap at all and 29 % of the tests had one question from the static test included in the CAT. This has no impact on the analysis and will be neglected in the following.

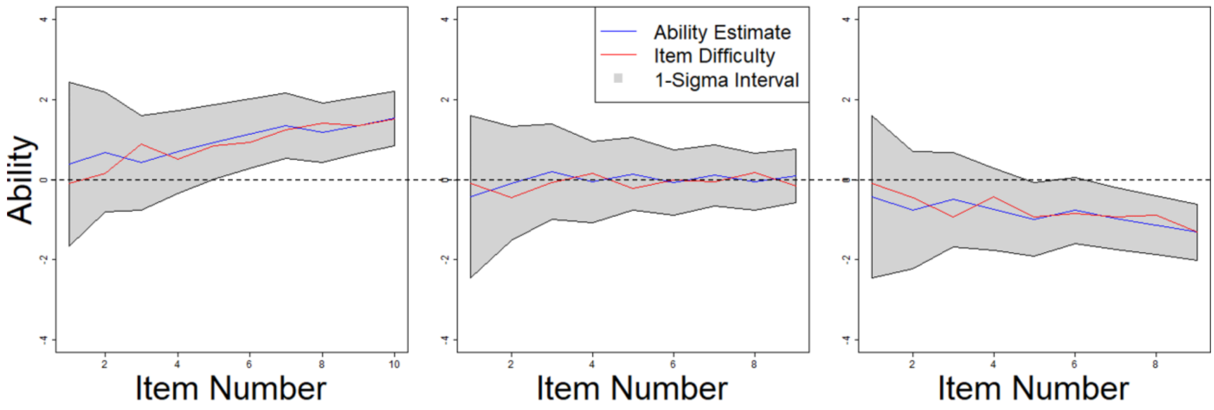

Fig. 4. Development of personal ability estimate and question difficulty versus item number for a test user with high (left hand), mean (middle) and low (right hand) personal ability

5 RESULTS

5.1 Comparison between CAT and Static Test

For the following analysis only the test results have been used where all four steps of the test procedure had been completed. As in the static test each user is forced to complete all 12 items, the number of items in the CAT depends on how many questions are necessary to fall below the error threshold. This leads to the distribution of the number of questions shown in figure 5. The mean value is 9.3 items. So, the number of items could be reduced by 23 % on average compared to the static test.

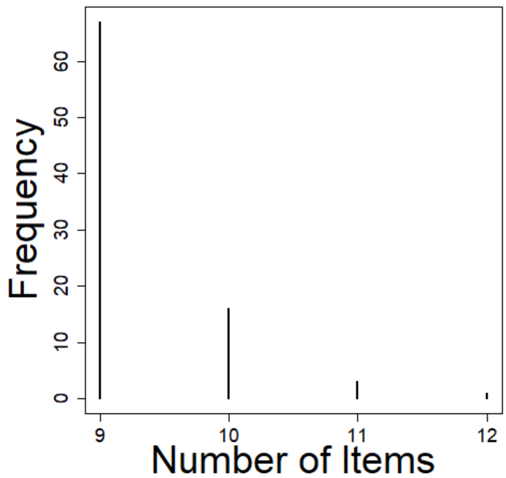

Fig. 5. Distribution of number of items in CAT runs

The comparison of the standard error of the personal ability versus the personal ability for the static test and the CAT is shown in figure 6. The error threshold for the

CAT is constant over the whole range of the personal ability whereas the error in the static test is a little bit lower around the mean value for the personal ability but rises to low or high values of the personal ability. Over the full range the error is comparable on average.

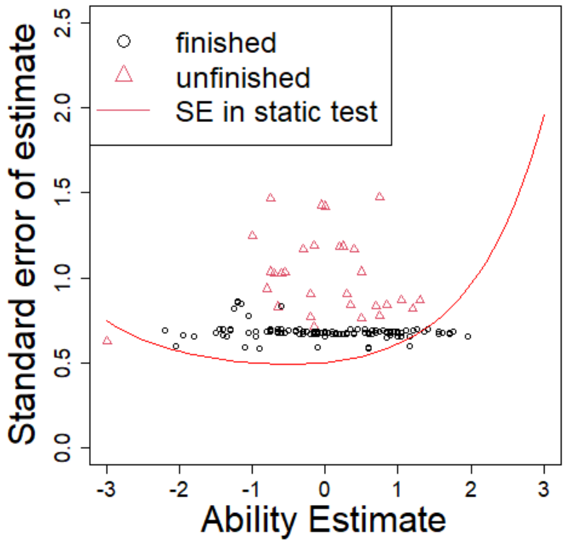

Fig. 6. Standard error versus personal ability estimate for static test (solid line) and CAT (finished and unfinished test runs)

As a quality check if the static and the CAT measure the same ability the correlation of the test results was determined. A satisfactory value of 0.56 was achieved (see table 1).

Table 1. Correlation between static test, CAT and school grades

	Static test	CAT	Grade in math	Grade in physics
Static test	1			
CAT	0.56	1		
Grade in math	0.46	0.49	1	
Grade in physics	0.56	0.35	0.47	1

For the correlation between the grades in math and physics a difference shows up for the two tests: the static test has a stronger correlation to the grade in physics whereas the CAT has a stronger correlation to the grade in math. From the social parameters only the academic background of the parents leads to a significant difference between the tests. The correlation between the test result and that at least one of the parents has an academic background is 0.12 for the static test and 0.31 for the CAT. Together with the difference in the correlation of the school grades this might be a hint that the two tests do not measure exactly the same ability of the test user. For a detailed understanding further investigation is needed.

5.2 Evaluation Results of CAT

In addition to the outcome of the test results the acceptance and judgement of the test users was determined with the two questionnaires.

In good agreement with the reduction of the average number of questions the perception of the duration of the test was significantly shorter for the CAT than the static test. On a five-point Likert scale ranging from “very short” to “very long” 45% chose short and 6 % very short for the CAT whereas only 25% selected short and none very short for the static test.

Both the static test and the CAT were rated in general as good by the majority: 58% “very good” and “good” for the CAT, 63% “very good” and “good” for the static test on a five-point Likert scale ranging from “very good” to “very bad”.

Astonishingly also the difficulty of the questions was comparably evaluated. In the CAT, 58% of the test takers rated the difficulty of the questions as “average”, and also 58% did this for the static test. The expectation was that the CAT mostly shows a mean rating as the questions were selected to fit the personal ability whereas the static test always has questions over the whole difficulty range, so weak students should give a feedback as the questions being “difficult” and strong students have the impression that the questions are “easy”.

6 SUMMARY

The prototype of the CAT was successfully implemented and tested. The number of questions could be reduced significantly by 23 % within a comparable error and hereby fulfilled the expectations. The assessment of the test users for the length of the CAT compared to the static test corresponds to the measured reduction. A satisfactory correlation between the results of the CAT and those of the static test was achieved. As the detailed knowledge of the item parameters is crucial, a further reduction of the test length seems achievable when there is more data available and the discrimination power of the items can also be determined.

7 ACKNOWLEDGMENTS

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Developing and improving competence profiles of project teams in engineering education

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ABSTRACT

This concept paper reflects an ongoing research on designing students' team projects in engineering education with a focus on soft skills development. The core idea is to relate project tasks with relevant team situations and team roles which require and train certain sets of soft skills. The paper proposes: a) a model for developing the relevant soft skills out of project tasks, and b) an approach to relate individual competence profiles of team members with an overall team competence profile. A core assumption is that if a team is formed, individual competences are aggregated in a certain way to form a single team competence profile. However, in the case of soft skills this aggregating is more complex than simply adding skill levels, e.g., soft skills in teams are a result of specific combinations of competences. Understanding these effects is relevant for project management and engineering education. The paper proposes a first draft of a systematic framework for investigating such effects and for making them usable for the design of student projects in engineering education. It also provides insight into an example of an agile cross-border project conducted fully online and using the scrum method. The paper is considered to be a contribution to the development of project-based learning.

1 INTRODUCTION

For being competitive, “tomorrow” graduates would need to demonstrate technical, professional and global competences [1], including knowledge of project management as a part of “technical” competence. Since much engineering work is done in project and teams, the individual competences are the basis of the team’s or project’s competence profile – a kind of competence aggregation. However, the research on competences in project management indicates a more complex concept: individual competences do not just add up to an overall team competence. In general, there are competence profiles of individual team members which cumulatively scale up to the competence profile of the team; but this aggregation, we believe, is connected to the interaction of members’ soft skills. Human interaction is not an option but a necessity to share knowledge, experiences, and lessons within teams and between teams. Whereas technical skills can be acquired by an individual through learning and practice, soft skills require the interaction of others either through mentoring, interventions, or specific trainings to be developed. Consequently, team competence and performance depends on soft skills and team interation while at the same time soft skills are formed and trained in such team situations. Our research should contribute to a better understanding of these effects and to ways to make such effects usable and applicable in engineering education.

2 RESEARCH MOTIVATION AND METHODOLOGY

We aim to contribute to existing research by proposing a concept on how the team member interactions can strengthen or weaken soft skills of the team. This will support the composition of student teams in project-based education and at the same time it will enable the project managers or project team leaders to have awareness of such interactions so they can strategically allocate team members to create team profiles. We acknowledge that technical skills of the team members are also of high importance in contributing to the effectiveness of the team competence.

Based on the structured literature research, this concept paper will:

a) Propose a model for developing a competence profile of a team
b) Propose a model for examining team competence profiles with focus on soft skills
c) Propose an approach of conducting effective student team projects based on the analysis of the competence profiles and with a focus on soft skills development

3 LITERATURE RESEARCH

The concept of competences is a very diverse research area with different approaches towards definition. In their research on soft skills, Marin-Zapata et al. [2] provide a clear taxonomy “competence → competency → (skills, motivation, knowledge)”, where skills are distinguished between soft and hard; in its turn, hard skills refer to technical expertise, and based on the proposed taxonomy, soft skills have two main components as intrapersonal and interpersonal skills. The development of soft skills depends on the interaction between individual innate traits (i.e., personality and abilities) and contextual factors, whereas in organizations the interaction between soft skills and training programs appears to be vital to enhancing employee job performance [2]. According to Matturro et al. [3], soft skills are a combination of the abilities, attitudes, habits, and personality traits that allow people to better perform in their workplace, complementing the technical skills required to do their jobs and influencing the way they behave and interact with others. Based on the systematic mapping study, Matturro et al. [3] provide main categories (including their definition) of soft skills relevant for software engineering; those are: communication skills, team work, analytical skills, organizational/planning skills, interpersonal skills, leadership, problem-solving skills, autonomy, decision-making, initiative, conflict management, change management, commitment/responsibility, stress management, customer orientation, flexibility, ethics, results orientation, time management, innovation, presentation skills, creativity, critical thinking, negotiation skills, listening skills, motivation, willingness to learn, fast learner, team management, and methodical skills category. Furthermore, Tam et al. [4] examined the people/soft factors that contribute to agile software project success, found that societal culture and personal characteristics of the team members can impact the overall capability of the team.

Although various studies have defined soft skills in different ways, there appears to be consensus that individual personality play a major role in influencing soft skills. Several factors can influence a person’s personality like individual attitudes, behavioural habits, personality traits and their individual competences (abilities). In their study, Yilmaz et al. [5] assessed the personality characteristics of software development teams using the Big 5 personality theory; they discovered that effective team structures support teams with higher emotional stability, agreeableness, extrovertsion, and conscientiousness personality traits.

Awuor et al. [6] study skills for teamwork and propose an assessment methodology of teamwork competence; authors highlight that through teamwork and project-based learning, students improve their knowledge in technical, behaviour and contextual competence areas of project management, and the study revealed that thanks to teamwork, student competences in creativity, leadership and negotiation were sufficiently improved. In their study on project management learning and teaching challenges, Ojiako et al. [7] revealed key components of students' experiences: transferable skills (interpersonal skills, time management, curriculum coherence, critical thinking and communicating) and virtual learning (quality of e-resources, accessibility of information managed online); due to the nature of the study, the paper provides a detailed self-evaluation survey on transferable skills. The authors conclude that institutions and educators need to re-think an integration of transferable skills into education agenda and allow engagement in project-based modules, where students become proactive problem solvers and critical thinkers [7].

To improve students’ performance in a project-based learning, Aranzabal et al. [8] propose a methodology to build a balanced project team. Using the Belbin’s role theory to raise student awareness about the benefits of teamwork, authors confirm that teams formed based on one-of-nine roles performed better than self-selected teams. The role theory developed by Belbin in 2010 states that a team role is a “a tendency to behave, contribute and interrelate with others in a particular way" and it is influenced by personality, mental abilities, current values and motivation, field constraints or external working environment, personal experience and cultural factors, and role learning. The authors highlight, that using the role theory, students realised a positive contribution to cooperative learning, interpersonal relationships, social skills, and abilities to work in the roles- and skills-based environment [8].

4 PROPOSED CONCEPTS

In our first concept (Fig. 1) we want to highlight different aspects influenced by hard/technical and soft skills. If we look at competences from a technical skills' perspective, then we believe it is enough to add up such skills to compose a project team competence profile. Whereas when we consider competences from the soft skills' perspective, it is not possible to add up soft skills of team members and a more complex interrelation among team individuals should be considered. Based on the task deliverables to be achieved (see (t_1 … t_n) in Fig. 1), we may define roles (r_1 … r_k) and relevant competence profiles (CP_1 – CP_m). Based on taxonomy given by Marin-Zapata et al. [2], competences are composed of soft and technical skills, and since the soft skills do not complement each other between team members in a simple way, we assume that deriving the interpersonal team aspects and soft factors from the individual soft skills is an unsolved scientific problem. While we assume that accumulating the technical skills (see "+" in Fig. 1) of the individuals into a technical team competence profile is adequately done by really just adding skill levels, we expect that accumulating the soft skills (see "++" in Fig. 1) is not possible by just numerically adding skill levels but only by an expert review and assessment, based on the experience of good managers.

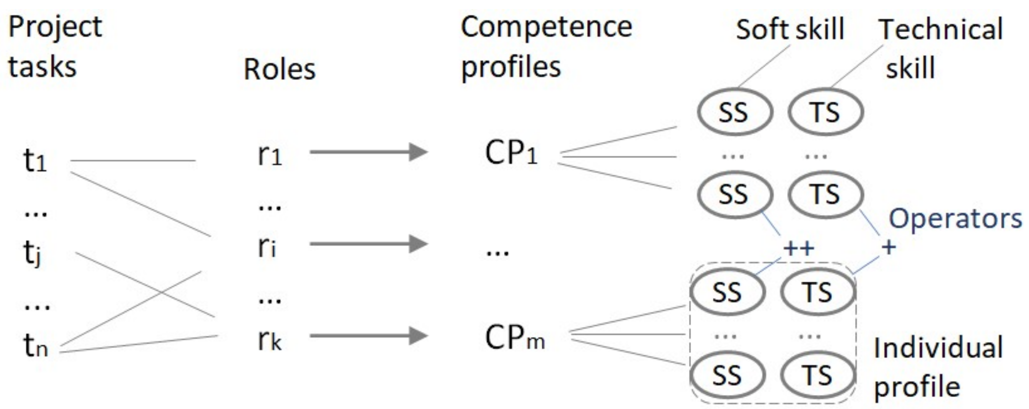

Fig. 1. A model for examining interrelations of project tasks, roles, technical and soft skills

As observed in the researched literature, a project team is comprised of individuals with various soft skills and different personality traits. It can happen that the personality traits of team members clash and, in one or another way, impact the team performance. But if the personality traits are aligned, it can lead to creating an effective working team. Therefore, we propose a second concept model (Fig. 2) to investigate factors that play a role in development of soft skills in teams. The model acknowledges the significant work done by existing research on team formation, but our aim is to find a way to select and allocate team members to form balanced teams. Through considering the personality traits of the team members, we aim to formulate team competence profiles that can be used both in education and project staffing for combining team members with the right set of soft skills and for developing soft skills by working in such teams. As highlighted in [4], [7] and [8] soft skills can be trained trough doing projects in teams, and as claimed in [5], team capability refers to the utilisation of knowledge, which, we believe, can be fostered by trust developed over time.

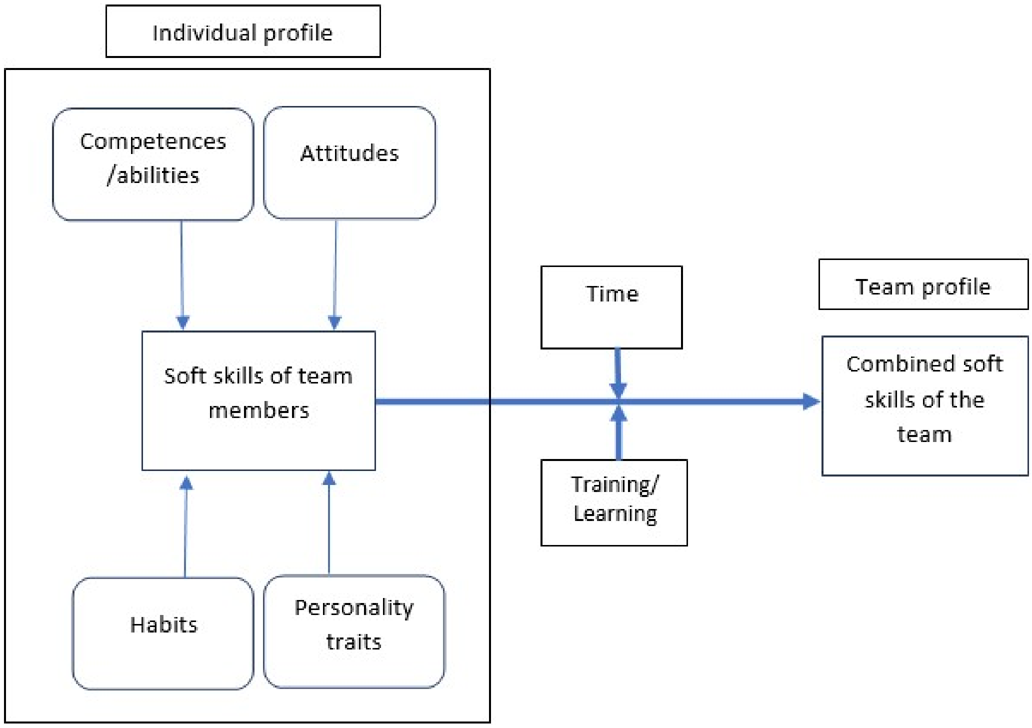

Fig. 2. A model for examining team competence profiles with focus on soft skills

Each team member has their own personality traits which can impact the way they associate with other team members, hence, impact the transfer of skills between them. This model proposes that the interrelation and transfer of soft skills between team members is influenced either negatively or positively by individual personality traits, thus, impact the overall soft skills of the team positively or negatively. In Table 1 we summarise meanings of personality traits and relevant scores to be considered when forming the team.

Our research is investigating methods and tools for composing “good” teams for a given project (set of tasks) as shown in Fig. 1 and for solving the problem of deriving the soft factors from individual soft skills by using more complex concepts like personality traits (see Fig. 2). After the elements and relations of these two conceptual models are properly investigated, we aim to incorporate the developed team formation approaches into engineering education. This can be enabled though project-based education and competence-based description of desired learning outcomes. Based on specific soft skills which are supposed to be trained, projects are constructed (or selected) which provide the learning settings and team situations needed to train the soft skills. The success depends on forming student teams with the right combination of individual competence profiles. In the next chapter, we will propose how such an approach could look like in an educational framework for project-based learning.

Table 1. Personality traits: meaning and measures (based on [5])

Dimension	Meaning	Score in the questionnaire
Extroversion	is the personality trait of seeking fulfillment from sources outside the self or in community	high scorers tend to be very social while low scorers prefer to work on their projects alone
Agreeableness	reflects many individuals adjust their behavior to suit others	high scorers are typically polite and like people, while low scorers tend to 'tell it like it is'
Conscientiousness	is the personality trait of being honest and hardworking	high scorers tend to follow rules and prefer clean homes, while low scorers may be messy and cheat others
Neuroticism	is the personality trait of being emotional	high scorers experience negative emotional state, sadness and anxiety, while low scorers emotionally more stable and even risk takers
Openness to Experience	is the personality trait of seeking new experience and intellectual pursuits	high scores may daydream a lot, while low scorers may be very down to earth.

5 PROPOSED APPROACH AND DISCUSSIONS

Rajala [1] provided a 3-D global engineer framework and described attributes of technical, professional and global competences required for future engineering graduates if they want to succeed. Our proposed approach aims to develop students' team projects which contain team situations – and respectively learning situations – which require a set of professional and global competences in connection with a technical tasks which requires technical competences. Engineering students conduct the technical tasks and inherently get into the team-related learning situations which train their soft skills. The project and learning design considers the connections between tasks, team roles, competence profiles, soft skills, and hard skills as described in Fig. 1.

Our research and the respective student projects are embedded into a cooperation (European Partnership for Project and Innovation Management – EuroPIM) between a number of European Master's programmes in IT, engineering and project management which gives us the chance to form international and interdisciplinary teams [9]. In this setting, we are developing a guideline on how to construct (or select) project cases and how to form student teams based on the intended learning outcome, specifically looking at the soft skills.

As an example, we refer to the development of an mobile app in teams of 4-5 students (mixed from two different countries) which was conducted in agile sprints, using the scrum method, in a 100% online setup [10]. This format was conducted and evaluated several times within the EuroPIM partnership.

The scrum project foresees individual work of the students and collaboration is happening only in specific team situations, the so-called scrum ceremonies. The scrum ceremonies are the relevant learning situations with respect to soft skills. In addition, this type of project foresees only 3 team roles: the scrum master who is a process-focussed facilitator and coach, the product owner who is a result-focussed driver and shaper, and the team members who are considered to be a group of equals. Therefore, the scrum ceremonies can be considered as tasks (see Fig. 1) which contain specific team situations (see description of the 5 ceremonies in Fig. 3) which are connected to specific soft skills (see [10]).

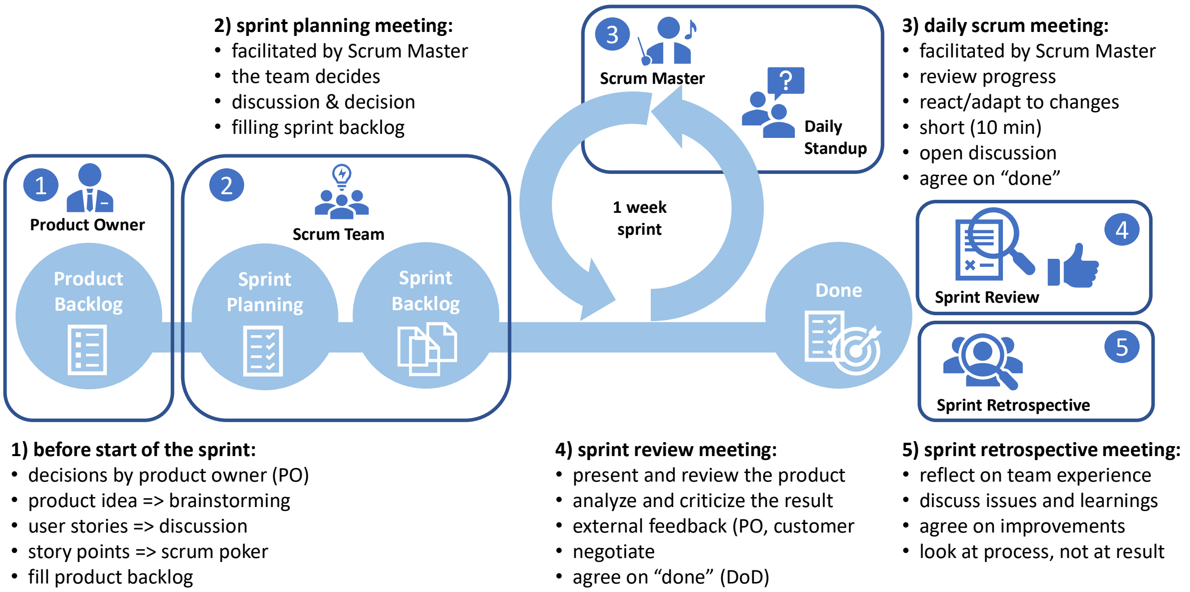

Fig. 3. Analysis of the 5 scrum ceremonies regarding team situations and team roles [10]

Based on the experience, we propose a 5-step approach for designing international and interdisciplinary cross-border projects where students from different back-grounds and cultures can train technical, professional and global competences.

1) Before the course:
   - Based on the planned learning of the course, define a possible case study to stimulate a relevant project scenario (preferably with industry involvement, e.g. the development of an mobile app as in [10])
   - Define the list of project tasks to be performed by the team within the course → Tasks will determine the roles of the team members → in case of the scrum project (Fig. 3) these are the 5 scrum ceremonies and the 3 scrum roles which are part of the project.
   - Design a self-evaluation questionnaire for the students to assess their soft skills before doing the course (e.g., as a catalogue of soft skills, the list provided by Matturro et al. [3] can be used; questions may be adapted from [7]) → initial profiles of students
   - Based on the required team roles, define which students will be assigned to a specific team and which role each student may perform in order to fulfil the project tasks → this is an initial assignment which will be refined at the beginning of the course

- Plan the intended learning outcomes based on the initial profiles of the students and the anticipated project (learning) situation during the project

2) At the beginning of the course:
    - Perform a team building exercise with each student team in order to define the set roles for the project → build a balanced team (based on personality traits assessment [5] or Belbin's role theory [8])
    - Invite company representative to provide the case → create a realistic project kick-off situation (e.g. in the discussion of user stories, see (1) in Fig. 3)
    - Reflect with students on the experience during team building and project kick-off and ask them to refine their self-assessment
3) During the course
    - Provide students with project management methodology → training of technical competence (e.g. a scrum training and test)
    - Provide students with tailored soft skills trainings and knowledge
    - Project work in cross-border (cross-cultural) teams → training of global and professional competences
    - If required, conduct team exercises, e.g. for conflict resolution
4) At the end of the course:
    - Organise reviews (e.g. pitches, feedback sessions) with company representative → training of professional competence
    - Assess the quality of the project results → evaluation of technical competence (e.g. in the sprint review in Fig. 3)
    - Conduct the self-evaluation survey on acquired soft skills → evaluation of the soft skills gap closed during the course (examples: see Fig. 4)

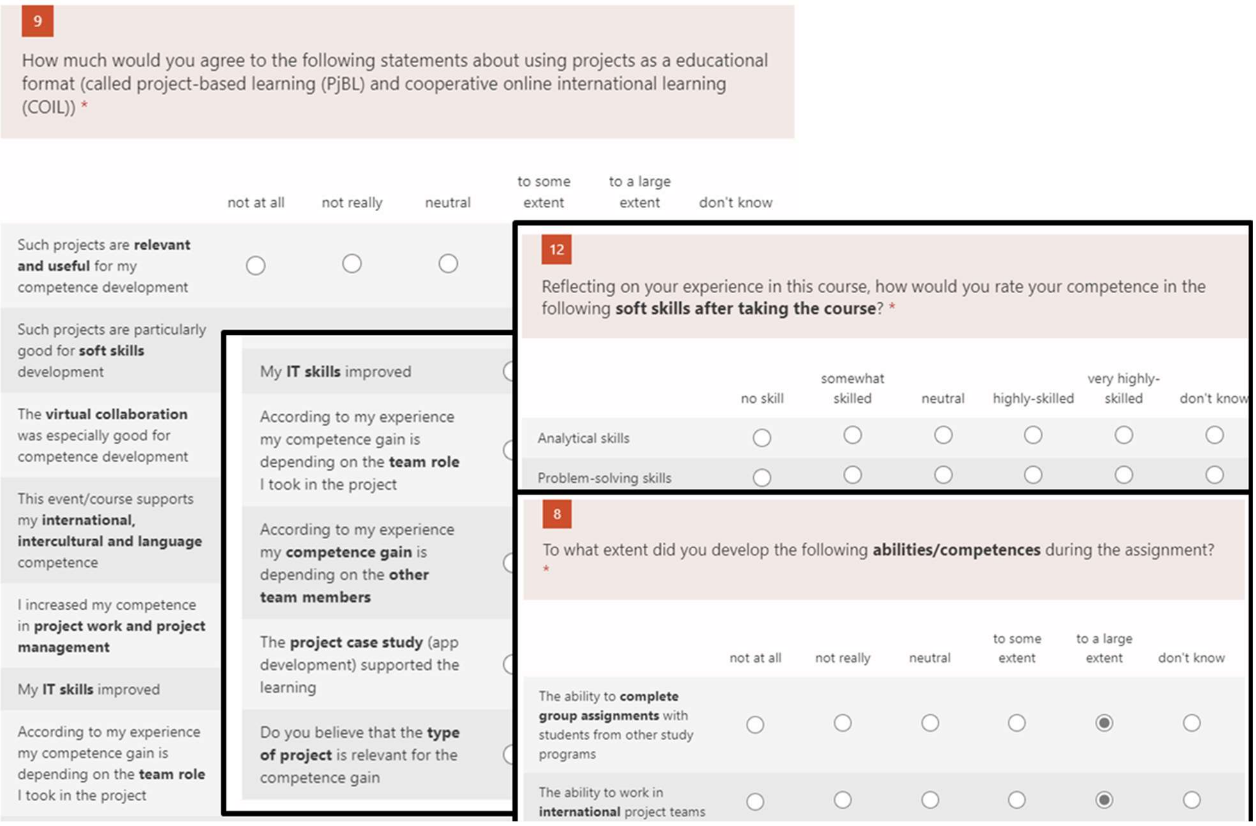

Fig. 4. Examples of survey questionnaires used in the agile cross-border projects

5) After the course:
    - Lessons learned workshop in order to reflect on the team situations and to raise the awareness of students for the soft factors

Our research is based on conducting student projects using above-mentioned 5-step approach. We conducted several trial runs with student teams from 2 countries (e.g. Germany-Kazakhstan [10], Germany-Spain) and participants numbers from 10-50. Evaluations showed positive feedback of students and teachers though some results were surprising (e.g. English language communication was a minor problem, while IT literacy was partly challenging). At the next step we aim at evaluating the impact on students' soft skills based on survey results and expert reviews. For this we intend to refine the methodology and to validate the concepts and quality of the methods based on conducting student projects within our European consortium.

6 SUMMARY

Designing student team projects with specific team situations in mind can support the development of soft skills of engineering students. Nevertheless, a straight-forward methodology for connecting project tasks, students' team roles, learning situations and soft skills in a meaningful learning design is a challenging task. The proposed 5-step approach is a first draft of a systematic framework which might finally support teachers and students in systematically increasing the learning outcomes in project-based learning, especially with respect to soft skills.

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Making sense of interdisciplinarity in challenge-based learning:

A two-step co-creation approach towards educational redesign

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ABSTRACT

Challenge-based learning gains popularity in engineering education for allowing students to transcend academic and disciplinary boundaries and to fully engage in real-world problems, but it is largely underexplored how to improve specific designs of such educational practices to promote interdisciplinary learning experiences and competencies. This paper describes two studies that together in two steps make up an evidence-based redesign of a challenged-based course featuring group-work projects in an undergraduate program combining engineering with liberal arts and sciences. A first study based on observation and interviews collects different and varying learning experiences throughout students' learning activities. The results showed that interdisciplinary experiences are constructed in complex dynamics between students' disciplinary identity formation and the interdisciplinary and collaborative course configuration. Such dynamics may result in positive learning

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experiences (engagement and interdisciplinary enrichment) as well as negative ones (disengagement and frustration). Especially regarding the discrepancy between common experiences across the three phases of tackling the challenge (mapping, mitigating, integrating), representatives of parties important for the course were invited to a roundtable session in a second study to discuss and reflect on the first study's findings and what they can mean for the course design. Understandings achieved in the session are used as input for upcoming course redesign towards a more desirably organized challenge-based learning. The two-step approach towards redesign is an example of involving researchers and students in evidence-based educational redesign, exemplifying the value of naturalistic research and educational co-creation in understanding and optimizing students' learning experience to achieve fruitful challenge-based learning.

1 INTRODUCTION

Our rapidly changing world calls for experts who can transcend traditional disciplinary regimes. Academic programs increasingly try to incorporate interdisciplinary elements in their curricula and there is a growing number of programs with an overall interdisciplinary signature. Challenge-based learning is a dominant approach in weaving interdisciplinarity in academic education [1]. Still, little is known about the way challenged-based courses contribute to interdisciplinary learning experiences and competencies. Analyzing how students reflect on their interdisciplinary learning experiences in specific challenged-based courses may provide insights in the strengths and weaknesses of such forms of academic education and help to identify course design characteristics with positive or detrimental effects on the development of interdisciplinary competencies.

This paper presents a case of understanding the interdisciplinary experience in challenge-based learning and applying such understandings to improve challenge-related educational design. The study focuses on a specific project-based course in a Dutch Liberal Arts and Science (LAS) undergraduate program. The entire program emphasizes students' self-determination and interdisciplinarity, allowing students to tailor unique academic trajectories based on personal pursuits and bringing students with different academic interests and backgrounds together in collaborative project settings. One of its courses, called Real-World Challenges, aims to prepare students for working on grand and wicked problems on a scale similar to real-world contexts. This 19-week course gives students substantial freedom in contributing their own interests and expertise to addressing societal challenges. Students themselves choose the specific topics to work on and accordingly form groups. In one semester, the groups try to diagnose and ease the challenges by developing interventions through, citing the syllabus, 'multidisciplinary solutions and systems thinking.'

Besides the preparing week during which students determine project topics and groups, the course consists of three phases. In the first phase (Mapping and Modelling, 5 weeks), groups of around 14 students analyze the challenge as a complex spatial-temporal system from different angles, decomposing it into heterogenous constituents, and comprehensively mapping and modeling it by describing involved critical issues, stakeholders, and their interrelations. In the second phase (Mitigation, 9 weeks), the groups divide into smaller 'expert teams' of two to four students. Expert teams apply their specialized expertise to devise mitigation strategies for the identified critical issues towards solving the general problem. In the third phase (Integration, 4 weeks), students return in the large group to attune and synthesize separate mitigation strategies into a collective final report that addresses the challenge in line with the overarching model made in the first phase.

Since the start of this LAS program more than eight years ago, this challenge-based course highlighting student autonomy and interdisciplinary exchange has undergone little change in design. In 2020, it participated in a practice-based educational research project, STRIPES2021 (STructuring Interdisciplinary Projects for

Engineering Students), which is supported by COMENIUS Leadership Fellows and aims to help educators better structure interdisciplinary education.

2 METHODOLOGY

Studies regarding the interdisciplinary nature of course were conducted in two steps. The first step featured of an in-depth qualitative research on students' learning experiences and perceptions of interdisciplinarity. The study engaged in classroom practices and especially focused on how interdisciplinarity emerged as cognitive-social systems through the process of challenge-based learning and project work [2]. Building on 35.5-hour observation of class and group meetings and informal talks with students, further interviews (N= 25) were conducted with students from the 2020 cohort. The interviews focused on the design and process of the project work, students' disciplinary identities, and their learning experiences throughout the course. This step served to develop a detailed overview of the strengths and pitfalls of challenged-based interdisciplinary education in such a free, autonomous setting.

The second step involved a roundtable session meant to provoke insights for possible redesigns of the course. The session invited a course coordinator who developed and supervised the course and two students from different years who had followed the course in different years. By involving the two groups, this step emphasized a student-staff partnership and followed a co-creation approach which directly enables the exchange between different knowledge and experience in education and reinforces the values of equity and interaction [3], as the program itself highlights. In the session, the participants were gradually presented with findings of the first study and brought into discussion. Along the demonstration of research findings, students were encouraged to share and compare their learning experiences, which simultaneously validified the first-part research findings by recognition. Participants structurally discussed, brainstormed, and reflected upon the research findings and what they may mean for the educational design of SP4. Therefore, the research findings were communicated with the educational community of the program highly respecting its autonomy and culture. The roundtable session resulted in a report about possible ways towards improvement and challenges to further investigate and address mentioned in the discussion. This step served to bridge the gap between research findings and the educational practice as well as to deepen the insights about the stakeholders' perceptions of interdisciplinarity in academic education.

3 RESULTS

3.1 Naturalistic study: identifying problems

Researchers' engagement in the first study showed variations of students' learning experiences in the course, both in a vertical dimension through three phases and in a horizontal dimension across individuals, particularly in the second phase, Mitigation. Analyses focusing on the horizontal variation have resulted in a detailed account about how interdisciplinarity has been constructed and enacted in this specific educational context where individual disciplinary identities manifest, negotiate, and act upon each other in the interactive groupwork dynamics. One an individual level, students showed different identities in how their academic pursuits were configured regarding disciplinary constellation. Working in expert teams, different patterns of group-work experience regarding interdisciplinarity emerged following various circumstances. The interplay between individual levels and group levels illustrates dynamics of interdisciplinarity in the course, partly orchestrated by the project design and partly shaped in concrete interpersonal transactions.

While in another publication we addressed intersectional academic identities and their construction of interdisciplinarity in details, we are also interested in the practical implications of our explorative and descriptive research regarding learning experiences for the design of the challenge-based course. The implications firstly concern the horizontal variation in learning experiences: During the mitigation phase, not all students shared a fruitful interdisciplinary experience. Instead, some students missed meaningful connections with other disciplinary input and considered their experience as monodisciplinary: 'But then you had the mitigation strategy in the mitigation phase …[I] didn't experience it really like that [interdisciplinarity] because I was just working on my own expertise. So, I didn't really feel very interdisciplinary'. Other students expressed an experience of shallowness and not being able to apply their expertise: 'I have the feeling that, for example, I got to apply some of my expertise, but a lot of it I also just have to look up online… [the topic] was what we were interested in. But it wasn't necessarily that we applied the knowledge that we already had. We had to gain more knowledge before being able to apply it. In that sense, in my opinion, it isn't really about the interdisciplinarity at that point. It's just more about Googling.' This non-disciplinary experience as well compromised the engagement of students.

Furthermore, the vertical variation of perceiving interdisciplinarity also matters in how students experience their learning journeys. Unlike the various patterns identified in the Mitigation phase, students shared large commonalities in how they experienced SP4's first and third phases. When the beginning Mapping and Modelling phase is commonly described as brainstorm and discussions full of exchanges between different disciplinary backgrounds, the third, named and emphasized as 'Integration', is surprisingly characterized by a lack of engagement, interaction and interdisciplinarity in students' experiences.

External factors such as heavy end-semester study load and communicational constraints during the Covid-19 crisis partly explained this problem. However, interviews yet showed that practices during the Integration phase were fairly limited to repeating the maps and models from the first phase. Similarly restrained were freedom, creativity, and flexibility regarding project work from which student have expected much. Some students questioned whether different approached were brought together during the integration phase and accordingly distanced themselves from taking tasks. Many students, similarly, contributed solely by summarizing their Mitigation-phase achievements without an overview of the whole project. Students often commented the Integration phase as mainly revising and editing documents, a mechanical process without actual mental challenges or growth to understand or synthesize different perspectives.

3.2 An analysis of the problem and educational design

Reflecting upon the structure of the course, the three-phased project design in addressing challenges implies a sense of reductionism and linearity, which related to students' disengagement during the Integration phase. Primarily, the three phases are demarcated based on an assumption that complex problems are aggregations of affiliated issues that connect but can be dismantled, tackled separately, and later brought together. Groups, in Mapping and Modelling, were asked to sort out various nodes in models and reduce holistic problem maps into jigsaw pieces. Therefore, what the large group achieves in this first phase largely determines following activities. Integration, consequently, becomes the closing section in a ternary form that repeats the opening, mainly patching together the previously defined critical issues, focusing hardly on content but formation of the final assignment documents.

Second, projects' three phases demonstrate a sequential, linear structure: One follows the other in time. However, the linearity cannot capture the logic behind the phases. When mapping and modelling problems, students were already asked to envision specific critical issues and consider their interlinks. Concerning Integration, the syllabus also suggested 'reflect[ing] on how the mitigations of the smaller phase-2 groups can be integrated in the original models of the overarching problems', explicitly referring to the two earlier phases. Therefore, the three phases are actually interwoven and symbolize recurring moments and iterative processes facing complex, holistic systems. The inconsistency between the time-wise linearity and logic-wise non-linearity in SP4's educational design actively acts upon students' learning experiences.

This reductionist and linear assumption also renders the Mapping and Modelling phase dominant impacts on the group dynamics and interdisciplinary experiences throughout the project. Specifically, the composition of expert teams in Mitigation largely complied with the underlying logics of initial problem definition and critical-issue division. When critical issues are framed as disciplinary aspects, corresponding expert teams are likely to be homogeneous, with members sharing similar disciplinary focuses. Contrariwise, identifying a critical issue as a specific phase or facet of the larger problem stimulates groups to recognize problems' interdisciplinary nature and promote miscellaneous teams allying distinct disciplinary expertise. In homogeneous and miscellaneous groups, where respective critical issues are established and approached differently, work dynamics also take place differently, leading to different perception and experience of the application of disciplinary expertise, transactions across disciplines, and thus interdisciplinarity.

3.3 Roundtable session: creating input for change

Empirical findings about students' learning experience and theoretical reflection on the course's set-up were together brought into the roundtable session to create an environment for discussion, reflection and co-creation. In the session, the researcher acts both as a party in the co-creation that provide outsider insights and as coordinator to facilitate the communication and encourage others to come up with possible ways to improve the course. When sharing the research findings about learning experience, both the compromised interdisciplinary experience (non-disciplinary and monodisciplinary) and the disengagement in the Integration phase were recognized by students from experiences of themselves and peers. For example, one student described the Integration phase as 'more like mixing and matching the parts in a report rather than trying to understand [different perspectives].' The analysis of the reductionism and linearity implied in the design to address challenges was also endorsed by both educators and students as a critical problem in designing interdisciplinary and challenge-based education.

The roundtable session first identified the links between different expert teams as the key to overcoming the problem in educational design and to improvement of the course. Although students expressed that 'integration feels a bit rushed in the end' and believed if given more time they would be able to experience more meaningful learning in the Integration phase, prolonging the Integration phase does not mean the definite solution: Students need to read into mitigation strategies of other teams during the extra time, thus a better in-depth understanding of other teams' work is pivotal for meaningful integration.

Consequently, the discussion focused on possible ways to enable links between expert teams and resulted in several proposals for educational (re-)design.

First, activities during the small-team-based mitigation phase could be planned to allow students to learn about others' work in an earlier phase and make connections. One example is a mitigation strategy market, where all expert teams would present their work by far and students could then walk around to talk with peers, sharing ideas and comments, pinpointing possible links between different disciplinary perspectives, and helping each other shape further mitigation trajectories. Similarly, a mid-term evaluation halfway at the Mitigation phase can give students chance to present their work at the current stage. Guided by course coordinators or external experts, open conversations during such an evaluation moment can involve more peer teaching and explanation from different disciplinary perspectives, so that individual members in expert teams can understand work in other teams better and identify links with other teams more easily in a more structured way.

Second, it is recognized that the challenges identified at the preparation phase of the course are too broadly defined. The elements and expertise recognized in the initial mapping and modeling of the challenge are impossible to be reasonably covered by four to six expert teams. Therefore, the mitigation phase can only attend a few knots on a web-like model and a lot in the model will be omitted in the whole Mitigation phase. According to students, even one critical issue treated in an expert team now is complex enough and have many perspectives to be qualified as a topic of challenge for the whole large group. A watered-down approach is proposed to better decide on the topic of challenge: After identifying different critical issues of a general, broad grand challenge, the group would further focus on one critical issue and repeat the mapping-modelling process until the resulting model is manageable for the group with a limited number of members. By narrowing down the scale of the challenge, students could also further engage together in connections between and among different aspects and perspectives of a problem, thus have a firmer base to integrate different mitigation strategies.

Therefore, the integrative endeavor is less emphasized or concentrated as the last phase of the challenge-based project work but is present throughout the entire course. In other words, the whole project is actually focusing on integration, not only in the last phase. This shows that specialization and integration are two simultaneous aspects in addressing challenges, not to be separated in time or activities. To accomplish the proposed (re-)designs for the course, educators need to either transcend the reductionist, linear curriculum design or instruct and scaffold closely through the first phase, from defining the scale of the challenge to the forming of expert teams.

4 SUMMARY AND ACKNOWLEDGMENTS

This paper, based on a case, described a two-step approach that brings educators and students together to reflect on a challenge-based course and together create improvement for the course in the future. In this co-creation approach, researcher functions both as mediator and catalyst. On the one hand, the researcher collects learning experiences that are used as input to help represent a student perspective for educational improvement. On the other hand, the researcher brings individuals from different positions in education together and facilitate the intensive discussion and reflection. Therefore, this two-step approach shows how the sociological, naturalistic epistemology and methods of social studies can contribute to educational practices. Unlike the researcher-centered approach commonly found in educational design and improvement, the two-step approach presented here puts educators and students who are directly involved in the learning practice at the center. Therefore, this paper demonstrates an initiative to engage different stakeholders, especially students, in educational design. The highly emphasized engagement in the co-creation approach also respects and complies with the values about student-involvement, autonomy and community favored by this LAS program.

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INTEGRATED CONCEPT FOR THE ENHANCEMENT OF MATHEMATICAL COMPETENCIES AT THE TRANSITION FROM HIGH SCHOOL STUDENT TO FRESHMEN IN ENGINEERING STUDIES

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ABSTRACT

This concept paper presents the large-scale measures and results that the Faculty of Engineering of the Friedrich-Alexander Universität Erlangen-Nürnberg (FAU) has developed to shape the future of learning and teaching of propaedeutic skills in the field of mathematics as a central basis of engineering subjects and to inspire pupils and young people for engineering studies. Since 2020, the Faculty of Engineering has developed a three-tier, structured voluntary program that is attended by several thousand pupils and freshmen per year:

1. Summer review courses in mathematics for pupils after the 10th and 11th school year during the summer holidays in accordance with the Bavarian school curriculum

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2. School leaving exam preparation courses in mathematics shortly before the university-entrance diploma acquired at a secondary school in Germany, the so-called "Abitur"

3. Math review courses for freshmen.

The methodological approach of the article lies in the presentation of the educational measures and in the analysis of the results of systematic student evaluations. This leads to generalizable, transferable recommendations for the future design of such large-scale measures for universities, derived from answering the proposed research questions and evaluation results.

1 INTRODUCTION: MATH ANXIETY - DIFFICULTIES FOR A SUCCESSFUL HIGH SCHOOL EXAM AND STUDY ENTRY IN ENGINEERING AND NATURAL SCIENCES

For years, the math skills of prospective high school graduates in Germany have been very "different" (many good, many just sufficient) with a large spread. There is a variety of literature available as mathematical support for pupils, such as "Taking Fear Out of Math: A Self-Help Guide for Parents and Students" [1] or – in German language – "Keine Angst vor Mathe" [2] or "Mathe ohne Angst" [3], and also scientific literature for teachers to overcome the "fear of mathematics" of their pupils and students such as "Math Anxiety: Strategies to Increase Confidence in Your Students Who Fear Math" [4], "I'm Just Not A Math Person! - Recognizing, Understanding, and Managing the Fear of Mathematics" [5] or "Mathematik-bezogene Angst" (in German language) [6]. On the other hand, the authors of this paper are not aware of any comparable books for other school subjects such as "Don't be afraid of English" or "History without fear". Due to the CoViD-19 pandemic, there are further gaps in skills due to the absence of contact teaching and initial difficulties with homeschooling during the lockdown phases, especially in 2020. All these topics discourage many high school graduates from taking up engineering and natural science study programs.

2 DESCRIPTION AND METHODOLOGY

2.1 Description and overview

For years, FAU has been offering its "Mathematics Review Course for Freshmen" ("Mathematik-Repetitorium") before the start of the winter semester. The mathematics topics from high school are repeated in the two weeks before the start of the lecture period. In this way, the heterogeneous degrees of knowledge of the first semester students can be evened out.

The integrated concept presented in this paper describes an approach that starts much earlier in the "student life cycle". For this purpose, the review course for freshmen was enhanced to a structured offer in three graded and coordinated courses offered online via Zoom (see Fig. 1):

1. Summer review courses in mathematics for pupils after the 10th and 11th school year during the summer holidays in accordance with the Bavarian school curriculum (tutorials in groups of around 15 participants each, duration 6 weeks during the summer holidays with 2 hours of tutorials per week). The educational ideas and objectives are to close gaps in education incurred in the previous 10th and 11th school year and to prepare the pupils for the coming school year.

2. School leaving exam preparation courses in mathematics in April shortly before the German high school leaving exams, the “Abitur” in May complemented by information events on the range of degree programs offered at FAU (tutorials in groups of approx. 15 participants each, duration 2 weeks during the Easter holidays with 3 hours of tutorials daily). The educational objectives are to transfer competencies to enable the pupils to pass the high school leaving exams in maths with good grades, especially for pupils that are not confident in their mathematics abilities, to attract them to engineering studies and – ideally – to FAU.

3. Math review courses for freshmen of FAU (lectures plus tutorials in groups of around 15 participants in the 2 weeks before the start of the regular lectures of the winter semester with daily 2 hours of lectures + 2 hours of tutorials; usually in attendance, in fall 2020 and 2021 online due to CoViD-19). The educational objectives are to refresh mathematical high school competencies for all students, especially for students that have passed their high school exam some years earlier due to a vocational education or a voluntary state service after the high school exam, and to prepare them for higher mathematics and mathematics oriented engineering courses in the first semesters.

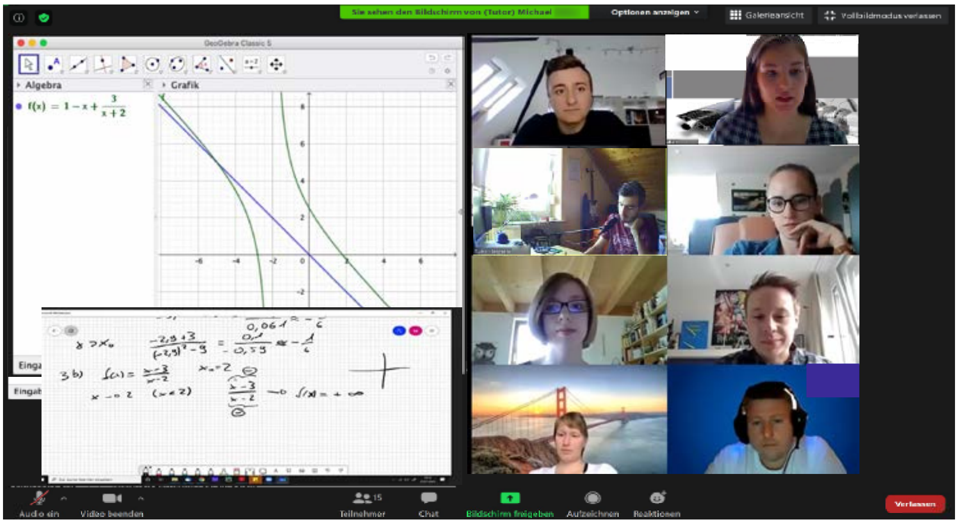

Fig. 1. Online tutorial mathematics

2.2 Key facts of the courses

Approximately 500 – 1 500 pupils registered for each course, which required the hiring of approximately 50 - 100 students per semester as tutors. The tutorials were mainly carried out by engineering students in order to ensure a high level of practical relevance. These were supplemented by students from the natural sciences faculty, mainly by students from the mathematics teacher training program. The costs for tutors also formed the largest part of the required material resources (approx. 25 000 – 50 000 € per course). The organization and scientific management was carried out by full-time staff from the Faculty of Engineering, here primarily from the Department of Mechanical Engineering.

Online research revealed that comparable courses are often offered at other universities for first semester students, but hardly any courses for pupils or courses to prepare for the high school leaving exam.

2.3 Pedagogical design: Engaging pupils' attention and motivating the pupils in the courses

Since the summer courses were announced as "first aid maths course" for 10th and 11th grade pupils and "math Abitur crash courses", mostly pupils with deficits in mathematics participated (in contrary to "tech summer courses for pupils", where mostly math and engineering interested pupils participate). Therefore, the pedagogical design aimed to help these pupils to close their competency gaps by active work and to lower their maths anxiety: "math can only be understood by self working on exercises, not by listening to a lecture or watching tutors solving mathematical problems". No "classical lectures" ("Vorlesungen") with mostly passive students were offered and also no "blackboard exercises", were a tutor writes solutions of math exercises on the board and the students write them down in their notebook, but only tutorials (see Fig. 1).

In online courses, it is often hard to motivate students to do active work. To engage the pupils' attention, the Zoom sessions were created in a very interactive manner: students were asked to edit exercises on their own, they were (repeatedly) asked to turn on their cameras and often they were distributed to breakout rooms with about 3 students each for about 10 minutes to edit and discuss exercises while the tutors "jump" between the breakout rooms and answer questions.

For the courses in the 10th and 11th grades, the Faculty of Engineering did not develop own exercises, but exercise books from the school book series "Lambacher Schweizer" [7], used by most high schools in Bavaria, were used, and for the Abitur courses, the collections of Stark publishing house of the official exams of the Bavarian State Ministry of Education of the last years were used [8]. This ensured that the taught topics fit well to the school teaching plan and Abitur exams.

The following list shows exemplarily the topics of the 11th grade summer course [7]:

- Graphs of proper rational functions
- Differential calculus of real-valued single variable functions
- Applications of the derivative
- Analytic geometry
- Advanced techniques of differentiation

- Natural exponential and logarithm functions
- Probability and stochastical independence
- Applications of differential calculus

In the Abitur courses, each day the complete Abitur maths-exam of one of the last years were worked, covering the topics analysis, stochastic and geometry.

2.4 Research questions and evaluation methodology

The following research questions were defined and were answered by analyzing student evaluations:

1. What is a good course design for universities to improve mathematical skills in the last high school years and for high school leaving exams "Abitur" regarding practical and organizational considerations?
2. Which pupils choose voluntary maths review and Abitur courses regarding their mathematical competencies (mostly good pupils who want to become very good – or mostly "bad pupils" in math who want to become average)?
3. Additional question: How can you attract prospective high school graduates for engineering degree programs and for your university?

To answer these questions, mid-term and final evaluations were conducted in all courses. The results of the summer courses lead to recommendations for action for the school leaving exam preparation courses and these led to recommendations for the freshmen review courses.

In the case of only a final evaluation, the course members are only moderately motivated to take part, since there can be no further improvement in the current course (response rates about 10 to 30%). In order to be able to implement improvement measures in the second half of the course, an additional mid-term evaluation was carried out halfway through each course as an anonymous survey on the e-learning platform StudOn (Ilias) with response rates of about 50%, what is very good for an online evaluation. As a 3rd evaluation stage, a short survey was carried out for the school leaving exam preparation courses about one month after the last high school exams took place to analyze retrospectively if these course were helpful to pass the maths exam.

3 STUDENT LEARNING GAINS

3.1 Evaluation outcomes and effectiveness of the program

The evaluation shows that the summer review courses after the 10th and 11th school year during the summer holidays had a clearly positive effect on the image of the university (Fig 2). Most of the pupils (approx. 80%) rated the courses "very good" or "good", the degree of difficulty was mostly rated "just right". Many participants also showed interest in studying at FAU (across all disciplines). A large number of pupils also would like to take part in a high school leaving exam preparation course based on this summer course. Due to these convincing evaluation results, the FAU offered this "Abitur" course for the first time in the Easter holidays 2021 and again in April 2022.

Here is a selection of typical quotes (translated from German) from the evaluation of the summer courses 2020 and 2021 [9]:

- "We think your offer is great, because maths teaching was almost completely absent for weeks - but everybody needs it as a compulsory subject in the 'Abitur'."
- "You never had the feeling of looking stupid, even if you had to ask more questions about an exercise before you understood it. I also thought it was pretty cool that we could always help each other and give tips."
- "The idea of a maths […] course was a really nice idea and I fully support it if this course would be offered again in the years to come."
- "I recommend the course to everyone and if preparatory courses are offered in the spring before the 'Abitur', I would definitely take part again and I would be very grateful to FAU :D"

Points for improvement were, among other things, the differing quality of the tutorial teaching, too many exercises dealt within a too short amount of time and the long duration of the tutorials.

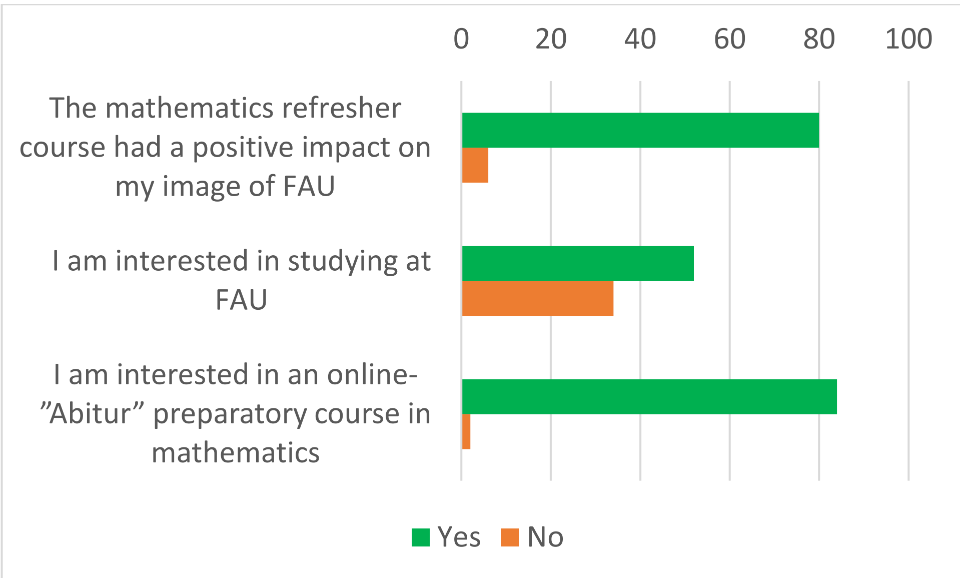

Fig. 2. Evaluation of the summer review course for 10th and 11th grades 2020

The final evaluation of the Abitur courses 2021 corresponds with the evaluation results from 2020 and was also very positive (Fig. 3). 85% of respondents rated the course as "very good" or "good" (n=582) and helpful, but they were still skeptical about their future success in their oncoming math high school leaving exams – only half of the respondents felt “very well prepared” or “well prepared” for their exams.

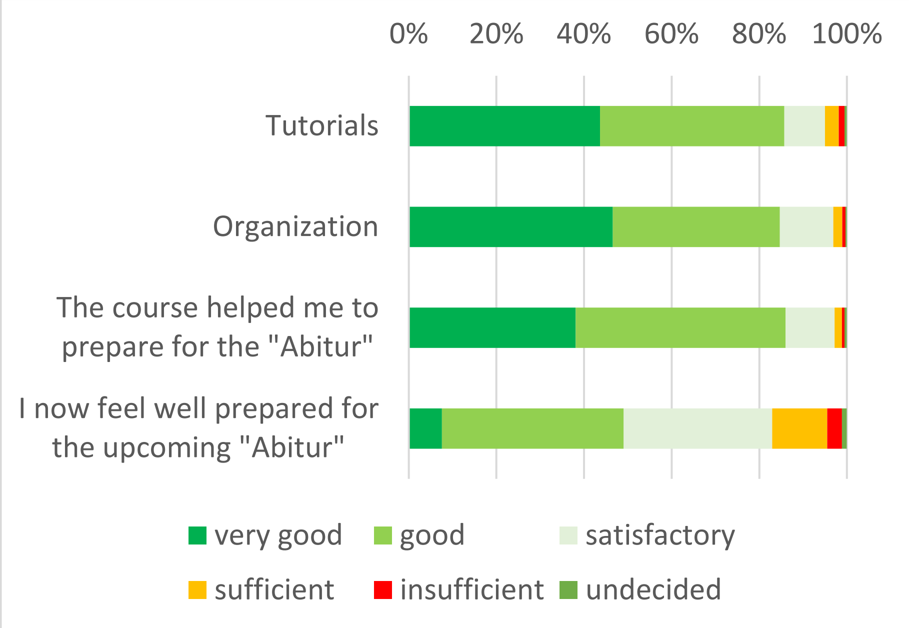

Fig. 3. Mid-term Evaluation of the Abitur course 2021, n=582

Due to the nationwide offer, many participants in the school leaving exam preparation course do not want to study at FAU, but rather at another university. Around 40% of high school graduates in the 2021 course did not yet know if they would like to study at FAU (see Fig. 4), which shows that there is great potential for the acquisition of future students at FAU. The evaluation also shows that fewer students who already have a strong affinity for technology and maths have taken the course, but rather those who have a lot of catching up to do in mathematics and who are a bit afraid of studying engineering. Only 15% were eager to study engineering (in 2022 this percentage was higher with 23%). Therefore, there is a great potential to attract future students for technical subjects who would otherwise hardly have sought out studying engineering.

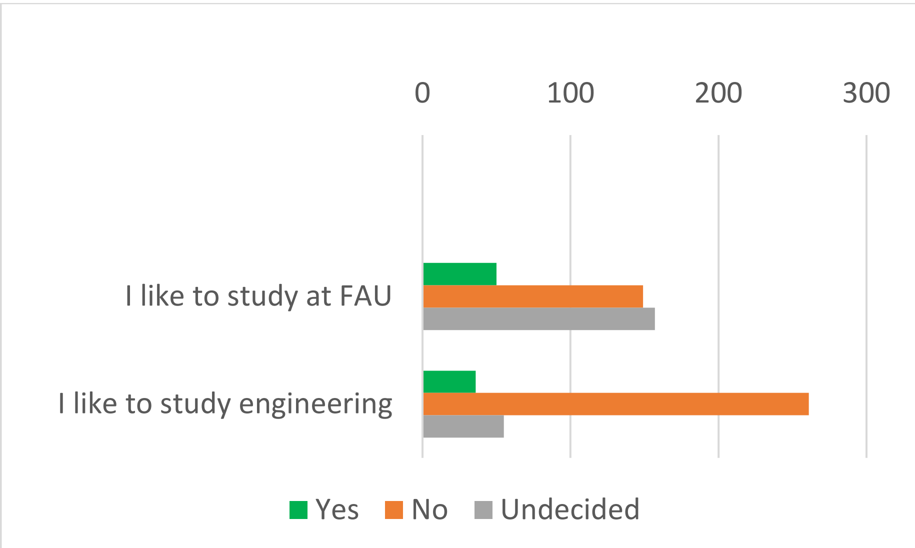

Fig. 4. Final evaluation of the Abitur course 2021

3.2 Answering the research questions

By analyzing the various evaluations, the following answers to the asked research questions were elaborated:

1. What is a good course design for universities to improve mathematical skills in the last high school years and for high school leaving exams "Abitur" regarding practical and organizational considerations?

    - It's too late to start maths review with freshmen – you should start much earlier - one or two years before the high school leaving exams.
    - Online courses (during school holidays) offered by universities are a great measure to improve mathematical skills. They transcend geographical borders and can make your own university/college known state-wide and even nation-wide.
    - Offering tutorials with pupils working on their own is better than offering "classical lectures" or blackboard exercises, since "math anxiety can only be lowered by calculating math exercises". The last survey of the pupils cohort after the completion of the "Abitur" exams in July 2021 via the platform strawpoll.de was particularly revealing and confirmed the effectiveness of the courses (Fig. 5):

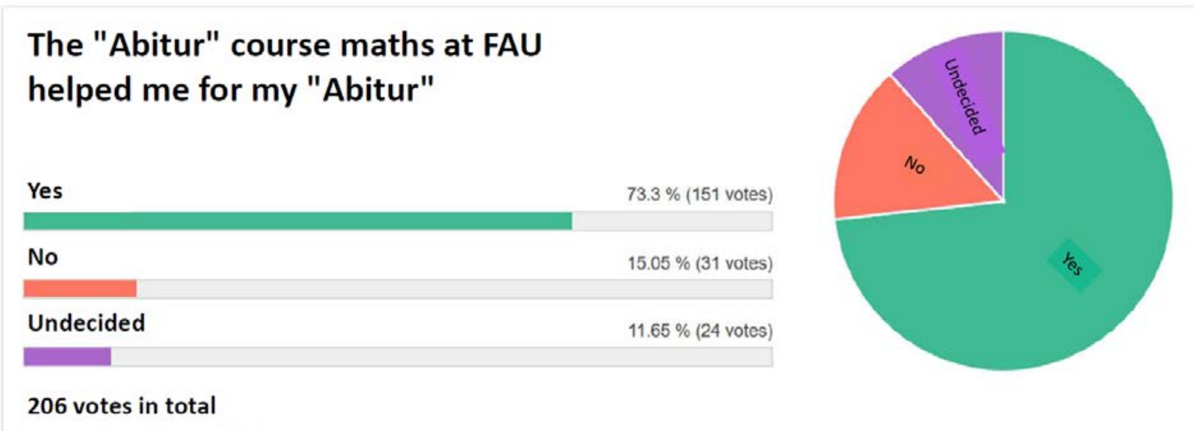

Fig. 5. "Post-evaluation" of the Abitur course 2021

Lessions learned - Recommendations for action

- Timely planning and information for schools (e.g. via e-mail to school mailing lists, parents' councils or publications [10])
- Provision of an efficient online registration system that pupils without a university account can use
- Timely licensing of the required teaching materials, publishers often offer cost effective bundled licences for teachers (so-called "Fachschaftslizenzen")

- Quality assurance of the tutors' teaching performance (partly criticism from the evaluation): conduct kick-off meeting with all tutors, implement tutor training with professional advisors (this was established from autumn 2021 on at FAU for all new tutors)
- Planning of sufficient administrative capacities for the student tutors
- Acquisition of financial resources if the courses are to be offered free of charge, or use of funding opportunities (e.g. federal programs like action programs to "catch up" after the Covid-19 pandemic)
- Pre-planning of evaluations, propagate feedback of the mid-term evaluation to the tutors

2. Which pupils choose voluntary maths review and Abitur courses regarding their mathematical competencies (mostly good pupils who want to become very good – or mostly "bad pupils" in math who want to become average?
   - As expected, the courses attracted mostly high school pupils and graduates which were less interested in mathematics and therefore had great difficulties in maths. Therefore, the course design focussed on tutorials to encourage the pupils to do math exercises on their own.

3. Additional question: How can you attract prospective high school graduates for engineering degree programs and for your university?
   - The course had a very positive impact on the image of FAU and especially its Faculty of Engineering.
   - Approximately 30-40% of high school graduates do not yet know whether or where to study. This shows great potential to attract these students for engineering study programs. Attractive accompanying study information events that are integrated in the maths review courses give the opportunity to strongly raise this percentage: "No fear of math" may lead to "engineering is cool".
   - Unfortunately, in the final evaluation of the Abitur courses, only 15% to 23% said that they want to study engineering. This shows that the "math anxiety" or disinterest in math and engineering could not be completely removed by these math courses, so further efforts must be made to inspire more students for engineering.

4 SUMMARY AND ACKNOWLEDGMENTS

Consecutive maths review courses offered by universities on different levels starting from 10th/11th graded over high school leaving exam courses up to freshmen courses strongly help pupils to overcome problems in maths and enable pupils and students to loose their fear of maths and to attract them for engineering degree programs. They can strongly improve the image of the offering university. Online courses transcend geographical borders and can make your own university/college known state-wide and nation-wide.The research questions of this concept paper will be further analysed and answered by ongoing examinations and evaluations of future courses.

Acknowledgements go to the Central University Administration of FAU and the Faculty of Engineering for financial support of the courses and especially to the many highly motivated student tutors and staff.

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A ROADMAP FOR ENGINEERING AND TECHNOLOGY EDUCATION REFORM AT THE NORWEGIAN UNIVERSITY OF TECHNOLOGY (NTNU)

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ABSTRACT

Through the project "Technology Education of the Future" (FTS), NTNU has developed a holistic, systemic framework for re-design of its educational programmes in technology and engineering. FTS delivered its final report in January 2022 – a roadmap focusing on 'how', i.e., the concrete steps NTNU should take in the upcoming years in order to implement FTS' previous recommendations on 'why' and 'what'. This concept paper provides an overview of this roadmap, which outlines 12 *Main Actions* (MAs) within five *quality areas*, plus an overarching 'umbrella action' to enable the MAs. For each MA, some *Prioritised Measures* (PMs) are described. Based on a risk analysis we also provide *procedural advice*, emphasising factors deemed critical for a successful FTS implementation.

1 INTRODUCTION AND BACKGROUND

In March 2017, NTNU's Rector decided that the project "Technology Education of the Future" (FTS) for renewal of the university's programme portfolio within engineering and technology (in all around 150 study programmes on bachelor, master and PhD level, involving five faculties) should be established, with an ambition to *"promote a new generation of engineering and technology education which is updated in all areas according to international development and society's needs."* For a number of reasons, the formal project start-up was delayed until August 2019. In 2019-2020 FTS reviewed international trends and global best

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practices, aggregating a broad platform of knowledge - cf. [1] and the many references therein, which among other things sum up FTS' aggregated findings wrt. international trends and state-of-the-art. This knowledge platform served as a starting point for SWOT analysis of NTNU's current technology education [2] and subsequent quality development in the FTS programme portfolio [3]. By February 2021 – based on the above analyses and findings – the project had also created a holistic conceptual framework for the future FTS study programme portfolio, consisting of a *vision*, *principles* and *competence profiles*. The vision is:

NTNU's technology programmes educate creative world-class graduates – able and willing to contribute to a better world and a sustainable future.

The *FTS principles* were developed as systemic guidelines for further portfolio development to realise the vision, and adopted by NTNU's Rector in June 2021. At 'short heading' level, the FTS principles are summed up in Fig. 1:

Figure 1 The 10 FTS Principles.

The term *holistic competence* in Principle I refer to the FTS *competence profiles,* which consist of 12 *competence objectives* that students should have achieved upon graduation. FTS has developed such profiles for bachelor engineering programmes, 5-year integrated master programmes in technology, and PhD programmes. The 12 objectives are divided into five categories, with digital competence and sustainability competence *embedded into* the objectives across categories [2].

The remainder of this paper is organised as follows: Section 2 describes the methodology used when developing both the above framework and the subsequent roadmap for implementation. Section 3 summarises the roadmap for implementation, with Main Actions (MAs) and Prioritised Measures (PMs) supporting the vision, principles and competence profiles. Subsections 3.1 – 3.6 discuss the individual MAs and selected PMs under each MA, while Subsection 3.7 outlines procedural risks and recommendations related to implementation. Section 4 briefly summarises the contribution of FTS and some future challenges and possibilities to follow.

2 METHODOLOGY: KNOWLEDGE FOUNDATION AND THEORY OF CHANGE

The FTS results have been developed in dialogue with key stakeholders [4], the main development done by a core project team of faculty and students, co-led by the FTS project manager and coordinator. The initial phase consisted of an outside-world analysis focusing on future needs, technology trends, and recent and expected developments in the higher education (HE) sector [1]. Through literature studies (cf. reference list in [1)], interviews, workshops, stakeholder meetings, study trips, and participation in international meetings, we identified state-of-the-art and expected trends in engineering and technology education, expectations and feedback from employers and alumni, and governmental expectations. These insights were subsequently "triangulated" with faculty and student input, views from a Nordic university expert group, and official university statistics, strategies and policies. Results were used to propose future-fit graduate *competence profiles* [1] and to perform a *SWOT analysis* [2]. Subsequently, a holistic *framework for future development* was developed [3]: Following a *Theory of Change* (ToC) methodology [5] we formulated the above *project vision* (in ToC terminology, *ultimate outcome*), and eight *long-term outcomes* (LTOs) to support the vision. Furthermore, we identified the 10 *FTS principles* – in ToC terms, *preconditions* – most essential for realising the LTOs [1, 3]. Finally, drawing on experience from FTS pilots, additional surveys by cross-faculty working groups, and integration of FTS perspectives into regular NTNU processes, we assembled a list of *interventions* identified as potentially helpful in realising the FTS principles. Those interventions considered to potentially have most impact – from now on referred to as *prioritised measures (PMs)* – were then clustered under 12 MAs, to create a roadmap for implementation.

3 RESULTS: MAIN ACTIONS AND PRIORITISED MEASURES

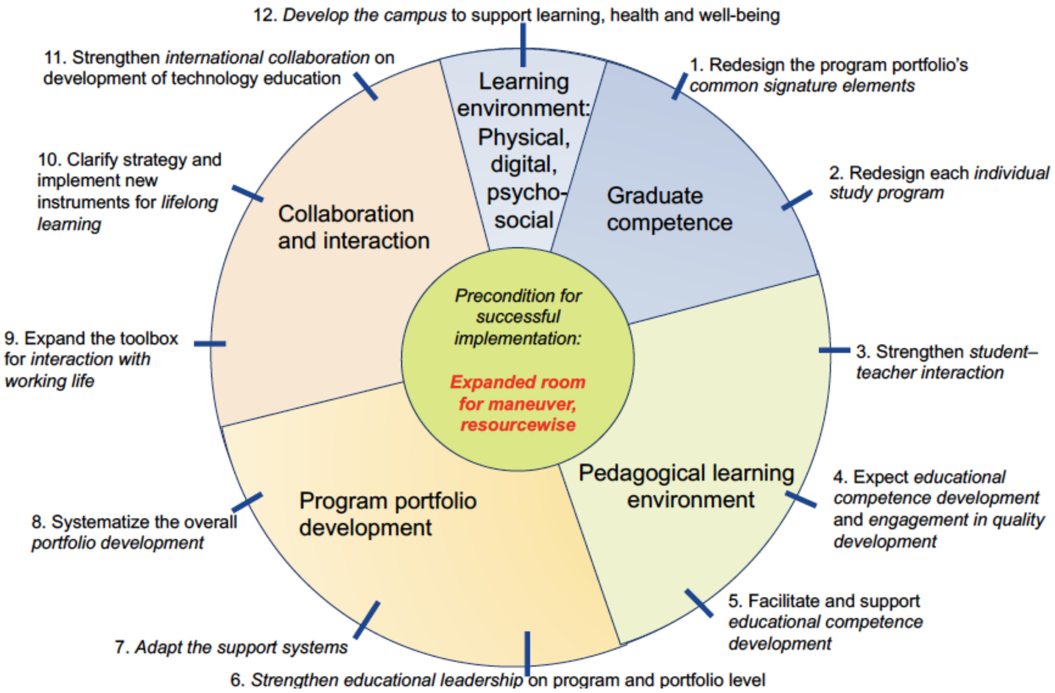

Figure 2 Overview of FTS' recommended Main Actions (MAs).

The core of the FTS roadmap for implementation are the 12 MAs, distributed across the five *quality areas* covered by the 10 FTS principles. In addition, we propose an ‘umbrella action’, *Expanded resource-related room for maneuver within the education area*, which spans all quality areas and is deemed necessary to enable implementation of the 12 MAs. At ‘heading’ level, the MAs, their distribution between quality areas, and the ‘umbrella’ action are illustrated in Fig. 2.

3.1 Main Actions for future graduate competence profiles

MA1: *Redesign the programme portfolio’s common elements and signature courses.* This MA supports FTS principles I and II. Elements and courses shared between many programmes in the FTS portfolio include: *Introduction to the Engineering Profession, Introductory Course in Philosophy, Technology Management, Experts-in-a-Team,* and common courses in mathematics, statistics and IT. *PMs* include:

- Review and revise the content and pedagogical approaches in all common elements and signature courses (using FTS principles III – V as guidelines)
- Establish dedicated introductory courses and sequential ‘ladders’ of core courses in all engineering and technology programmes
- Integrate team-based and project-based learning on authentic and ‘wicked’ problems in courses from the early phases of the programmes.

MA2: *Redesign each individual study programme.* This MA supports FTS principles I and II. MA2 does the same for the *programme-specific* elements as MA1 does for the common elements. Together they lead to a complete redesign of each programme - an operation at the very core of the FTS implementation. *PMs* include:

- During its next periodic review, gap-analyse each study programme against FTS principles I - VI and the FTS competence profiles
- From the general FTS competence profiles, derive a programme-specific competence profile and a Learning Outcome Description
- Using e.g. a programme-to-course mapping matrix, redesign each programme’s course plan, learning activities and assessment methods to align with the new profile and FTS principles, and create an *integrated programme description* [6].

3.2 Main Actions for pedagogical learning environment

MA 3: *Strengthen Student-Teacher Interaction.* This MA supports FTS principles III and IV. It is known to be important for students’ motivation, retention and learning that the *first years of their studies* promote learning, belonging, well-being and identity. Hence *PMs* include:

- Prioritise more teaching capacity to the first part of the study programmes
- Strengthen collaboration between programme core and discipline departments, to facilitate more contextual learning in e.g. mathematics and statistics courses
- Strengthen along-the-way assessment, student feedback and dialogue
- Focus on teaching as a *collective responsibility*, and *collaborative teacher teams*.

MA4: *Expect educational competence development and engagement in quality development.* This MA supports FTS principle V. NTNU’s current guidelines and personnel regulations clearly emphasise the importance of documented educational competence for appointments or promotion, but should be more clear wrt. *expectations on the actual use of such competence in development of educational quality after appointment.* The *PMs* are therefore:

- Revise guidelines for academic appointment and onboarding to emphasise educational development
- Discuss educational competence and quality work in annual appraisal interviews.

MA5: *Facilitate and support educational competence development.* This MA supports FTS principle V. Here, the following points have been identified as particularly important: That a relevant *offer of courses* and a good *support apparatus* are available, that teachers are given *time* to develop educationally, that *heads of departments* and *study programme managers* also develop educational competence, and that the institution recognises *the value* of educational competence development and quality work. The *PMs* therefore include:

- Further strengthening institutional support and course offerings for educational competence development – and freeing up teachers' time to use it
- Strengthening NTNU's *Centre for Science and Engineering Education Development* (SEED), and establishing didactic resources at individual faculties
- Creating FTS-specific development modules for study programme managers, and including basic educational competence modules in NTNU's development programme for Heads of Department
- Revision of NTNU's incentive structures related to educational development.

3.3 Main Actions for programme and portfolio development

MA6: *Strengthen educational leadership at programme and portfolio level.* This MA supports FTS principles VI and VII. *PMs* include:

- Revise mandates and clarify process descriptions in the education quality system
- Strengthen dialogue between study programme leaders, faculties and departments on programme development, and provide study programme leaders with dedicated programme development funds
- Create arenas promoting educational dialogue and culture building, and dissemination of educational practice, across study programmes and faculties.

MA7: *Update NTNU's support systems for learning, and for educational quality work.* This MA supports FTS principles VI and VII, and shall ensure that NTNU's educational support systems are appropriate, functional and suitable for services and quality processes which are important for FTS implementation. *PMs* include:

- Adapt administrative IT systems and learning support systems to actively facilitate programme and portfolio development in accordance with FTS principles
- Facilitate automated data capture to enable knowledge-based educational quality development. In particular, strengthen *the programme perspective*.
- Enhance NTNU's ability to analyse societal needs and technology trends, to strengthen the knowledge base for portfolio development and dimensioning.

MA8: *Enable more holistic programme portfolio development.* This MA supports FTS principle VI. *PMs* include:

- Assess and if necessary revise the structural constraints for NTNU's programme types, to ensure they are aligned with FTS principles and competence profiles
- Regularly revise the overall FTS portfolio's orientation, balance and scope with particular focus on academic-strategic *relevance*, academic and economic *sustainability*, good *communicability* and appropriate *agility.*

Note that MA6 and MA7 support MA8 - educational leadership and well-functioning support systems are both vital to programme portfolio development.

3.4 Main Actions for collaboration and interaction

MA9: *Expand NTNU's toolbox for collaboration with working life.* This MA supports FTS principle IX. *PMs* include:

- Introduce elective courses giving ECTS credits for *supervised professional practice* in all technology and engineering programmes.
- Strengthen strategic working life collaborations on *projects and student assignments*, at all levels from individual courses to master's and PhD theses.
- Expand *industry sabbaticals* as a collaboration instrument.
- Link *Business Networks* to all study programmes, focusing on programme recruitment, retention and relevance.
- Develop a scheme for *practice-oriented international student exchange*.

MA10: *Clarify the institutional strategy on lifelong learning and develop instruments for its implementation.* This MA supports FTS principle IX. Lifelong learning (LLL) has been high on the political agenda for several years, and the FTS mandate particularly emphasises this issue. *PMs* include:

- Develop a clear institutional strategy and associated new tools for LLL
- Facilitate open online access of learning resources in all ordinary courses
- Incentivise development of *small, digitally delivered course modules* – facilitating future micro-credentials, cross-disciplinary course design and integrated learning.

MA11: *Strengthen international collaboration on development of technology education.* This MA supports FTS principle VIII, and serve to heighten NTNU's international visibility, and enable sharing with and learning from international education networks. *PMs* include:

- Stimulate NTNU's teachers to participate in international education networks
- Prioritise participation in international education initiatives and consortia where NTNU can be inspired by internationally leading technical universities
- Link international student exchange agreements systematically to institutional collaboration on educational research and development

3.5 Main Action for physical, digital and psychosocial learning environment

MA12: *Develop campus solutions for learning, health and well-being.* This MA supports FTS principle X. NTNU's ongoing *Unified Campus* (UC) project [7] aims to gather NTNU's academic communities in Trondheim from scattered locations to one unified campus. The UC project's *Thematic User Groups (TUGs)* on *Learning Spaces* and *Campus Hubs* have recently developed principles for learning space and campus hub development which we view to be in line with FTS' principles. The *PMs* are thus:

- Develop new learning spaces and campus hubs according to the principles developed by the corresponding TUGs in NTNU's UC project.
- Establish a physical 'Learning Hub' centrally located at NTNU's campus, as a user-centered '*one stop shop'* support centre for teachers in their development of educational competence and new forms of teaching.

3.6 Enabling Main Actions by increasing resource-related room to manouver

It is not realistic to carry out the MAs and associated PMs without expanding – at least temporarily - the *resource-related room for maneuver* within NTNU's education area. There are significant cost drivers related to, e.g., capacity building, competence development, infrastructure development, and pedagogical renewal. FTS therefore proposes the enabling 'umbrella action' *Expanding the resource-related room for manouver within education,* with the following PMs:

- Establish *'NTNU Education Boost 2030'* – a temporary institutional initiative to increase strategic investment in education, to restructure the educational portfolio and improve its quality, and thus reduce drop-out rates, strengthen throughput and improve recruitment - and over time increase education-related income
- Critically review resource use on teaching and assessment in the FTS portfolio - to uncover activities and practices that should be deprioritised, changed, or terminated – so that resources can be reallocated to support FTS implementation
- Strategically re-dimension the FTS portfolio (programmes and courses) to ensure that long-term portfolio development can be carried out on the desired quality level within the resource frame expected to be available after 2030
- Actively seek to expand funding within the field of education by means of external sources, e.g., project funds from the Norwegian Directorate for Higher Education and Skills or Erasmus+, and industry co-funding e.g. for professorships, education infrastructure, continuing education, and internships.

3.7 Responsibilities, risks, and procedural advice

FTS' final report [2] includes a tabular overview of all MAs and PMs, with proposed timelines, qualitative assessment of resource needs, and assigned main implementation responsibles. To maximise clarity, it also contains six sub-tables focusing on one main responsible each: The Rector, NTNU's executive committees for engineering education, faculties, departments, programme leaders, and course coordinators. Table 1 shows the PMs where the *departments* are main responsibles.

Table 1. Prioritised measures for which the departments are to be primarily responsible.

Quality Area	MA	PMs for which the departments are primarily responsible
Pedagogical learning environment	*3: Strengthen student - teacher interaction*	3.a: Prioritise more teaching capacity to lower-year courses
		3.d: Facilitate collective teaching responsibility (for the dept's courses)
	4: Expect educational competence development and dedicated quality work	4.b: Discuss educational competence and quality assurance work in performance assessment interviews
	5: Facilitate educational competence development	5.a: Develop support and courses for teachers' educational competence development – and free up time for them to use the courses (department's responsibility is to free up time for its own teachers)
		5.b: Develop subject-specific didactic resources at departmental level
Collaboration and interaction	*11: Strengthen international collaboration on technology education development*	11.a: Stimulate teachers to participate in international education networks

In Oct. 2021, Dr. *Ruth Graham* did a snapshot FTS review [8], identifying implementation-related risks. Graham found that *"the single biggest risk facing the successful delivery of the FTS vision appears to be … the governance and ownership of the change effort post-January 2022."* In response, FTS has given NTNU the following *procedural advice* regarding the change process:

1. *The Rector, executive committees, deans, department heads, study programme leaders and course coordinators must first take ownership of the FTS proposals.*
2. *Subsequently, carry out a broad, thorough anchoring and motivation process*.
3. *Then make and communicate clear decisions on MAs and PMs to be prioritised.*
4. *All parties assigned as primarily responsible for adopted decisions must then be given a clear mandate and resources to follow up their responsibility*.
5. *The follow-up should be integrated in NTNU's regular, periodic quality processes.*
6. *Re-schedule resources to support prioritised follow-up at all organisation levels*.
7. *Link reasonable indicators to the follow-up - and ensure that they are monitored*.
8. *Along the line, gain experience by running pilot projects within selected areas.*
9. *For the first two years, implement a central support function for coordination, communication and various operational work related to the FTS follow-up.*

4 SUMMARY

The FTS roadmap has been designed to give NTNU's technology and engineering education a significant and systemic boost. The most important job – the implementation - is now underway; the final report is subject to organisational review in the spring of 2022, with actual implementation expected to start in the fall. This will require wise, visionary and inclusive leadership, prioritisation of fresh resources to education, and commitment, motivation and effort from the entire organisation. Several FTS proposals challenge established NTNU traditions, frameworks, cultures and practices. However, if successful, the change process should provide great opportunities and could potentially increase NTNU's international visibility.

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APLICATION OF A GAMIFICATION LEARNING SYSTEM IN MECHANICAL ENGINEERING STUDIES

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Keywords: *Gamification; game-based learning; improving classroom teaching; mechanical engineering; Interactive learning environments*

ABSTRACT

The purpose of this study is to examine the effects of using a gamification tool as a new teaching strategy. Specifically, Kahoot! is evaluated as a tool for enhancing student learning. We test the tool empirically in a university class setting in an engineering degree, namely as part of the laboratory sessions of the subject Mechanism and Machine Theory during two consecutive academic years. The students were randomly divided into three different groups (control group, gamification group and writing group) and their results were evaluated depending on the learning method applied during the class. In terms of gamification, this project introduces real-time feedback to stimulate the interest of students and help them use the typical tools and methodologies of game-based learning. The analysis of their performance in the laboratory exam shows significant differences between the group that used gamification and the groups that did not. The study concludes that game-based elements and competitive activities enhanced student performance and recommend their use in educational environments to support the learning process.

1 INTRODUCTION

In recent years game design elements have started to be used for non-playful purposes [1]. Although the term is still being revised conceptually, gamification can be defined as using game-based mechanics, aesthetics and thinking to engage people, motivate action, promote learning, and solve problems [2]. In education, the idea is to motivate and stimulate students by using activities other than traditional ones, and facilitate – almost without them being aware – teaching-learning itself, especially in a social context in which student engagement needs to be increased [3].

Bearing in mind that the objective is to gamify the process not the outcome, it must be clear that gamification is not a panacea: it provides new tools but it is not the solution to all problems or applicable to all situations. Rigorous studies are required to fully examine the effects of gamification and determine how learning is best achieved.

In general, gamification techniques have positive effects on the involvement and motivation of students [3]. Gamified learning environments contribute to the learning and teaching process by raising levels of engagement, creating enjoyable learning environments and ensuring active participation [4–6]. However, some studies have not identified any significant effects on learning or have even detected worse academic results when students are forced to use game elements [7, 8]. The present study aims to provide new evidence on the effects of gamification in the classroom.

Personal response devices (PRDs) appeared at the beginning of the 21st century and they consist of an emitter and a receiver that, together with the corresponding software, enable teachers to ask their students a multiple-choice question (the question is projected on a screen) and students to send an answer using their individual control or *clicker*. Clickers provide a simple way to generate an atmosphere of student interaction that can enhance teacher-student communication. These systems increase attention levels, discussion, participation and engagement.

Kahoot! is a free virtual tool that has gained in popularity among teachers for its user-friendly nature and its ability to establish working dynamics in the classroom. It is highly appreciated by students. *Kahoot!* allows teachers to create surveys, questionnaires, puzzles and debates, and obtain students' answers in real time. Various studies on *Kahoot!* agree that this tool improves participation and the positive relationship between class members [9–11].

Mechanism and Machine Theory is a core subject taught in the fourth semester of the Degree in Industrial Engineering at Universitat Politècnica de Catalunya. It is one of the first times that the Industrial Engineering students have come into contact with the world of mechanical engineering. The evaluation of the laboratory sessions prior to this subject had not given expected results: the percentage of students who passed the practical exam was very low, and the teachers considered it a problem since it suggests that students were not able to put into practice the knowledge they had acquired in the theory classes. On average, the percentage of students passing the course is 70%, whereas the percentage passing the practical examinations is 40%, notably lower.

We hypothesize that the introduction of gamified feedback will help to highlight the most important concepts at the end of each laboratory session, and therefore, improve the learning process. The second hypothesis of this study is that the first of these two factors (gamification) is more important than the second (the feedback itself). In order to test this hypothesis, the questions that the students in the gamification group were asked were also presented to another experimental group in which students did a written test without using *Kahoot*!. The solutions of the test (feedback) were also provided after the practical session.

2 METHODOLOGY

The present study uses an empirical-analytical methodology to study gamification as a tool in laboratory sessions. The subject Mechanism and Machine Theory has a large number of students each semester (between 270 and 320) so the students were randomly distributed into 11 laboratory groups taught by 4 different lecturers. The aim of our intervention was to improve learning in the laboratory sessions.

A test questionnaire has been introduced as a feedback tool. Quick feedback helps students become aware, and they have greater perception of what has happened in the laboratory. This feedback has been introduced as a test questionnaire that has to be answered in the last 15-30 minutes of each session.

Two different feedbacks are analyzed. The first uses *Kahoot!* questionnaires. Since *Kahoot!* is a fast response system for the student, it is expected to be effective at improving knowledge retention and skill acquisition. The second uses a traditional questionnaire which, therefore, involves no competition or cooperative learning. To determine the effect of introducing not only a feedback tool but a feedback gamification tool, the laboratory groups were divided into three groups:

- An experimental group given feedback through the *Kahoot!* questionnaires– (Gamification group, GG). These learners use the mobile version of the app.
- An experimental group given a written test at the end of the session (with the same questions as in *Kahoot!*), acting as reinforcement and feedback, but without the other components that *Kahoot!* may have (Writing group, WG).
- A control group subject to no intervention (Control group, CG).

The students were divided up in this way to avoid teacher and timetable factors. Table 1 summarizes the number of students in each group. Note that some students do not participate in the laboratory sessions.

Table 1. Overall number of students for each group and academic year

Number of students	**2016-17**	**2017-18**
Gamification Group – GG	37	41
Writing Group – WG	115	86
Control Group – CG	113	100
Not attending	41	56
Total	306	283

Academic performance was assessed by comparing the marks of students in each of the pedagogical groups. The mean mark, standard deviation and number of students who passed the exam were calculated for each evaluation. In this work we focus on three laboratory sessions. Along the text, M_{lab1} is the mark for the first laboratory exam (assessing sessions 1, 2 and 3). A Student's T-Test was also used to find significant differences between the experimental (GG and WG) and the control (CG) groups.

Therefore, for the GG the relation between the *Kahoot!* test score and the grades in M_{lab1} was studied. Likewise, for the WG, the relation between the writing test score and the grades M_{lab1} was examined. To this end, linear correlations were calculated and Pearson, Spearman and Kendall coefficients determined.

Finally, whether or not there was a teacher effect was studied (that is to say, whether a particular student gets a better or a worse mark depending on the teacher who has taught the subject). Therefore, the students were grouped according to the lecturer who taught the sessions and a Student's T-Test was used to determine significant differences between the four groups.

3 RESULTS

Because feedback is now a part of laboratory sessions 1, 2 and 3, differences in the laboratory exam 1 marks (M_{lab1}) can be expected among the three groups. During the academic year 2016-17, 62.16% of the students who took part in the gamification passed the exam while only 54.87% of the control group and 58.26% of the writing group did the same. Similarly, during the academic year 2017-18, 87.80% of the students who took part in the gamification passed the exam while in the control group and the writing group the percentages were 74.74% and 77.91%, respectively.

Moreover, it can be seen that for laboratory exam 1 (M_{lab1}), the mean grade obtained by the students who took part in the gamification sessions (5.59±2.43, academic year 2016-17; and 6.90±1.68, academic year 2017-18) is more than one point higher than the control group (4.50±2.17, academic year 2016-17; and 5.75±2.30, academic year 2017-18). However, this difference is not so clear for the writing group (4.71±2.37, academic year 2016-17; and 5.57±2.24, academic year 2017-18). A Student's T-test between GG and CG demonstrated that there is a significant difference between these two groups (p-value < 0.05). The differences between the WG and the CG group are not statistically significant.

Figure 1 shows the boxplot obtained for M_{lab1} for both academic years and for each teaching methodology. The central block is delimited by the position of Q1 and Q3 quartiles and the line representing the median is drawn in the box. It can be seen that the median is also higher for the gamification group than for the writing and control groups.

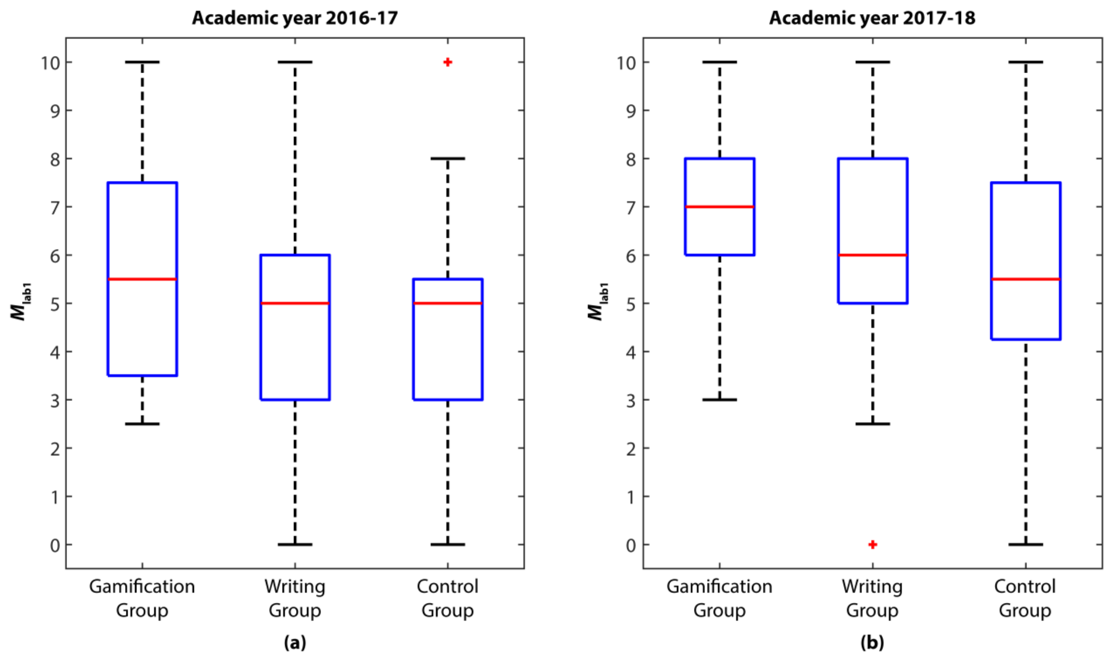

Fig. 1. Boxplot of laboratory exam 1 marks. (a) Academic year 2016-17 (b) Academic year 2017-18.

Differences between GG, CG and WG are not presented for other evaluation marks obtaining during the course. This could be a way to ensure that students are randomly distributed among groups. Differences only appear when a gamification methodology is applied.

The relation between the grades obtained in feedback tests and the laboratory 1 exam was studied. As well as the *Kahoot!* score (based on both correctness and speed of the answers), the grade the students would have be given in the final exam was calculated. Figure 2 shows, the relationship between the calculated *Kahoot!* grades ($M_{Kahoot!}$) and the grades obtained by students on the laboratory exam 1 (M_{lab1}) for the gamification group (GG). Similarly, Figure 3 shows the relationship between the writing test marks (M_{WT}) and the ones obtained in the laboratory exam 1 (M_{lab1}) for the writing group (WG). The graphs also show the polynomial regression line that adjusts these values and the corresponding R^2 parameter.

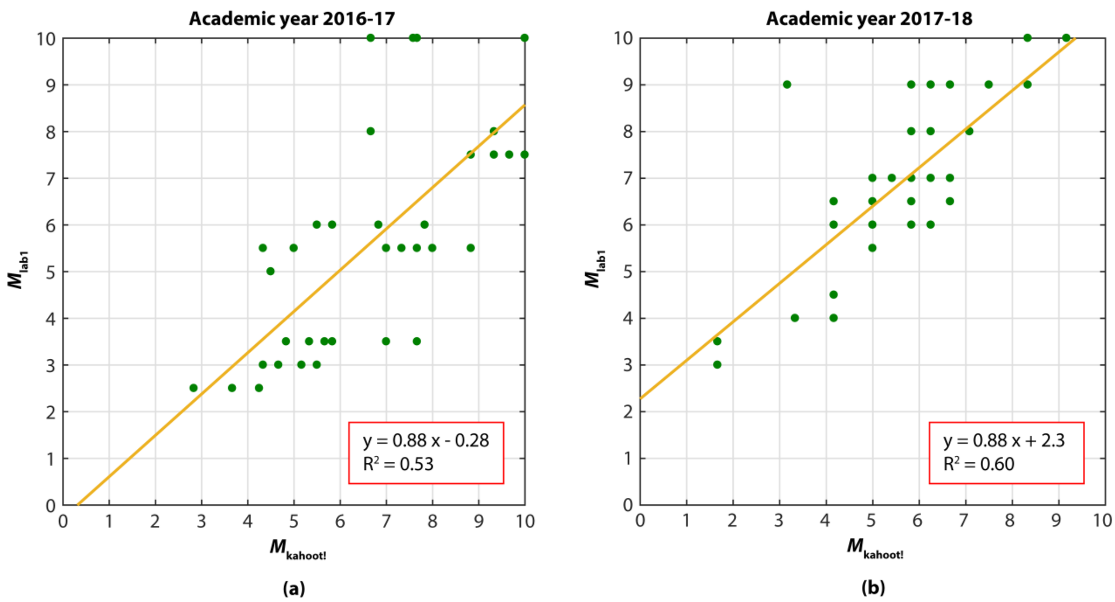

Fig. 2. Scatter graph of the lab exam 1 marks (M_{lab1}) versus the Kahoot! marks ($M_{Kahoot!}$). (a) Academic year 2016-17 (b) Academic year 2017-18.

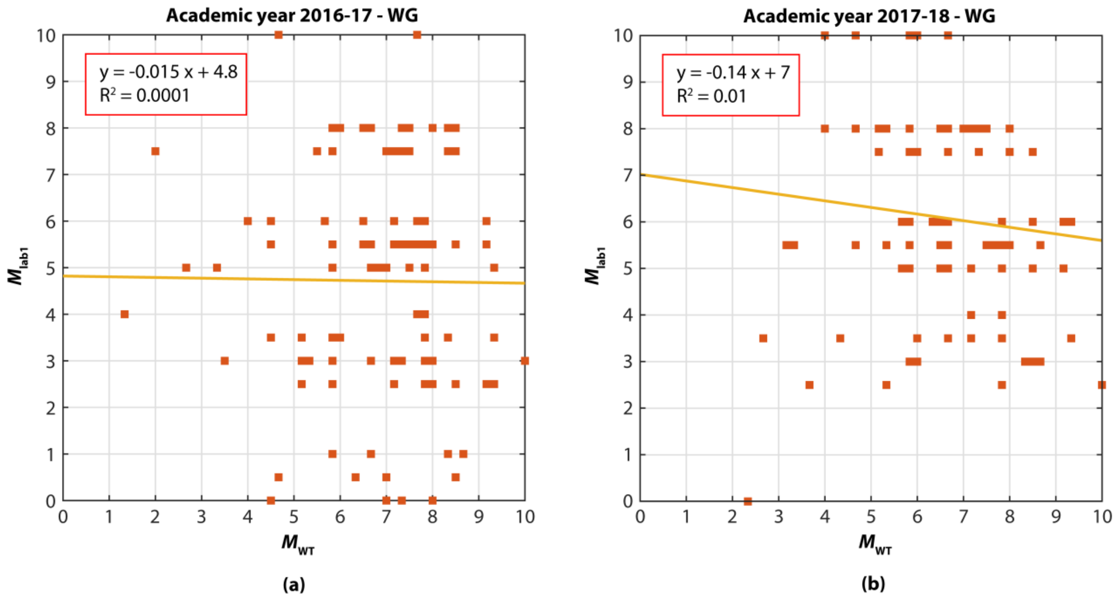

Fig. 3. Scatter graph of the lab exam 1 marks (M_{lab1}) versus the writing test marks (M_{WT}). (a) Academic year 2016-17 (b) Academic year 2017-18.

Three different correlation coefficients (Pearson, Spearman and Kendall) and the p-values of the statistical tests were calculated. For GG, the p-values were much lower than 0.05, so there is a significant positive correlation between the marks obtained in the *Kahoot!* test and the ones obtained in the laboratory 1 exam (correlations between 0.5 and 0.7 depending on the indicator used). However, the correlations for the writing group are not significant.

The teacher effect was also analysed. As explained above, the sessions are taught by four different lecturers. For this analysis, students were grouped according to the lecturer who taught their laboratory session. However, the Student's T-test does not detect any significant differences between the four groups studied (p-value > 0.05). Therefore, it cannot be affirmed that the teaching staff has an effect on the grades of the students.

4 SUMMARY AND ACKNOWLEDGMENTS

The main goal of this study was to analyse whether a gamification tool could improve learning in the laboratory sessions of the subject Mechanism and Machine Theory. For this purpose, during two consecutive academic years, we divided the students into three groups each of which was subject to a different methodological intervention. At the end of the first three sessions, the gamification group (GG) answered a *Kahoot!* questionnaire; the writing group (WG) answered the same questionnaire but on paper, and the control group (CG) was not given a test of any sort.

The results show that:

- The gamification group had a higher success rate in the laboratory exam (Laboratory exam 1) than the control group. Moreover, on this evaluation, the average grade of GG students was statistically greater than the average of

CG students. Furthermore, the grades of the other evaluations do not show these differences. It can be seen that gamification has a positive effect on grades.

- The writing group shows no significant improvement with respect to the control group. When the feedback is not gamified, it does not enhance academic results. These results suggest that gamification is the key to the improvement not the feedback itself.
- A statistically significant positive correlation was detected between students' Kahoot! scores and laboratory exam 1. This correlation fulfils one of the initial objectives of the study, which was to provide students with tools (questionnaires) for self-evaluation so that they could better manage their learning process.
- No significant differences were detected in the grades of the various groups who did laboratory exam 1. This reveals that it was not the lecturer of the laboratory session who marked the difference but the intervention itself.
- As has been mentioned, there was a need to elucidate whether *Kahoot!* is effective or not. The reasons why it seems to improve active student learning, participation and retention of concepts or why it is no guarantee of better learning need to be determined. In the light of the results presented, in general it seems that gamification has provided a (modest) increase in the teaching-learning process in the laboratory practicals of the subject Mechanism and Machine Theory.
- Finally, from a general perspective, further educational research is needed to evaluate whether enjoyment and, in this case, the use of game-based student response systems really help with teaching and learning or are simply more fashionable at present in the field of education.

The authors would like to thank the students who participated in the study.

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A MATHEMATICS PEER ASSESSMENT PROCESS FOR FLEXIBLE MODES OF DELIVERY

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ABSTRACT

Educators have experienced significant challenges managing assessment processes over the last two years, particularly when converting in-person interactive and group-based activities to an online format. This was of immediate concern during the initial stage of the Covid-19 pandemic, when interim measures for online assessment were introduced rapidly without the benefit of prior planning and design. As we emerge from the emergency phase of the pandemic, it appears there will be lasting changes to delivery and assessment in higher education, involving more hybrid and blended solutions. This paper discusses how an on-campus peer feedback assessment process for mathematics has been converted to a digital format to facilitate flexible modes of delivery either on-campus or online. A weekly paper-based peer-feedback process had been previously established in our large (150+) first-year engineering mathematics class. The new process involves weekly submission of work through the university Learning Management System (LMS), Canvas, which is peer marked by students using model video solutions for selected questions. Students complete a rubric and provide comments. After each session, students complete a reflective journal, considering their work over the week and the comments they have received. Engagement with the new flexible process has been shown to be comparable to the old system, while the quality of feedback given to peers in the online process is superior to those provided in the paper-based system. The system has been shown to be robust when rapid changes in delivery modes occur.

1 INTRODUCTION

1.1 Peer assessment and reflection

Peer assessment has been used as a tool across a number of disciplines to encourage students to think about how assessments are evaluated and make critical judgements about quality of work [1], and has been considered to be a fundamental

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skill that graduates will need in their future careers [2]. A number of studies over the years have highlighted the benefits for students in engaging in peer review and assessment processes in mathematics. These include developing critical thinking skills, increasing agency over their own learning and improving outcomes [3-5].

1.2 Context of module and the assessment process

The stage 1 mathematics module in the School of Mechanical and Aerospace Engineering is a large core module, typically with 150+ students, taken by all year 1 students from the mechanical, aerospace and product design engineering pathways. Prior to the onset of the Covid-19 pandemic, the module was delivered by means of a traditional two-hour lecture, followed by a one-hour “feedback session”. The feedback session format was developed and introduced in the 2016-17 academic year [6] and involved students completing weekly worksheets in a logbook, then attending a session where they worked in a small group. At the feedback session some model answers were demonstrated on the board, and students marked their peers’ work, making some comments. After the session, students wrote a short weekly reflection, and at the end of the year submitted their entire logbook along with a longer reflection piece. This process worked well for several years as an in-person activity that encouraged weekly participation, interaction with peers and active learning. This continuous assessment element contributed 40% of the module mark, with the other 60% from a final examination. The continuous assessment element was intended to evaluate the ability of the students to reflect on their own work and make improvements, and develop their transferable skills over the year such as technical communication and groupwork, while the examination tested their mathematical ability (Table 1). For this reason, it was compulsory for students to pass both elements in order to pass the module.

Table 1: Assessment weighting and major learning outcomes

Continuous Assessment	**Written Exam**
Based on submission of worksheets, reflections and contribution to peer feedback	End of year
worth 40%	worth 60%
Tests Learning Outcome: evaluate and reflect on the quality of your work and learning.	Tests Learning Outcome: identify and apply appropriate mathematical techniques for solving engineering problems
Formative and summative	Summative

After the rapid switch to online learning due to the Covid-19 pandemic, an interim solution was developed to allow the students to carry out the peer review process online using groups on MS Teams during the 2020-21 academic year. Several key issues were identified during the year, including the fact that the process was cumbersome for students, not all students engaged well and monitoring of this was very difficult for academic staff, and marking at the end of the year was extremely challenging as there were a large number of documents to look at for each student. However, a clear benefit of the process was that the quality of the feedback left by students for their peers was very high, with many leaving detailed and helpful comments every week. This constrasted with the short handwritten points that students had previously tended to make in the paper-based logbooks.

2 METHODOLOGY

2.1 Development of a new flexible process

In September 2021, the university returned to full in-person teaching for the first time since the pandemic. While issues had been found with the online peer-review process, it was not possible to return to using the old paper-based method for three reasons:

1. There were clear health and safety concerns with students sitting in close groups and passing physical logbooks around the group.
2. There was a high probability that some students would be self-isolating at different times throughout the year and so would be unable to meet their groups in person.
3. There was a possibility that teaching staff would contract Covid-19 and so would need to teach from home, or that the campus would close for a period of time and teaching would revert online.

It was also recognised that students generally spent more time writing longer and more detailed feedback comments when working digitally than they would have previously handwritten in books, and so it was felt it was desirable to retain this.

The first consideration was how to structure the assessment and determine what systems needed to be put in place for the 2021-22 academic year. In order to address the issues found with the interim online system, and the three concerns listed above, the decision was taken to manage all submission of worksheets and peer marking online, but to use the university Learning Management System (LMS), Canvas, to manage this. Students were required to submit their scanned worksheets to Canvas each week by 9am on the day of the feedback session, and were then randomly assigned three anonymous peer worksheets to review. Students could attend a computer suite, or an assigned groupwork room if they prefered to use their own devices. Students who were unable to attend in person due to self-isolation or for other reasons could access their assigned peer reviews from home. As students were working across different locations, pre-recorded video worked examples were provided, which were only made available for the duration of the feedback session via the LMS. Using the video exemplars, and through conversation with their peers and the session facilitators, students were required to give feedback by completing a rubric (Table 2) and by writing comments about the work. The set of peer scores received by each student each week was reviewed by the lecturer, any outliers in scoring were moderated, and an average value returned. This provided ongoing weekly feedback to students. Guidance was provided to students to ensure they understood that the aims of giving feedback were to be constructive and to provide opportunities for improvement, and that the benefits to themselves included: receiving regular feedback on their own work, learning from looking at others' work, developing independent learning, recognising their own strengths and weaknesses, gaining opportunities for active learning and improving reflection and communication skills.

Table 2: Rubric for peer scoring

	3	2	1	0
Effort	Clear evidence of effort in answering (even if not correct)	Good effort in answering but room for improvement	Some effort, but not satisfactory	no effort
Correctness	All correct	Mostly correct with some small errors	Mostly incorrect	no effort
Coherence	Method can be followed very clearly (even if answer not correct). Excellent annotation, notation and clear steps	Method can mostly be followed, a few steps missing or would benefit from better annotation or notation	Difficult to follow method, unclear working (even if correct)	No effort
Conciseness	Method used is appropriate and very efficient	Method is appropriate but could be simplified	Method is overly complicated or long	No effort

After the session, students transferred the reviews they gave and received into a "reflection journal", a template for which was provided, and wrote a weekly reflection consisting of around five bullet points. There was an optional opportunity for students to submit their "work-in-progress" to the lecturer for formative feedback in the middle of semester 1, to ensure that their work was at an appropriate level. At the end of each semester students were required to write a 500-word summary reflection and submit the whole journal for review by the lecturer. The breakdown of the final mark allocation for the continuous assessment piece is shown in figure 1, and includes marks for the quality of the student weekly and end of semester reflections (20 marks assessed by lecturer), the quality of feedback left by the student for others (5 marks assessed by lecturer), and the moderated peer scores discussed above (15 marks obtained from scaling the sum of each student's moderated and averaged peer reviews).

In the original paper-based system there was a requirement for students to attend a minimum of 75% of the peer review sessions to ensure engagement. To allow for more flexibility in the 2021-22 year, and to take into account that students could be working remotely, this requirement was modified to require students to complete at least 75% of the work, i.e. submitting 15 out of the 20 assessed worksheets, and providing peer reviews on at least 15 out of the 20 sets assigned to them.

2.2 Data reviewed

Data was extracted from Canvas to show the number of submissions over the year and the number of peer reviews completed. The grades across the academic year 2021-22 for the continuous assessment element are compared with the final grades for the continuous assessment from the year prior to the pandemic.

Reflection journal							
Criteria	Ratings						**Pts**
Quality of weekly reflections on own work over the week	5 Pts	4 Pts	3 Pts	2 Pts	1 Pts	0 Pts	**5 pts**
- Commentary on how difficult or easy the work was	Excellent	Very good	Good	Satisfactory	Poor	No merit	
- Commentary on particular areas of focus							
- Indication of time management							
- Indication of resources used							
Quality of weekly reflections on comments received from peers	5 Pts	4 Pts	3 Pts	2 Pts	1 Pts	0 Pts	**5 pts**
- Evidence that comments from peers are being read and reflected on	Excellent	Very good	Good	Satisfactory	Poor	No merit	
- Commentary on whether you are learning from others' work or not							
- Evidence that you are identifying areas of improvement or areas of your own good practice as appropriate from the peer feedback							
Quality of end of semester reflection	10 Pts	8 Pts	6 Pts	4 Pts	2 Pts	0 Pts	**10 pts**
- Commentary on what problems have you encountered and how have you dealt with them?	Excellent	Very good	Good	Satisfactory	Poor	No merit	
- What was especially satisfying to you about either the process or the finished piece of work?							
-What does your work this year reveal about you as a learner?							
-Have your goals changed as you have progressed through the module?							
-How have you used the feedback received to improve your work?							
-What have you seen in other students' work or learning that you would like to try in your next module?							
-How have you contributed to the group in the feedback sessions?							
-Looking back at this module, what would you like to try to improve?							
-How confident are you that you will pass this module?							
Quality of the peer feedback you left for others	5 Pts	4 Pts	3 Pts	2 Pts	1 Pts	0 Pts	**5 pts**
Is your feedback:	Excellent	Very good	Good	Satisfactory	Poor	No merit	
- Constructive?							
- Specific?							
Does your feedback:							
- Offer opportunities for improved performance?							
- Show that you are reviewing the work carefully?							
Worksheets (from peer reviews)	15 to >11.0 Pts	11 to >9.0 Pts	9 to >7.0 Pts	7 to >6.0 Pts	6 to >0 Pts		**15 pts**
	Excellent	Very good	Good	Satisfactory	Unsatisfactory		

Fig 1: End of semester rubric (marked by lecturer)

3 RESULTS

3.1 Engagement with the process

The engagement of students with the process was evaluated by comparing data from 2019-20, when the on-campus paper-based system was used, and from 2021-22 when the digital method was used. In 2019-20 there were 158 students in the class compared with 167 in 2021-22. Figure 2 shows the percentage of students who submitted each worksheet and the percentage who submitted the worksheet *and* completed their peer reviews. This is compared with the percentage of students who attended the sessions in 2019-20. Comparing the students who completed both tasks in 2021-22 (submitting worksheet and completing peer reviews) with the student attendance in 2019-20, it can be seen that the data is remarkably similar during the majority of first semester, up to worksheet 10. In the second semester some divergence is seen with the 2021-22 cohort having higher engagement in the early part of the semester, and lower engagement later. Overall, the average engagement per session was 89% with the paper-based, on-campus only system, and 88% with the digital system used in 2021-22, with students flexibly completing the work on campus or at home. It can be seen that the engagement was high for both years, with a minimum of 83% in both years, and a maximum of 96% in 2019-20 and 94% in 2021-22. It is worth noting that the module was taught by different lecturers in the two years, but engagement remained similar. This shows that using an online or blended system for carrying out peer review can work very well, and agrees with work carried out in other disciplines [7-8].

Figure 3 shows the number of students who completed different numbers of worksheets in 2021-22, and is compared with the number of students who attended a certain number of sessions in 2019-20. It should be noted that only 19 worksheets were provided in 2019-20, so the numbers have been scaled for comparison. It can be seen that almost half of all students completed all worksheets in 2021-22, while nine students (5%) failed to complete the minimum of 15/20 worksheets. It was also found that a further five students did not complete the required number of peer reviews despite submitting their own worksheets, resulting in 14 students (8%) overall failing the continuous assessment element. In 2019-20, eight students (5%) failed to attend the minimum number of sessions.

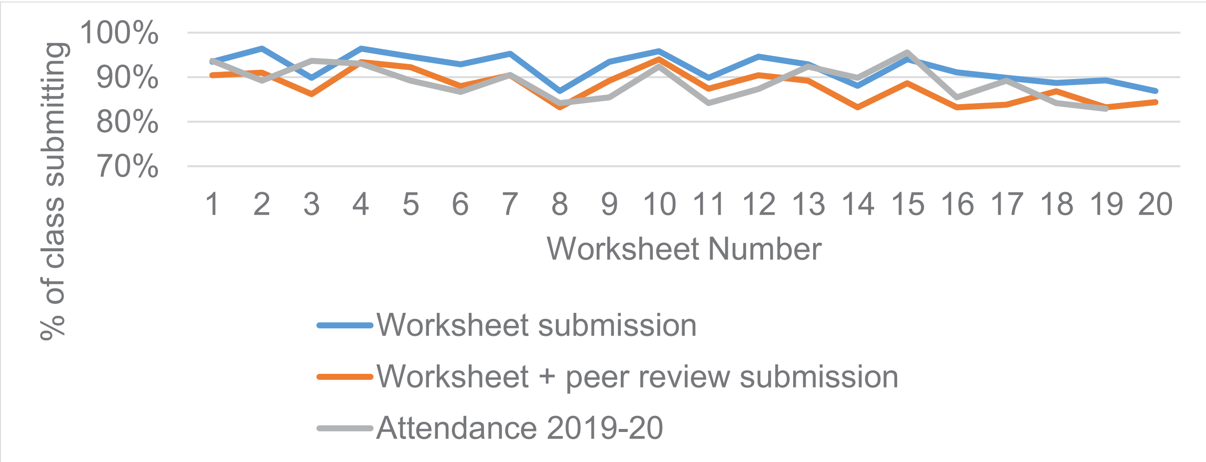

Fig. 2: Engagement with each feedback session

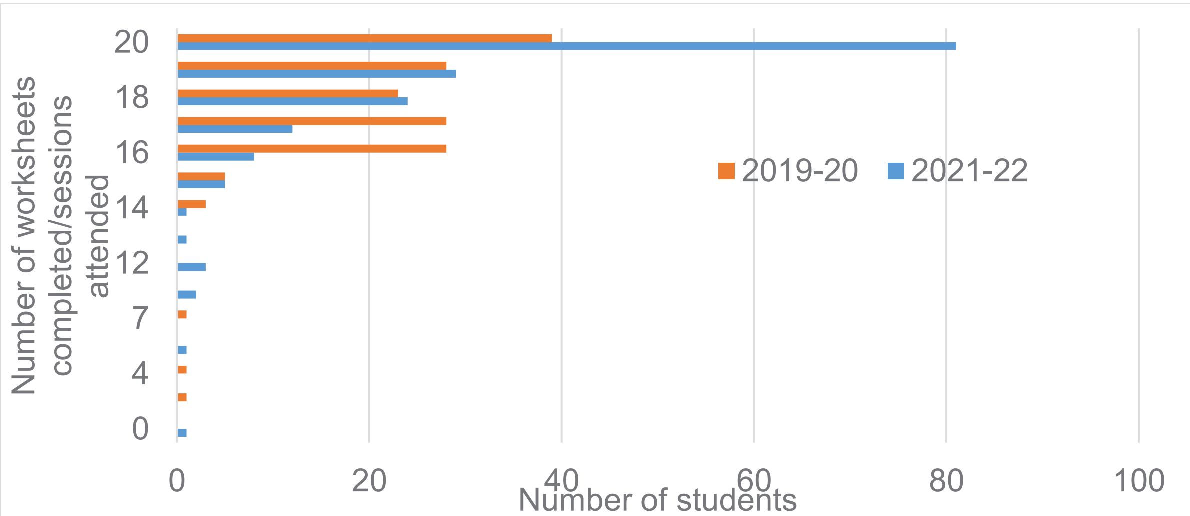

Fig. 3 : Number of students completing a given number of sessions

3.2 Grades across the year

115 students (68%) took the opportunity to submit their work-in-progress reflection journal for feedback in the middle of semester 1. The average formative grade awarded was 76%, with a standard deviation of 15%. Students were provided with rubric scores and feedback. The end of semester 1 summative submission had an average grade of 74%, with a standard deviation of 18%. The second semester submission showed an average grade of 66% with a standard deviation of 18.5%.

This drop was anticipated as semester 1 contains content that should mainly be revision to the students from their previous studies, whereas semester 2 content is likely to be new and therefore more challenging Overall the final average for the continuous assessment was 69%, compared to a 58% average in 2019-20

3.3 Student peer reviews

The average peer review scores given to each worksheet varied between 9.3 and 11.3 out of 12, with a standard deviation between 1.5 and 2.7 across the year. It was noted that there was good consistency across the worksheets, however, the scores are on the high side and may indicate leinent marking by the students, or an issue with poor differentiation by the rubric that was provided. This may need to be addressed next year to provide a better spread of marks. However, the peer scores contribute only 15 out of 40 marks and if they are extracted from the final marks for the continuous assessment, the overall average would drop to to 64%.

3.4 Student comments for their peers

As found in 2020-21 when the peer review process was carried out online, it was clear that the students provided good quality feedback for others when working digitally in 2021-22. Some examples of student feedback are shown in figure 4.

9) correct answer found using appropriate method, well done. Be careful as when you wrote inverse= (matrix), you put a value of -5/15 for the element a12. Whereas the correct value is -5/18. However, your working was clear so I was able to identify that you had found the value to be -5/18 previously and had simply made an error when writing, hence I haven't removed any marks.

Question 3 c is a very concise solution to the question with the correct answer. Well done. Question 5 e would have benefitted from a single additional step just before the final answer however it is all correct. Question 6 e gives the correct answer and an easy to follow solution. One change I would have made would be to explicitly reference the standard integral that you used. In question 8 d you have made a mistake regarding your partial fractions in obtaining -1 2 and 3 and values for the numerators. The correct answers were 2 2 and 1. Please try this question again as your integration was not what led to the wrong answer.

Figure 4: Examples of student peer comments

3.5 Adaptability and accessibility online and in person

As anticipated at the beginning of the academic year, there were times when students were unable to attend in person for various reasons including the fact that a substantial number of students tested positive for Covid-19 at various times across the year, the semester 1 lecturer tested positive for Covid-19 and delivered teaching online during the weeks corresponding to worksheets 7 and 8, and the university switched to a short period of online teaching during the weeks corresponding to worksheets 12, 13 and 14. It can be seen that during these periods the system continued to function as before with no discernable difference in engagement, suggesting that the process is robust and adaptable to rapid change. In addition, improvements in technology have made the process relatively straightforward to implement, compared to findings in earlier studies which found adapting peer review processes to online courses to be more complex and difficult [9].

3.6 Student feedback on process

Module evaluation surveys are issued to students electronically at the end of each module in the school. For this module, 57 responses were received (33.5%). Some freeform comments boxes were provided to ask students open-ended questions about what they found valuable in the module and what they would like to be improved. There were 35 comments about what students found valuable, 17 of these related directly to the peer feedback process, with students indicating it helped them to develop skills and to identify their strengths and weaknesses:

“The worksheets, along with the associated peer reviews, were very useful in developing my skills”

“The worksheets … showed me not only what I knew but what I didn’t know”

“I enjoyed the fact the assessment on the course was peer assessed as it allowed me to see how well my peers were coping with the module. It also allowed me to compare how well I was doing with the module”

There were 22 comments about areas that the students would like to see improved, with only four of these about the peer feedback process, mainly indicating that the quality of the feedback left by some students was not always helpful or accurate:

“Student feedback was mostly unhelpful. Students aren't well equipped to give valuable feedback. I found filling in my reflection journal very challenging, since the feedback I received was mostly bad.”

“I don’t like the peer review / reflection journal. Sometimes, people marking my work understood the topic less than me and tried to correct things that did not need corrected. In my opinion maths should just be an exam, like in school.”

4 SUMMARY

Converting an in-person paper-based peer review process to a digital flexible format for a year 1 engineering mathematics module has shown that engagement with the process remained high, with at least 83% participation in each session in both formats. Similar percentages of students met the minimum attendance/participation requirements. Continuous assessment marks with the new system appear to be higher than with the previous system, some of which may be attributed to the fact that peer review marks may be overly high, and this will be looked at next year, however they contribute only a minor fraction of the overall mark. Quality of the comments left for students by their peers is higher in the new system, and student opinions of the process are generally positive. This type of process could be adapted across other mathematics modules, but also many other types of engineering module to provide flexible means of students accessing and participating in continuous assessment and peer review. As this is based on only one year of data, the process will continue to be monitored and adapted as appropriate.

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EXPLORING THE PRACTICAL USE OF A COLLABORATIVE ROBOT FOR ACADEMIC PURPOSES

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***Conference Key Areas**: Engineering Skills*
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ABSTRACT

This article presents a set of experiences related to the setup and exploration of potential educational uses of a collaborative robot (cobot).

The basic principles that have guided the work carried out have been three. First and foremost, study of all the functionalities offered by the robot and exploration of its potential academic uses both in subjects focused on industrial robotics and in subjects of related disciplines (automation, communications, computer vision). Second, achieve the total integration of the cobot at the laboratory, seeking not only independent uses of it but also seeking for applications (laboratory practices) in which the cobot interacts with some of the other devices already existing at the laboratory (other industrial robots and a flexible manufacturing system). Third, reuse of some

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available components and minimization of the number and associated cost of required new components.

The experiences, carried out following a project-based learning methodology under the framework of bachelor and master subjects and thesis, have focused on the integration of mechanical, electronic and programming aspects in new design solutions (end effector, cooperative workspace, artificial vision system integration) and case studies (advanced task programming, cybersecure communication, remote access).

These experiences have consolidated the students' acquisition of skills in the transition to professional life by having the close collaboration of the university faculty with the experts of the robotics company.

1 INTRODUCTION

A collaborative robot (cobot) is an example of an industrial robot in which, basically, the measurement of force in the end effector and mechanical joints has been added to the traditional way of controlling the position and speed of the end effector in order to sometimes allow the physical contact with the human operator. A second characteristic is the elimination of the physical barrier between the cobot and the operator: through sensors and programming, the approach of the operator to the cobot translates into a reduction in the speed of the cobot and even its stoppage [1]. A third characteristic is the flexibility of the cobot's tasks, in the context of cooperation between the cobot and the operator, which allows a cobot to be started up accompanying the operator in jobs in small and medium-sized companies in tasks that were initially carried out manually (assembly).

As can be seen in the previous paragraph, one of the challenges in the implementation of tasks and processes in which the cobot and the human combine their skills to improve performance. The cobot can be useful both at the organizational level of the company and at the level of interaction with the operator [2]. In this last aspect, a cobot oriented to access and use by a human operator must allow various operators with different training to develop skills, or perfect existing ones for an effective teamwork.

It is necessary to address the practical use of cobots in higher education for various reasons, including:

a) current manufacturing processes are in transition towards a connected industry (industry 4.0) in which collaborative robotics is included as an emerging technology [3]
b) the improvement of the functionality of the cobot through programming algorithms (basic task programming, recursive programming, programming using artificial intelligence algorithms) can transform the cobot in the direction of a cognitive robot in a few years [4]

Higher education must accompany the engineering student in this adaptation. This requires changes in the engineering curriculum [5], specifically the inclusion of collaborative robotics concepts in industrial robotics subjects, the creation of laboratory practices with cobots, and the development of final degree projects.

The Section two explains the methodoly developed, paying attention to the relationship between different users. The section three explain in more detail the effectiveness of this approach in the development of three case studies. Finally, conclusions are future steps are presented.

2 METHODOLOGY

The methodology used in this work is project-based learning. The methodology has been adapted to three scenarios:

a) Subject within an engineering degree
b) Final degree project
c) Life-long learning

The agents involved in this methodology are:

a) Teachers of various subjects
b) Teachers and experts from robotics companies
c) Teachers, laboratory maintenance staff, final degree students

2.1 Subject

There are two subjects, Industrial Robotics and Computer Vision (RIVC) and Integration of Automatic Systems (ISA) that use the same laboratory resources. The first one divided in two parts show industrial robotics and the relationship with computer vision (2 h in laboratory each week, 14 th weeks). The second subject is a project oriented subject (3h in laboratory each week, 14 th weeks), with the aim to encourage students to the development of final projects in automation. Both subjects share in the experimental part the need to consolidate teamwork skills.

2.2 Final degree project

Some final degree projects have been proposed and developed [6], [7], [8], [9], [10], all of them oriented towards the integration of a collaborative robot UR3e [11] in the laboratory: development of electronic prototypes, design and programming of robotic applications. The main aim is to reduce the gap between undergraduate engineering students and professionals in electronics and automation companies. The first final degree project related to the start up of the cobot in the laboratory (two months) allowed the robot station to be shown at an open session for future engineering students (february 2020) at the hall of our school. Finally, the student published an article into an Spanish Journal as a first author [12].

2.3 Life-long learning

In this aspect, collaboration between the University and robotics companies is being promoted. Some students carry out internships and final degree projects in companies with the advice of the teaching staff.

The teaching staff provides students with the possibility of attending an annual fair (Advanced Factories) with the latest developments in industry 4.0. Students are asked to attend, meet with business experts and prepare a small document with a list of companies and future job opportunities.

3 RESULTS

3.1 Electrical gripper

The end effector is the device that, mounted on the end of the robot (or cobot) arm, allows it to perform a certain task. There are two main categories of end effectors, grippers that allow the manipulation of objects, and specific tools that allow implementing tasks such as welding, painting, etc. In academic environments, it is common to illustrate the use of robots and cobots mainly in tasks that involve the manipulation of small objects. According to this, the most commonly used type of gripper are electrical grippers.

When thinking about equipping the collaborative robot with a gripper, multiple commercial models available on the market could have been compared and one of them could have been purchased and installed on the cobot. This would have been a quick and easy solution, but it would also have been expensive. And, perhaps more important, very little would have been learned from the process. That is why, instead of acquiring a commercial gripper, the design and prototyping of it from scratch was considered as an alternative and a final degree project with this goal was proposed [10]. This option is viable, since the challenge is within the reach of students who are finishing the degree in Industrial Electronics and Automation and since the necessary means are available at the school. In addition, it is an option that has its advantages, the main ones being that both the student and the supervisor (teacher) acquire new knowledge and that the obtained product has a much lower cost than its commercial equivalent.

Taking previous considerations into account, and using as reference the basic models of adaptive electric grippers commercialized by some of the most important manufacturers (Schunk, Robotiq and OnRobot), a 2-finger parallel gripper with electrical actuation has been designed. The mechanical design is simple and it can be easily implemented with conventional 3D printing equipment. The actuation and control are based on the use and programming of a Dynamixel AX-12A servo motor and an Arduino Nano board. The result is a gripper with a maximum opening of 80mm, which allows handling objects of up to 1kg and with an opening/closing time of less than 1 second. These characteristics are comparable to those of simple commercial pliers, but obtained at a much lower economic cost: the total cost of the prototype remains around 100 euros, while a comparable commercial model can be around 1,000 euros. All the details about the mechanical, electrical and electronic design of this gripper can be found in [10].

Figure 1 shows the first prototype of the gripper. This prototype has already been installed in the cobot. It works correctly and it is going to be used extensively. Additionally, according to available economic resources and opportunities, more collaborative robots will be acquired and new copies of the gripper will be manufactured and installed with reduced effort and cost.

Fig. 1. First prototype of the 2-finger parallel gripper.

3.2 Workpiece classification using computer vision

Another relevant result of the work carried out so far has been the implementation of a complete example that combines the use of collaborative robotics with computer vision [8].

In this example, the objective is to classify objects of different types and colours that at the beginning are randomly distributed in a given area close to the robot. To do this, an artificial vision system must identify the type and location of the different objects and provide this information to the cobot. At the left side of Figure 2, a photo of the whole system is presented, where the initial zone and the destination zones and containers can be observed.

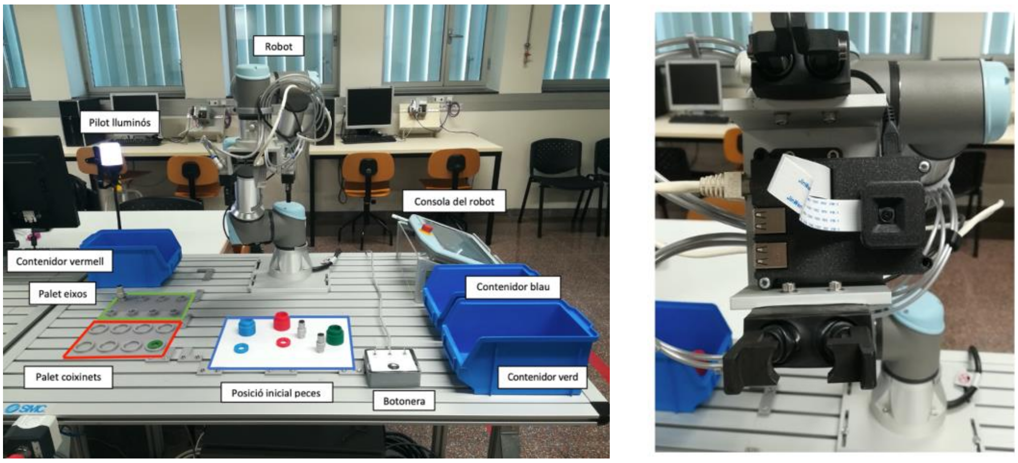

Fig. 2. Workpiece classification system: (left) whole system; (right) detail of the integrated vision system.

For the development of this example, and again following the principle that designing from scratch is much more educational and cheaper than acquiring commercial devices (the cost of an industrial vision system is also in the range of a few thousand euros), a vision system based on a Raspberry Pi and a Pi camera has been designed and integrated into the robot. The choice of the Raspberry is motivated by its small size, its low cost (not only for the Raspberry but also for the camera) and for the possibility of using a standard environment for the development of computer vision applications: Python (programming language) + Open CV (Computer Vision library). The system has been mounted on an end effector with two pneumatic grippers (which was acquired just after the cobot and before designing and prototyping the electric gripper presented in the previous section), using a custom case with a fixation system that has been manufactured using 3D printing. Communication between the Raspberry Pi and the UR3e controller is established using the Ethernet ports available on both devices. In Figure 2, at rhe right, a photo of the vision system after installation is shown.

The scope and complexity of this example makes it suitable to be used, under a PBL (Project Based Learning) methodology, as a project to be solved in the Industrial Robotics and Computer Vision subject, an idea that will be put into practice starting the next academic course.

The resolution of the project will be planned according to the four fundamental problems to be solved: recognition and location of objects; transformation of image coordinates to robot coordinates; Raspberry-UR3e communication; manipulation by the robot. The solution of these four problems will go through the programming of both the Raspberry and the UR3e. In principle, all the work groups established in class will have to solve the same project (which accepts different types of solutions), but if considered pertinent, different variants may be established, such as those that may result from considering different sets of object types.

3.3 RoboDK tutorials and exercises

Both in industry and in academic environments, off-line programming and robot simulation environments are useful. In an industrial context, this type of software tools allow programs to be developed and simulated before testing them on real robots that must finally execute them. In addition, in an academic context, the availability of simulators makes it possible to have more working groups (pairs of students) in the laboratory than the number of real robots available (in the Industrial Automation and Robotics laboratory there are eight working places equipped with PCs + programming and simulation software, while there are only three robots, two conventional industrial robots plus the new collaborative robot; each group of students spends a good part of the time at their working place and they only use one of the robots to do the final tests).

RoboDK is an off-line programming and simulation software [13]. As a programming environment, it allows robots to program robots of different manufacturers by using a same high-level graphical language (this is a double advantage since the graphic language is easier to use and it is also universal and independent of proprietary language of each manufacturer). As a simulation environment, it allows programs to be tested independently of the fact that they can later also be tested on the real robot. As a whole, it can be useful both in laboratory sessions and in theory sessions to be able to illustrate many concepts.

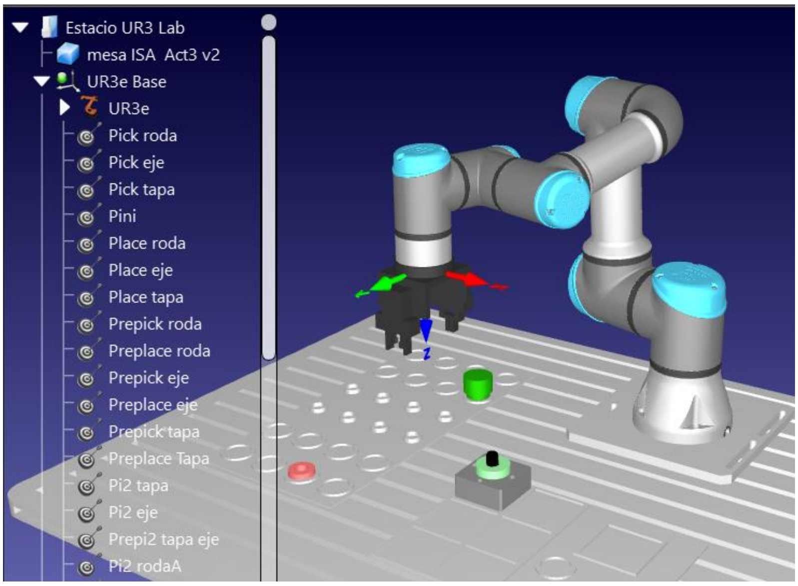

Fig. 3. Assembly example in RoboDK.

Given the potential educational utility of RoboDK, its study was proposed as part of a final degree project [9]. The result of this work was a set of basic tutorials and a set of programming and simulation exercises with different levels of difficulty (all of them documented and resolved). Figure 3 shows a screenshot of the solution of an exercise in which it is requested to program and simulate an assembly task.

Unlike the electric gripper and the parts classification system, which have not yet been used within the framework of laboratory practices of any subject, RoboDK tutorials and practices have already been used during the academic year 2021- 2022 in the subject Integration of Automatic Systems.

Thus, in the recent edition of this subject, the students enrolled (12) have carried out two 3-hour laboratory sessions about the use of the simulator and a third 3-hour laboratory session about the use of the real cobot. After these sessions, the students answered a System Usability Scale (SUS) satisfaction questionnaire with scale 0-100, obtaining a mean value of 61.2 and a standard deviation of 19.4 [14]. Figure 4 shows the response to question 5 “I found the various features of the tutorial to be fairly well integrated”, Likert scale 4 strongly agree, 0 strongly disagree.

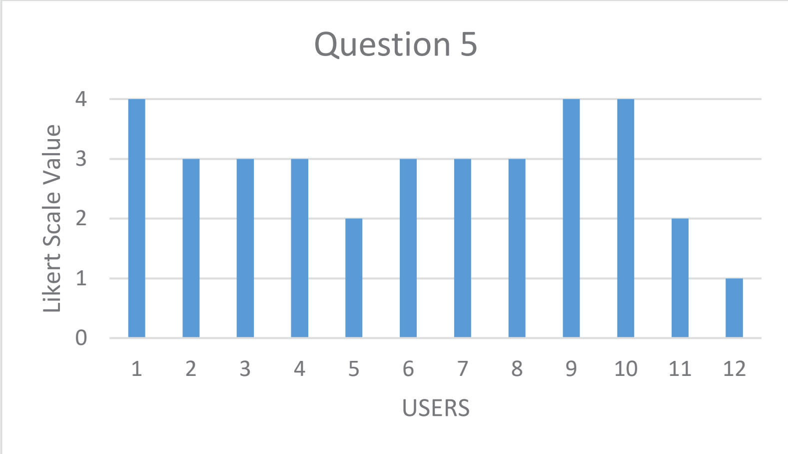

Fig. 4. Answers to question 5 of the SUS questionaire.

In this questionnaire, the students emphasize that the 3D simulator is easy to learn and use, although the quality of the tutorials must continue to be improved, since the 3D simulator interface is apparently in graphic format, while the advanced functionalities are in text format and it uses Python programming, so learning the simulator is not so easy.

4 SUMMARY AND ACKNOWLEDGEMENTS

This article shows how to promote the development of projects in industrial robotics in the teaching laboratory, achieving integration with the rest of the equipment and facilitating the learning and skills of undergraduate engineering students.

Taking into account the projects already developed, the next steps are in the direction of add a second robot and develop collaborative task between students and robots, measuring in more detail the satisfaction of the students with this approach and promoting innovation projects (design of a sensitive gripper, use of OPC UA communications in collaborative robotrics).

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STRENGTHENING LEARNING OUTCOMES THROUGH STUDENTS WORKING WITH QUIZZES

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Conference Key Areas: *Student Engagement*
Keywords: *Strengthening learning outcome, engaging students, quizzes*

ABSTRACT

Most instructors of engineering students will be familiar with students who – instead of engaging actively with a given field of knowledge – merely reproduce the curriculum at the exam. This study hypothesizes that students will achieve a higher taxonomic level of learning outcome by using a didactic tool – with a higher degree of understanding, application, and reflection as a result. We have developed such a didactic tool, Quizry, to create engaging teaching sessions through a special learning process: students producing quizzes for one another.

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We applied the French researcher Guy Brousseau's theory of didactical situations in teaching and his five phases as a theoretical basis for our study. In the first phase, the didactic contract is established between the students and the instructor, i.e. the assignment of producing quizzes is handed over. During phases 2-4, the students work with the concrete quizzes (a-didactic parts), and lastly in phase 5, recap, cohesion of learning and transfer is established.

We examined the relationship between producing quizzes and student learning outcomes through the lens of the American professor Vincent Tinto's influential three-fold model of motivation: self-efficacy, sense of belonging and perception of curriculum. The students' self-efficacy and perception of curriculum are strengthened by working with the topic several times.

Among other things, the study showed that 79% of the respondents reported that preparing quizzes for other students improved their learning outcome compared to traditional learning.

1 INTRODUCTION

1.1 Background

Most instructors of engineering students will be familiar with students who – instead of engaging actively with a given field of knowledge in class and as preparation for class – merely reproduce the curriculum at the exam [1]. This often leads to low learning outcomes and subsequently to poor grades. Furthermore, research has shown that students tend to quite rapidly forget knowledge acquired in this way: a dissatisfactory learning result for students, instructors and institutions of higher education alike. This study hypothesizes that students will achieve a higher taxonomic level of learning outcome by using a didactic tool, hereafter known as Quizry – with a higher degree of understanding, application, and reflection as a result [2]. We have developed Quizry to create engaging teaching sessions through a special learning process, i.e. students producing quizzes for one another.

We applied the French mathematics didactician Guy Brousseau's theory of didactical situations in mathematics [3], according to which teaching situations may be divided into five phases. In the first phase, devolution, the didactic contract is established between the students and the instructor, the academic problem is handed over, and the students accept the responsibility.

Phases 2-4 are generally about the students being engaged in activities. In our study, the students are preparing multiple choice quizzes, both individually and in groups, and they answer the quiz questions individually. In phase 5, institutionalization, the results from phases 2-4 are collected. This activity took the form of a joint recap of the students' answers to the quiz questions.

In our study, we examined the relationship between Quizry and student learning outcomes through the lens of Vincent Tinto's influential three-fold model of motivation: self-efficacy, sense of belonging and perception of curriculum [4]. Furthermore, we examined the relationship between Quizry and student learning.

The students' self-efficacy is strengthened by working with the topic several times [4]. The group work with the preparation of the quizzes can help to strengthen the students' sense of belonging. In addition, if students experience the work with the quizzes as meaningful, it can strengthen their perception of curriculum.

The washback effect, which has been described by several theorists, e.g. [5], says that the purpose of participating in a course, for many students, is to a large extent to be able to pass the exam with a satisfying result. By having the students prepare quiz questions for each topic, the students are forced to reflect on what they have learned, which can contribute to avoid simple reproduction.

1.2 The didactical tool Quizry

Initially we contemplated methods for engaging students more inside and outside class, enhancing their learning outcomes. Thus being able to apply and transfer that knowledge and these competencies much more easily and qualified later in their study programmes as well as eventually in their professional lives as engineers. Based on our reflections, the idea of students producing quizzes emerged. We decided on developing and implementing a study process involving quiz work as part of preparation for class and as a didactical tool in class. In addition to implementing Quizry in different study programmes, we also had the opportunity to simultaneously conduct a systematic study of how to strengthen students' learning outcomes by using Quizry.

The basic idea is, as mentioned, to engage students through quiz work and to make the students do the work, as this often results in better learning processes and outcomes [6]. For this purpose, all students are part of a quiz-group, and the quiz-groups have different tasks at each teaching session.

At the end of each teaching topic the students worked on Quizry:

Before teaching sessions all students prepare for class as usual; however, in addition we ask them individually to bring to class one quiz question with at least three plausible, valid answers and one possible answer should be the better answer.

During the teaching sessions, the students first discuss the quality of their individual questions/answers in their quiz-groups; second agree on one quiz question/answers; and third send that question to a so-called quiz-responsible group. The task of the quiz-responsible group is to produce the quiz for the teaching session, and in doing so they decide which questions/anwers to use, modify and add. All quiz-groups are at one point during the semester responsible for producing a quiz. Quizzes consist of 10 questions/answers, and the quiz-responsible group makes sure that there are sufficient questions/answers.

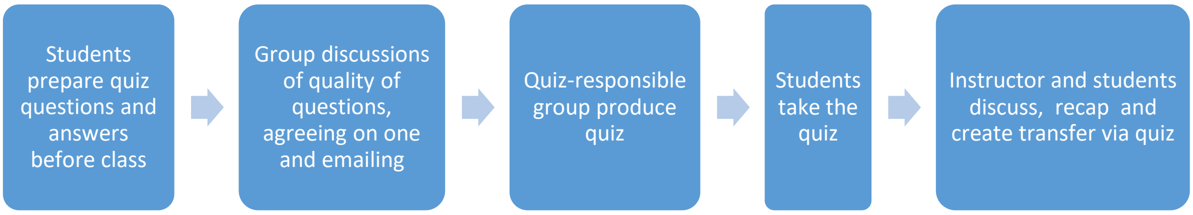

Figure 1: Overview of the Quizry learning process

The study was conducted in the autumn semester 2020 at Technical University of Denmark in three different BEng courses across two study programmes. Quizry was used in two subject areas: managerial economics and cultural understanding in the 2nd and 4th semester. A total of 76 students participated in the courses. Due to the pandemic, we partly experienced lockdown, students being tested positive for COVID-19, online teaching and online exams, which complicated the data collection.

1.3 Hypothesis

The study hypothesis is that students who work with quizzes will strengthen their competencies of understanding, applying and analyzing within selected topics in different disciplines.

We expect that the teamwork will result in a positive impact on students' perception of curriculum, self-efficacy and sense of belonging alike. In addition, we anticipate that the students' learning outcome will reach the highest level in connection with their teamwork on their own concrete, specific quiz.

2 METHODOLOGY

2.1 Methodology

During the study, we have collected various qualitative data through questionnaires answered by the involved students and undertaken indirect partipant observations by instructors.

We have chosen the questionnaire format as it gave an opportunity to receive anonymous answers, so that students did not have to worry about giving very honest answers/opinions of the learning process or other concerns. The questionnaire consisted of five open-ended questions and one closed question regarding quality of learning with the categories "Yes, better", "Yes, however, almost the same" or "No". At the end of each Quizry, each student in the quiz-responsible group individually answered a questionnaire; furthermore time was set aside for all students to answer a questionnaire of self-reflection on their learning outcome.

Besides the questionnaires, we decided to use covert indirect participant observations during the Quizry process. We chose covert observations in order not to influence the learning process itself and not to affect the answers of the questionnaires. As for indirect observations, we observed the students' behaviour during the Quizry process in class. As a result of our positions as instructors, we became participants in the Quizry process.

3 RESULTS

3.1 Quantative and qualitative results

We have systematically researched and evaluated the students' perception of their own learning in connection with the use of the Quizry. Each student from the 10 quiz-responsible groups was asked to answer a survey regarding their learning. The overall results are shown in Table 1:

Table 1. Overall results from surveys.

		Enhanced learning through quiz work		
Group	Answers	Yes, improved substantially	Yes, slightly	No improvement
1	2	1		1
2	5	2	3	
3	5	3	2	
4	3			3
5	4	3	1	
6	4	2	1	1
7	3	2		1
8	4	2		2
9	3	1	2	
10	4	2	2	
	37	18	11	8
In %		49%	30%	22%

We received a total of 37 answers in the three different courses. 79% of the respondents answered that preparing quizzes for the other students improved their learning outcome compared to traditional learning. As the table shows, 49% state that their improvement was substantial, whereas 30% state that their learning outcome improved slightly.

The respondents were asked to qualify their work with the quizzes in general, and the students gave us statements such as:

- "Very educative and interesting to see the groups quizzes"
- "The idea with quizzes is very good. Should be extended to all lectures"
- "A good way to recap a topic"
- "You remember the questions you prepare"

- “Funny and different way to learn”
- “Educative to prepare quizzes, less rewarding to answer the other groups quizzes”

As is evident from table 1 and the statements above, the students found the learning activities very educational, i.e. Quizry underpins Tinto’s self-efficacy and perception of curriculum.

Through our observations during teaching sessions, the following came to surface:

- All Quizry groups were inclusive during the teamwork
- In the process of making Quizry, students started revisiting teaching materials such as books and assignments
- Some students started out by resisting the learning process, Quizry, with comments such as “why do we have to make a quiz, we are used to instructors making quizzes?”
- Students found it difficult to phrase valid questions and plausible answers
- The quality of the various Quizries was to a large extent dependent on the time students spent both preparing at home and in class
- Tendency to cut corners and preference for easier parts of the topic
- The teamwork was at times challenged by the fact that some students were not well-prepared or did not attend class that day
- By the end of the semester, students increasingly focused on exams and and less on working on Quizry
- As instructors we experienced the need to continously frame Quizry in order to maintain students’ focus and motivation on the process

The Learning Management System used is DTU Learn/Brigthspace, which has multiple possibilities to set up quizzes, but also lacks some features which would have been beneficial for our use. When the students had answered a quiz question, the students were taken to the next question without being told whether their answer was right or wrong. The same was the case when finalizing the quiz. This resulted in some students working around the system; they answered the quiz as intended but without delivering it in order to keep it open, so they could still see what they had answered.

It seems like the quiz module was originally designed for testing purposes and not as a didactical tool in itself. Answering the quiz is quite an independent and individual task for the student, and not until everybody had finished the quiz were we able to discuss answers and results in class. A didactical software tool such as Kahoot might have suited our purpose even better. The gamification and the possibility to take discussions after each question might have improved the process further, which actually was our initial idea.

4 DISCUSSION AND CONCLUSION

4.1 Discussion and suggestions for future research

During the project we have obtained some insights:

Formulating good MC questions is not easy and can be quite challenging. Lotte D. O'Neill [7] mentions several design errors, which should be avoided. For a student, who may only design MC questions once, and under strict time limitations as well, it is a difficult task. As part of the quality control, we had to go in and modify some of the questions and anwers.

- The framing of the quiz work to the students at the beginning of the project could be repeated advantageously more in depth during the course. We observed that it was more difficult to maintain a few students' focus regarding the quiz work later in the process.
- Some students did not use sufficient time at home preparing the quiz questions, which resulted in some of the input to the quiz-responsible group was not of sufficient quality. As a consequence, instructors used more time than planned during and in between classes. The lack of engamement from some of the students due to not preparing the quiz questions at home influenced these students' learning.

We would like to research further the impact of engaging students on self-efficacy and sense of belonging. Moreover, we are very interested in examining to which extent students' course expectations influence their quiz work, e.g. students' resistance to learner-centered-teaching (LCT) and lastly reasons, including socio-economic, why students fail to prepare. We would like to conduct such research with a higher qualitative focus, e.g. semi-structured interviews and various observation methods to an even greater extent.

4.2. Conclusion

Our study results show that an extensive part of students experienced improved learning outcomes compared to traditional teaching.

It is evident from our study that students who work with Quizry will strengthen their knowledge and compentencies; however, it is also clear that the students putting most effort into Quizry are the ones who obtain the highest learning outcomes. Furthermore, the students appreciate the opportunity of various didactical tools. The study shows that Quizry enhanced the students perception of curriculum, self-efficacy and sense of belonging.

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LESSONS LEARNED DURING A BLENDED TRAINING FOR NEW EMPLOYEES IN AEROSPACE COMPANIES

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ABSTRACT

This research follows a previously published paper presented by Pourtoulidou and Frey which describes the conversion of a classroom-based to blended training for new employees entering aerospace companies [1]. This paper presents the lessons learned that derived from the analysis of the results after evaluating the blended training according to the participants', subject matter experts', and trainer's perspectives.

Prior to the training, Pourtoulidou and Frey analyzed the demands of aerospace companies and the labor market in order to develop this introductory training [1]. The classroom-based training was developed, implemented and evaluated in 2018/2019. Utilizing this evaluation, the blended training consisted of an online phase, which

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lasted six months and provided access to lecture videos, literature material, quizzes, forums and virtual meetings over the Moodle platform. In the middle of the online phase, a face-to-face session took place in October 2021 in which the participants worked with practical applications and associated with subject matter experts operating directly in industrial projects.

The lessons learned focus on the training development for employees' blended courses and on the specific limitations resulting from developing a joint training for entry-level aerospace engineers. The flexibility and further benefits of the training's online phase were well received from the participants, while the opportunity to meet, work and exchange experiences in person during the training was highly appreciated. The impact of COVID-19 on participants' experience and feedback was also visible and commented on.

1 INTRODUCTION

In 2017 a network of eight German companies formed under the publicly funded research project "Avionic System Software Embedded Technologie 2" (ASSET-2) formulated the demand for an introductory training course for new employees entering the aerospace industry [1 - 9]. This demand derives from the recruitment process in the aerospace industry that draws employees from pertinent fields, e.g. automotive engineering and STEM. Aerospace companies need to reach out to software engineers or software architects with a wide variety of academic and professional backgrounds. Afterwards, the challenge remains for each company to train the new software engineers or software architects through training courses, which cover the basics for their introduction to aerospace software development depending on their role.

2 PROJECT BACKGROUND

2.1 ASSET-2

Ingolstadt University of Applied Sciences developed an introductory training course as a classroom-based training for the "knowledge transfer" subproject of ASSET-2 to cover the companies' demand [2 - 9]. This training contained theoretical knowledge, practical applications and contact with subject matter experts in order to offer to companies' new employees a common elementary introduction to aerospace software development. The development of the classroom-based training started with the needs analysis; followed by the implementation and the evaluation of the training [2 - 9]. The feedback from the participants and the companies confirmed the initial consideration for the training and revealed the need for individualization of the training, as the individual background of the participants shows a wide spread. The participants expressed their individual learning needs and stated that they were in favor of the opportunity to self-regulate which parts of the training they will attend.

2.2 IDEA

Based on the ASSET-2 feedback, the further development of the training started in 2020 under the publicly funded research project “Integrierte Design- und Entwicklungsumgebung für Aerospace” (IDEA) by the Federal Ministry for Economic Affairs and Energy[2]. The subproject “knowledge transfer” within IDEA aimed at minimizing the restrictions and disadvantages of the aforementioned classroom-based training by offering flexible training units that fit into the employees’ working schedules and make the training adjustable to participants’ needs. The ASSET-2 main goal of introducing the new employees to aerospace software development and promoting the knowledge transfer among the participants remains a primary goal for the extended network of twelve German aerospace companies and academic institutions. However the IDEA blended training, which is the result of the conversion of the ASSET-2 typical classroom-based training, foregrounded the learning needs of the individuals. The criteria for the conversion of the ASSET-2 classroom-based to IDEA blended training are described in a prior publication of the authors [1].

3 LITERATURE REVIEW

The development of blended or hybrid trainings started before the 2000s and therefore is a rather old trend. The sudden obligatory shift in online learning that resulted from the mandatory reduction of the face-to-face training sessions since the beginning of 2020 is obvious and lies in the COVID-19 restrictions. The explosion of the amount of online trainings and online digital learning resources is evident.

Since the early 2000s, researchers have studied the use of blended learning in training development [10]. Training courses containing a mix of online and face-to-face learning modules are called blended or hybrid courses [11]. The positive influence of blended approaches on learning outcomes has been shown through studies in university settings or in vocational education [12, 13, 14]. Vitally relevant for this research are studies about professional trainings, which were developed for employees and take place within employees’ current job position aiming at their professional development. The advantages of professional trainings concern both the employees and the employers. Employees benefit from blended learning methods due to the flexibility and the accessibility of participating in blended courses [11]. Employees’ learning success results in increasing employers’ benefits while reducing the costs of training development [11, 15]. An explorative study in a Belgian-Dutch context confirmed these benefits of blended learning [16]. Other studies highlight the ability to enrich the learning process in a blended course with the use of online material beyond one institution, and to allow the participants to engage with it at their own pace [17, 18]. Research evidence shows the improvement of the effectiveness in industrial trainings when comparing the different

[2] It was renamed to Federal Ministry for Economic Affairs and Climate Action in January 2022.

learning approaches using experimental design [19]. The dropout rate is, also, positively influenced by blended learning but is highly dependent on the setting of the blended course and is not relevant for this research [20].

4 METHODOLOGY

This chapter describes the research methods, the implementation and analyses the feedback of the blended training after its evaluation from the subject matter experts', the trainer's and the participants' perspective.

A challenge for evaluating these trainings is that the companies demand data protection and absolute confidentiality regarding the employees and the training material. The mandatory data protection issued for the companies and their employees forbid any external evaluation. This influenced the methodology of evaluating the ASSET-2 classroom-based and the IDEA blended training, which is described as follows. The evaluation was executed by interviewing all contributors in semi-structured interviews. Due to the geographical distance the researcher conducted telephone interviews with the 22 participants and the 3 subject matter experts and a face-to-face interview with the trainer. The collected data were recorded via a voice recorder, anonymously transcribed and analyzed using content analysis.

4.1 ASSET-2

The ASSET-2 classroom-based training was implemented in October 2019 in which 11 employees participated [2 - 9]. At that time, they were starting their careers within the network in the field of aerospace software development in Germany. This training lasted two days and took place in Ingolstadt. The participants of this training belonged to 6 different companies and had various educational backgrounds from STEM fields. Before the training, the participants answered a prior-training questionnaire about their knowledge and their educational and professional background. Directly after the training they were asked to fill out a post-training evaluation questionnaire with close-ended and Likert Scale questions. Approximately three months afterwards, telephone interviews took place to get feedback after the new employees had actively been participating in work projects and had settled in their new position.

4.2 IDEA

The implementation of the blended training got caught up by the COVID-19 restrictions. During the COVID-19 restrictions in 2020 and 2021, the availability of the participants for the face-to-face session was difficult to foresee.

The duration of the online phase was planned to last 7 months during which the face-to-face session would take place. During the online phase the participants had access to lecture videos, literature material, quizzes, forums and virtual meetings over the Moodle platform. After the conversion of the ASSET-2 classroom-based training, the proportion allocated to the online phase was planned to cover approximately 78% of the training's material, which resulted in approximately 22% for the face-to-face session [1]. The average commitment for the online phase was estimated to be 10 hours. The online modules were staggered in chapters not dependent on each other. A participant could either skip a chapter or a video. Skipping an online module or part of it was up to each participant according to their educational and professional background. All online material was from the beginning of the online phase available with no restriction other than not being able to download the videos due to license restrictions. Rewatching a video at any time was possible with a working internet connection.

The duration for the face-to-face session was originally planned to last 5 work hours but was extended to one day (approximately 8 work hours) due to adding extra time for discussion and break time. The desired date for the face-to-face session was planned so that the participants could access the online material before and after the face-to-face session simultaneously while working in their business projects. The face-to-face session consisted of multiple parts. It started with a team event to get to know each other that took place the day before the main session. The participants were welcomed and met each other face-to-face with the trainer and the experts in an informal environment. The team event reached all participants, where 70% would need to travel a day in advance to arrive in Ingolstadt and 30% were locally based. As part of the actual face-to-face session subject matter experts were invited to offer insights about common problems in the field and advice according to their past experience. Also the participants engaged in group activities with practical applications.

The actual implementation of the IDEA blended training "Fundamentals in Avionics Software Development: Verification" took place in 2021/22. After consultation with the companies in order to ensure the maximum availability of the participants, the online phase started in August 2021 and ended in February 2022, the face-to-face session took place in October 2021. 11 employees from 5 different companies participated in the blended training.

The methodology of evaluating this training consisted of three steps. At first, before engaging with the training, the participants completed an online questionnaire about their educational and professional background. The online questionnaire prior to the training investigated the learning needs of the participants while they were starting their new job position. At the end of the face-to-face session, directly after participating in the training the participants answered a second questionnaire to assess in which level the materials and the teaching methods of the online and face-to-face sessions correspond to their needs and learning preferences. Both questionnaires contained multiple choice, Likert scale and open-ended questions. Step three included interviewing the participants, the trainer and the subject matter experts, who contributed in developing and implementing this training. Approximately three months after the face-to-face session the participants assessed the training's effects on their current professional role and their everyday working challenges in interviews. The interviews with the participants were conducted three months after the training in order to evaluate the training after gaining relevant experience in their new position. In addition to the participants' interviews, interviews with the trainer and the subject matter experts took place, which assessed the training from their perspective.

5 RESULTS

The results after evaluating the two trainings are presented here without referring to any personal information on the participants and every person that contributed to the trainings' development and implementation. In every research study the participants' personal data are highly protected. An additional requirement for the ASSET-2 and IDEA research projects was the confidentiality regarding job projects in which the participants are currently or were formerly working. The network's companies cooperate within the projects but are also competitors in similar and/or the same fields. Due to companies' privacy policies the employees participating did not take an exam or a test that would evaluate their knowledge. The participants could at any step of the evaluation withdraw their consent to participate in this study or skip a question. Their feedback on these trainings relied on their self-assessment according to their personal experience and opinion.

5.1 ASSET-2

The evaluation of the ASSET-2 classroom-based training outlined two main points; the demand for an introductory training in aerospace software development and the accessibility of the classroom-based method for this training [2 - 9]. The new employees that attended this training entering the aerospace industry with relevant or non-relevant educational and professional background confirmed the demand for such an introductory training. The appropriate time of participating in this was concluded to be directly after entering and up to one year working within the aerospace industry. The training method satisfied 80% of the participants and contributed to gaining knowledge. Nevertheless, they expressed further needs such as individualizing the training due to its long duration and large input, which was for some participants maybe already known or not absolutely related to their current position. 80% of the participants were in favor of the opportunity to self-regulate which parts of the training they would attend. 70% stated that they are willing to attend a training with online sessions that will cover a part of the training. Only 10% answered positively to participating in a strictly online training. All participants assessed as most important the practical activities and the interaction with the other employees from different companies and projects, with the trainer and the subject matter experts. The feedback from ASSET-2 was extensively analyzed in [1].

5.2 IDEA

The evaluation of IDEA blended training offered the following results, which will be presented from three different perspectives: the participants', the subject matter experts' and the trainer's perspective.

Participants' perspective

The IDEA blended training was well received from the participants. All participants mentioned as main benefits of this blended training the accessibility and the flexibility. Everybody appreciated participating asynchronously during the online phase without being limited in place and time when accessing the material and completing any tasks. 60% of the participants accessed the whole material before the face-to-face session, 20% of them only parts of it before the face-to-face session and 20% after the face-to-face session due to lack of time. The 20% of the participants, which did not access the material before the face-to-face session, stated during the interview that they intend to engage with it in the future depending on their workload.

All participants of the IDEA blended training commented very positively on the opportunity to meet and discuss with other employees from different departments and companies, who are experienced approximately in the same level as themselves. 90% of the participants stated they experienced a trustworthy environment and were encouraged to express their problems and questions during the face-to-face session. The participation in the team event was highly regarded by all. In particular, 70% explained that the team event contributed to "*breaking the ice*" and to feeling assured that neither comparisons nor (informal) assessments take place during the session. Also the participants living near the place of the training, stated that they were glad that they had joined the team event.

According to 70% of the participants, the contribution of the subject matter experts and the trainer played an important role in the atmosphere of the training because they were open and shared their experience from real-life work projects transmitting a feeling of "*everybody faces problems*". This was highlighted by 30% of the participants as "*cool, friendly and approachable experts*" which encouraged their self-confidence. In general, all participants liked the use of the blended learning method and emphasized the importance of the face-to-face session for collaborating.

For 60% of the IDEA blended training's participants this was the first training and business trip within their new position in their new company and in this industry. 40% mentioned that they were likely more excited to participate in a face-to-face training in October 2021 because of the long absence of face-to-face trainings and generally face-to-face sessions due to the past two years of COVID-19 restrictions.

Subject matter experts' perspective
This interest for face-to-face interaction was also reported from the subject matter experts, which participated in the face-to-face session. The subject matter experts presented the daily problems and experience gathered, while working in this field. 40% of the participants gave feedback personally to the experts directly after the expert discussion during coffee and lunch break. The experts perceived that the participants were feeling able to discuss openly and showed interest about their experience.

Attending the face-to-face session remains time-consuming for the subject matter experts but according to their opinion, this contributes to everybody's openness, and feeling of safety on a professional level. So, as one subject matter expert stated, "*can the participants express themselves without being afraid of being judged, what enriches the training outcomes*".

Trainer's perspective
The trainer received positive feedback from 40% of the participants directly after the face-to-face session. The trainer's feedback on the blended training highlights the difficulties of implementing a blended training. The flexibility during the online phase resulted in a lack of information about the participants' learning process during this phase. How the participants were engaging with the online materials was visible for the trainer only through their participation in the quizzes. This allowed some assumptions but the extent of the engagement remains unknown, since a participant may have taken a quiz without having watched the relevant video. Therefore, the trainer is required to be prepared for participants that are not at all introduced to the trainings' subjects. This issue did not negatively influence the implementation of the face-to-face session because of the session's topics. In other technically more challenging trainings and in particular exercises, which would require specific technical knowledge, this could cause problems for the training's implementation.

6 LESSONS LEARNED

The above results confirm the importance of the blended learning's benefits for employees entering a new role at a company and led us to following valuable lessons learned for the blended training.

- Offering a blended introductory training helps to quickly cover any theoretical deficits of new employees in the first stages of their new role. Not having to wait until a specific amount of participants is available for a training to be carried out results in a significant gain for companies [16, 18].
- Clearly structured material in the online phase containing all information regarding the training and its implementation are necessary. This determines the level of flexibility that can be offered.

- Self-assessment tools and/or a final exam aiming at a certificate for the successful participation enhance the gain the training has for the participants. The opportunity to choose themselves if they take an exam or not remains important.
- Employees working in tech-related industries possess a professional tech affinity and welcome the use of technologically advanced tools. This assured that the target group of this training would be able to engage easily with the online material. Nevertheless, offering tech support during the online phase is considered an inevitable requirement to ensure the desired level of flexibility regarding user experience.
- The value of human interaction is proven to positively influence the effectiveness of blended learning trainings [21]. The time allocated to the face-to-face session is highly valued by the participants and ought to be filled with activities which reinforce interaction and promote developing practical skills. Even small coffee breaks as the ones that were planned directly after the expert discussion with the subject matter experts are valuable, as participants expressed their appreciation for presenting examples and problems, which the experts faced in past and present projects. The participants in conjunction with this stated that the trustworthy atmosphere eliminated their hesitation of expressing and comparing themselves with other new employees. This confirmed their confidence and self-esteem in their professional expertise.
- Our experience confirmed the need for at least 22% of face-to-face session, but the blend between face-to-face and online modules depends on the training material and the availability of the participants [1]. The time allocated to the face-to-face session can differ according to the availability of the participants. One work day devoted to the face-to-face session was evaluated as adequate for this training but a second day devoted to extra practical exercises would be welcomed.
- The subject matter experts enhance the training’s outcome but have to align with the training’s goals. The communication between the subject matter experts and the trainer influences the atmosphere during the face-to-face session.
- According to the experience gained during the IDEA training’s implementation if the same level of knowledge is needed for a practical application, it is important to either require specific preparation from the participants prior to the face-to-face session or plan more time for introducing the learners to the subjects of the exercises. Problems deriving from the flexible conditions during the online phase depend on the content of the training and the target group. Answering a short questionnaire before attending the face-to-face session and stating the level of engagement with the online modules may offer insights to the trainer about the knowledge level of the participants taking part in the face-to-face session and if they have questions up to this point. The absence of such requirements for this training was purposely decided in

order to offer the maximum level of flexibility in engaging with the online modules.

- 40% of the participants explicitly stated that they preferred gathering their questions during the online phase and asking those in the face-to-face session rather than contacting the trainer during the online phase. Although different options of contacting the trainer and posting a question in the online platform of the training were available, they mentioned that they wanted to discuss their question(s) with the trainer in person during the face-to-face session. Planning a time slot during the face-to-face session for answering these questions is needed in any case. The trainer and/or the subject matter experts should expect questions during the face-to-face session that were gathered during the online phase or the practical applications. Although there could be a time slot for clarifying questions in the beginning of the face-to-face session, we suggest to plan, also, a closing open discussion, where participants can express any unsolved issue.

7 SUMMARY

This paper presented the lessons learned that derived evaluating the blended training according to the participants', subject matter experts', and trainer's perspectives. It outlined the gain for new employees entering the aerospace industry after participating in a joint training within the network. The benefits of the flexibility a blended training offers were confirmed while highlighting the necessary existing conditions during the online phase: clear structure, guidelines, self-assessment tools and tech support were mentioned as the most important. The face-to-face session has proven to be an absolutely essential part of a blended training due to the interactions among all associates. Successful interactions require communication between the trainer and the subject matter experts prior to the training and additional time for open discussion during the face-to-face session. The participants emphasized the positive effect of interacting with the subject matter experts and the trainer on their confidence and self-esteem. The ideal blend between online and face-to-face modules is not a universal fixed percentage because it highly depends on the training material and objectives. Conducting further research in professional blended trainings of different industries may enlighten the influence of such trainings on the employees' later performance.

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The engagement of students using the virtual platform tools. A successful case in a required subject of 1st year in mathematics in engineering (UPC)

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ABSTRACT

Fonaments matemàtics is a required 1st year subject in engineering career at the university EPSEVG (*Universitat Politècnica de Catalunya*) with approximately 270 students enrolled each semestre that traditionally it had a medium pass rate.
Over the last 6 years we have introduced gradual changes in the teaching planning of it with the idea of achieving: 1) that students work throughout the course, 2) leveling knowledge and 3) reduce the number of students not presented to any exam. The changes have been implemented and corrected based on our feedback from students (engagement, grades, acceptance and survey assessments). The introduction of the calculator, laptops and tablets in everyday life and the use of the tools of the UPC virtual platform have been key.
In this contribution, we present the strategies used and the good results obtained.

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1 INTRODUCTION

1.1 Background

The Universitat Politècnica de Catalunya (UPC) is a federated university that brings together 16 school centres, such as the *Escola Politècnica Superior d'Enginyeria de Vilanova i la Geltrú* (EPSVG) [1]. EPSEVG is a School Engineering centre since 1901, currently with 6 Bachelor's degrees in industrial and ICT engineering and about 1400 students. The paper focus on the analysis of a required subject of 1st semester (1st year) at the EPSEVG, called *Fonaments matemàtics* (hereafter FOMA) with about 260 students enrolled each year (in Setember). Specifically the study is done with the students of Bachelor's degree in: Industrial Design and Product Development Engineering, Mechanical Engineering, Industrial Electronics and Automatic Control Engineering, Electrical Engineering and Marine Sciences and Technologies. All students of different degrees are mixed and divided into 5 groups of about 52 students each group and the teaching involves between 3 and 5 teachers.
The type of student enrolled in this subject is heterogeneous in terms of knowledge of mathematics and in general with low cut-off marks. For example, in the academic year 2020-21, 1st semester of which the school already has a published report (see Table 1), 246 students were enrolled, the cut-off mark for entering university (moving in the interval [5,14]) was 5.4, ie the student's grade with the worst grade), of which 58% have a low grade, in the range [5,8) with respect to previous studies before university. In addition, the type of student is heterogeneous with respect to the knowledge of mathematics acquired: 17% of students come from 'higher degree training courses' (CFGS) and therefore have a very low level of mathematics while the remaining 83% have entered through the PAU tests. The university entrance exam (PAU) is a requirement for students with a high school diploma or equivalent to enter college.
In summary, traditionally FOMA had a low-medium pass rate (see Table 1).

Table 1. Enrolled students at FOMA subject (EPSEVG) each semester since 6 years ago and cut-off mark for entering EPSEVG.

Semester	Enrolled	Cut-off mark
	#	[5-14]
2016-17Q1	277	5,34
2017-18Q1	247	5
2018-19Q1	259	5,25
2019-20Q1	273	5,3
2020-21Q1	246	5,4
2021-22Q1	276	5,94

1.2 Contents and teaching planning

FOMA gives the student the first mathematical contents at the university: 1) calculus of one variable like differencial and basic integral calculus, 2) linear algebra with linear systems, vectorial spaces and basic linear aplications (with only diagonal matrix associated).

The distribution of classes throughout the course is: 2 sessions of 2 hours per week during the 15 weeks of the course. Although the Bologna plans are being implemented, and all subjects should be assessed continuously throughout the course, in practice it is very common for subjects to be assessed with only two exams: a mid-term partial examination and a final exam at the end of the course, proof of this is that EPSEVG has reserved two weeks exclusively for the partial and final exams, respectively.
In this article, when we refer to continuous assessment, we mean all the acts we do throughout the course, in addition to the partial and final exams.

The coordinator of FOMA for 6 years, since 2016-17 academic year, in its beginning focused on placing teaching in the context of engineering adding to the traditional CV the learning of errors and numerical methods, as well as the use of calculators and the computer in the day to day - with the use of Matlab / Octave or Geogebra software - as complementary work tools.
Over the years, there have been several mathematics teachers who have helped at some point in this process of change - all of them highly qualified with a teaching career of no less than 20 years.
During the covid-19 period the teaching was completely online and we designed Moodle activities for the students. In the last two years, we have taken advantage of it and increased the online activities of the continuous assessment.
In this paper we show the academic planning of FOMA and the academic results.

2 METHODOLOGY

To compensate for the lack of homogeneity in mathematical knowledge and in general the low rate of the students (see section 1.2), the teachers involved continosly try different strategies. In general teachers try
- to avoid bad academic results,
- to reduce the number of students not presented to any exam,
- to promote that students work throughout the course,
- to level mathematical knowledge.

Specifically over the last 6 years we have introduced gradual changes in the teaching planning of it with the idea of achieving it.
The changes have been implemented and corrected based on our feedback from students (engagement, grades, acceptance and survey assessments). The introduction of the calculator, laptops and tablets in everyday life and the use of the (Moodle) tools of the UPC virtual platform have been key.

2.1 Continuous evaluable activity

Table 2 shows, across the years, the evolution of the design of the continuous evaluable activity, number of activities and weight.
The table does not show the self-learning activities in the virtual classroom that were prepared from the beginning so that they would be leveled in Derivatives and Integrals, these activities were very well received and are introduced in all courses somehow. These are Moodle quizzes with Wiris [4] which can be done as many times as you want, and the solution always comes out. Wiris math calculator is integrated in the UPC Moodle platform and allows you to define quizzes with random parameters / constants, and mathematical tools. This is the strategy we propose to level knowledge.

Table 2. Design of the continuous evaluable activity at FOMA subject (EPSEVG) each semester during 6 years.

Semester	**Weight**	**Hand exercises per student**		**Moodle activity per student**		**PC activities per student**	
	%	%	#	%	#	%	#
2016-17Q1	25	-	-	-	-	25	2
2017-18Q1	40	-	-	-	-	40	2
2018-19Q1	40	-	-	-	-	40	2
2019-20Q1	40	-	-	5	1	35	2
2020-21Q1	50	-	-	10	2	30	2
2021-22Q1	40	5	2	20	10	15	1

Table Moodle activities are Wiris-type quizzes where questions are taken at random from a question bag. The questionnaires are individual, lasting 1h, distributed throughout the course to do at home, from Friday to Monday, with between 3 and 5 attempts, each time a quizze of the same type but different qüestions. The grade obtained is the maximum of the attempts grades. We propose this strategy to make the student work continuously and do not leave the subject.
The PC activities consists of doing an individualized project at home during 5 days, in pairs or individually, with the computer and the use of Matlab / Octave and Geogebra. This is performed in order to develop the students skills in applied mathematics and allow the mobile / tablets, calculators or laptop to form part of the learning process of the subject and not just tools for personal use. The hand exercises are individual, performed in class, previously notified, with notes and calculator and under the supervision of the teacher. The aim is to prepare for specific problems of interest to the subject that may arise in the exams. Finally, all these strategies were implemented together in the continuated activity of last semester 2021-22.

3 RESULTS

3.1 Continuated academic results

We find the relevant academic results during last semester 2021-22, and that can be compared somehow to 2019-20 one, when begun the use of the Moodle tools of the Virtual Platform, in form of quizzes (see Table 3). The more deliverables you order, the more they make. Especially important is that when we increase the number of quizzes, and therefore make them follow in time, the percentage of students who do not do any activity drops from 9 to 3. And total deliveries move to 668 to 6657. Also relevant that deliveries per enrolled student increase from 2.6 to 25. Last setember, an student that followed the course sent an average of 29 activities.

Table 3. Continuated academic results and survey satisfaction at FOMA subject (EPSEVG) each semester during last 2 years, except the covid-19 semester.

Semester	**Total deliveries**	**Deriveries per student rated**	**Deliveries per student**	**Students without any delivery**
	#	#	#	%
2019-20Q1	698	2,81	2,56	9,2
2021-22Q1	6657	28,8	25,0	2,9

3.2 Continuated academic results of 2021-22Q1 semester

The engagement of 276 students is shown in figures 1 where for each activity (quizzes) it is plotted: the number of deliveries (between 3 to 5 attempts of each quiz), the averaged grade (the grade is the maximum of all attempst) and the percentage of students that deliver it. Last deliver (no 10) was two days before Christmas.

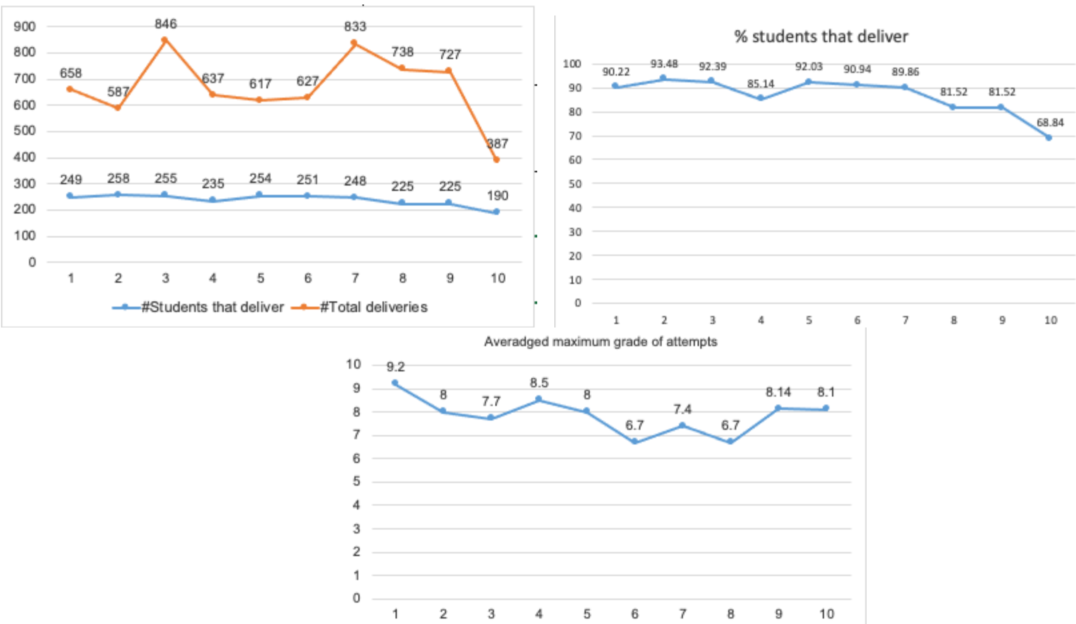

Figure 1. Continuated assessment results in 2021-22Q1 semester for each (approximately) weekly deliver at the x axis (time line).

3.3 Academic results

The objective data for measuring the results can be found in Table 4. Table shows information of final grades of students every semester since 6 years ago,:
-the average final grade (measured from 0 to 10), calculated with respect all enrolled students,
- the percentage of not presented students to any evaluative act, the approved students with a grade greater or equal 5 and finally the excellent grades.

Table 4. Global academic results and survey satisfaction at FOMA subject (EPSEVG) each semester during 6 years. NP=not presented, A=Aproved (≥5), E=Excellent (≥9)

Semester	Average grade	NP	A	E	Student survey	Rating survey
	(0-10)	%	%	%	%	(1-5)
2016-17Q1	4.6	10,11	54,2	6,86	27	3,8
2017-18Q1	3.8	7,69	44,9	1,62	37	3,1
2018-19Q1	4,6	9,30	55,2	1,50	27	3,2
2019-20Q1	4,6	6,96	61,17	0,73	24	3.1
2020-21Q1	-	5,28	82,93	13,82	-	-
2021-22Q1	5	4,70	59,00	2,50	11	4.2

Firstly observe that the grades of covid-19 period (2020-21Q1) are out of context, as the teaching was completely online and all the evaluative acts were performed at home, with quizzes and without any physical control of teachers. Eventhough the

grades are overdimensioned, a value to keep in mind is the small value of 5.3% of not presented students, compared with the 10% we had at 2016-17. At that time the students were confined at home every day; that value probably approaches the minimum possible of non presented. It is gratifying to see that we have even improved this value in the last semester to a 4.7% of non presented.
We also observe that the total average grade increases to 5 at last semester, and we reach a 59% of approved with 2.5% of excellent results. Although it has been passed with higher average grade, in return it has been more difficult for students to obtain maximum marks, above 9.5.

Table 4 also shows the survey results from students:
- Percentage student that perform the survey.
- Rating survey, from 1 to 5, agreement to the question: 'Overall I am satisfied with this subject'. In the context of the EPSEVG school, the answer of this question is 3.6 in mean value of all subjects.

Again last semester, FOMA has the best ratings, compared with other semesters, improving the average school result. It is right that there is a low percentage of students who take the survey, but experience tells us that when there are few students who take the survey, they are the ones who are dissatisfied with the subject.
The personal perception and the feedback received from the students and comments to the surveys tell us that they don't like, or find it difficult, to run the Matlab / Octave programs, anyway they still gain skills in their applied use, as we have seen when students have to use it in other subjects of higher semesters.
The other perception of all the teachers of the subject is regarding the last semester, taken from the comments of the students in class, in all the groups, it is that: it has gone very well and the students liked to have the questionnaires every weekend for practice, even stated this in the survey comments.
Finally, the downside is that it has taken a lot of work for the teachers involved to prepare the material and follow up, that includes preparing and activating quizzes, correcting problems, projects and exams.

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Supporting global competence learning for engineering students: Four key lessons (to be) learnt

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ABSTRACT

Global competence is an essential attribute for engineering graduates working in an interconnected and culturally diverse world, and higher engineering education needs to adapt to ensure that their students will acquire it before entering the labor market. For universities, the only way to ensure comprehensive global competence learning for all students is the holistic integration of related learning outcomes throughout curricula – which requires engineering educators to be able to (re)design their courses and programs accordingly. Considering that most engineering educators are subject experts of their discipline – but lay people when it comes to such competencies – we set out to compile a practical guideline for those wanting to integrate global competence learning within their disciplinary courses.

Following a participatory action research approach, we connected our own insights as global competence educators at a technical university with those of several cohorts of engineering educators and students enrolled in global competence courses. Synthesizing these insights, we could identify four essential lessons for integrated global competence learning: 1) learning opportunities can be found (nearly) everywhere, 2) relevance and authenticity must be emphasized, 3) theory and practice need to be integrated and 4) global competence cannot be taught, but it can be learnt. These lessons are illustrated with practical examples for fostering global competence learning in regular engineering courses.

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1 INTRODUCTION

Professional demands on engineers are evolving, and global competence has recently emerged as a key factor for ensuring that graduates can succeed in our interconnected and culturally diverse world. Following calls from industry to instill global competence – described typically as the knowledge, skills, and attitudes needed to collaborate with diverse others appropriately and effectively (e.g., [1]) – numerous institutions have begun efforts to introduce such learning into their curricula. While the exact competencies constituting global competence are still under debate, several authors have attempted to identify those relevant to engineering contexts. Some of the most frequently quoted and used conceptualizations are those developed by Downey and colleagues [2], Lohmann and colleagues [3], and Ball and colleagues [4]. While their ideas of competencies differ slightly, e.g., in how individual aspects are named, they all appear to revolve around the same dimensions: intercultural communication skills, openness and appreciation for others' perspectives, teamwork and leadership skills, adaptability to living and working in different contexts, as well as global awareness, and an understanding of how culture may affect engineering work.

Despite an increased attention to global competence learning in technical curricula, scholars still emphasize that engineering education needs to catch up to equip graduates with those practical competencies so demanded in industry [5, 6]. There is no denying that technical expertise constitutes the basis for engineering students' future employment, but for the time being, global competence is what will make graduates stand out among their highly-trained competitors on the global labor market [7]. For universities, well-known approaches thought to enable such learning are international mobility experiences such as studies, internships, service learning, or research abroad, or in some cases specific courses or modules on the issue. However, as typically only a small minority of students take advantage of such offers, and considering the need to foster global competence in *all* students, calls for more comprehensive global competence strategies have been made [8-10]. Key agents to achieve this goal are engineering educators who sensibly design their courses for integrated disciplinary and global competence learning.

This is, however, easier said than done; global competence learning is different from much other engineering learning, and any attempt to comprehensively integrate it with disciplinary technical contents requires careful consideration. A recent study by Passow and Passow [11] identified three principles for such curriculum design in engineering: 1) engineering practice extends beyond science-based tasks to both technical and social tasks critical to project success, 2) non-technical skills should be taught in context rather than in isolation, and 3) engineering education should display a greater connection to practice including authentic problem-solving, iteration, working towards a bigger picture, and realistic social dimensions (p. 501). Their work clearly shows how the traditional differentiation between hard and soft skills is outdated and an integrative approach to teaching competencies in context is needed. Considering that those aspects are interconnected in the professional world, such an approach should certainly be of interest for engineering teachers, as they are responsible to prepare their students for their future life as professionals.

However, with engineering educators themselves often being educated in a hard-science teacher-focused tradition, rather than an integrative student-focused pedagogy, these ideas of global competence learning may appear foreign, and can be perceived of as potentially troublesome ad-ons rather than as easily integrated aspects that ought to be part of their discipline. Additionally, considering the vagueness of the concept, its complex and multifaceted nature, and the fact that global competence goes beyond knowledge and also comprises attitudes and skills [12] educators wanting to practically work with it are faced with a daunting task.

Looking more closely at specific classroom environments that could support global competence learning, Mullins and Wood [13] suggested that lessons should be student-centered, authentic, contain continuous feedback, and provide students with clear expectations and opportunities to be in charge of their learning. Other important factors were pointed out by Atadero and colleagues [14], who proposed that academic activities fostering appreciation of diversity in engineering should be explicit in their intent while relevant to engineering, have a longer-term focus for sustained engagement with such issues, and measure the students' perceived links between engineering and diversity. While these suggestions provide useful contributions for global competence learning in engineering classrooms, they may still be too vague for non-experts, such as engineering educators, to practically implement

This paper aims to illustrate practically applicable guidelines for global competence education including crucial questions that educators need to reflect on when wanting to integrate global competence learning. Based on our own background as global competence educators and the practical insights and experiences from engineering educators and students at our home institution, this paper synthesizes insights from theory and practice and presents key lessons for the successful introduction of global competence learning within disciplinary engineering courses.

2 METHODOLOGY

We followed a participatory action-based research approach, which is characterized by the collaborative co-creation of knowledge with stakeholders to solve practical problems [15].This approach connects theory with practice and reflection, and, in our specific case, combined our own insights and experiences as global competence educators with those from engineering educators and students as stakeholders and experts of their discipline and classroom settings. Accordingly, we collected and synthesized both insights and best practices from literature with discussions and reflections of several cohorts of engineering educators and students enrolled in elective global competence courses at a large Swedish engineering university. This helped us in connecting the rather general insights from internationalization literature with the real-life contexts of engineering education. The result of our efforts is a practical and broadly applicable set of guidelines for integrative global competence learning in regular disciplinary engineering classes.

3 RESULTS AND DISCUSSION

Finding ways to instill global competence in students is already a challenging endeavor, but finding ways to ensure that engineering educators – whose teaching expertise lies in the technical rather than the social realms – can do that is on a whole different level. To support this process, we have connected theoretical and practical insights to create the four most essential lessons learnt for those wanting to foster global competence learning in their students: 1) learning opportunities can be found (nearly) everywhere, 2) relevance and authenticity must be emphasized, 3) theory and practice need to be integrated, and 4) global competence cannot be taught, but it can be learnt. In the following, we will elaborate on those four lessons and provide examples of how they can support the practical implementation of global competence learning within a wide range of disciplinary engineering classes.

3.1 Learning opportunities can be found (nearly) everywhere

The first lesson to be learnt – something that may otherwise be a perceived obstacle for engineering educators – is the fact that global competence learning might happen nearly everywhere. When thinking of global competence learning opportunities, many might first think of the classics: studies, internships, or field trips abroad or potentially even specific courses for students. While those certainly are great learning opportunities, they are not the only ones, and may in many cases only reach a small subset of students. A common misconception of many engineering educators and students is the idea that global competence just does not fit to, or into, specific engineering courses, particularly when it comes to highly logic- or science-based courses. However, we would like to introduce Kahn and Agnew's [16] poignant conclusion that "[n]ot all coursework needs to include global learning outcomes, but it is increasingly understood that all courses can be internationalized, including the hard sciences" (p. 58). When looking more closely at certain typical global competence learning outcomes, it becomes clear that even highly logic-based or technical courses provide opportunities for developing at least some competencies. To illustrate this better, we will take a deeper look at popular global competence learning outcomes, such as intercultural communications skills, openness and appreciation for others' perspectives, team-working and leadership skills, adaptability for living and working in different contexts, as well as global awareness and an understanding of how culture may affect engineering work.

Most of these competencies can be directly practiced through collaborations with diverse others, prime examples for such would be intercultural collaborations with other student groups (in person or virtually), as well as collaborations with industry partners or other stakeholders of engineering work, which is the focus of several service learning courses. Such learning opportunities bring students together with others from diverse backgrounds (e.g., national/regional, university, discipline) and introduce them to different perspectives, and in some cases even allow glimpses into different professional context, with their own rules and standards. For all these reasons, it is no surprise that such activities are often first thought of when it comes to integrative global competence learning. While invaluable chances for competence development, it must be considered that setting up courses including such activities involves much planning and resources, and the majority of these examples is only feasible for some courses and not others. The Covid-19 pandemic has proven that many courses could move to the virtual sphere, which in some cases attracted more external course participation – which would be very advantageous for especially those courses that otherwise would not allow much interaction with external actors.

Relatedly, another obvious learning opportunity potentially touching several of the social or interaction-focused competencies are cooperative learning, or group exercises, where diverse students will have to collaborate on problems together. Here it is important to note that in their everyday usage at engineering universities, some of the concepts we talk about are easily misunderstood or overgeneralized: *culture* may be interpreted as "people from different countries," and *diversity* may be equated with "people of different genders" or in some cases "people of different abilities." It should be clear that such isolated factors are not the sole defining aspects making up a person's perspective, and when global competence scholars talk about culture or diversity, they typically refer to a wide variety of factors potentially affecting one's viewpoint, including the aforementioned aspects, but also ethnicity, religion, education, discipline, professional background, and many others. Following this line of thought, it is easy to see that all classrooms – even those consisting of students having similar nationality, gender, or abilities, can be inherently diverse.

During discussions and the exercises themselves, students will have the chance to practice communication, teamwork skills, and conflict management, and they are likely introduced to diverse perspectives. By mixing student teams, and ensuring they interact with diverse others, a first step for global competence learning can be laid. Considering that the majority of engineering subjects allow for group exercises of some type, they are an easily implemented and non-disruptive addition to many courses. The engineering educators we talked with had at minimum small in-class group assignments or discussions, and several had students collaborate in labs or longer projects. They generally acknowledged the value of bringing students with different values, backgrounds and skills together to work on common problems, both for the potential for new perspectives and more creativity, and believing that working with others will prepare the students better for their professional life. This was, however, not always unproblematic, and conflict within groups was something both the educators and students were familiar with. A particular issue repeatedly highlighted was certain team members' lack of contributions, which the students found particularly frustrating when such behavior affected grades. Educators, aware of such conflicts, had different approaches to deal with this: some allowed students to choose their own groups in order to reduce conflict potential, others implemented group work reflection exercises to find out whether they should intervene, and others believed that students should learn to navigate such situations by themselves since they will have to do that later in their jobs.

For especially the knowledge-based competencies, a fruitful way to introduce new perspectives and widen students' horizons is by careful selection of course materials – for one, course readings or case studies could be chosen to represent the perspectives from authors from around the world. Additional discussions on how engineering is done differently around the world, examples could be the introduction of different engineering cultures and, if applicable, professional standards and regulations. The mutual interaction between historic, socio-cultural, or economic aspects and developments of the field may also be easily integrated in a variety of different subjects. For almost all disciplines, the history of how the field developed – and where it may be headed – may also comprise relevant knowledge and support a deeper understanding of the subject. If planned carefully, also insights into historical or societal contexts affecting the field could be incorporated in this regard. Another very contemporary approach could be in illustrating the potential connections of the basic science concepts of the field and local, international, or global challenges [16].

3.2 Relevance and authenticity must be emphasized

The second lesson for integrative global competence learning revolves around its perceived relevance and authenticity. The importance of global competence for professional practice has been acknowledged by universities, but the longstanding approach to solving that – the classic distinction between hard and soft skills – is now recognized as outdated, as it both differentiates between aspects that are connected in practice, and wrongly implies little diligence or depth to the "soft" aspects of the profession [7]. From a linguistic perspective, competence notions on the other hand may appear more pertinent to engineering education, but that should not distract from the fact that students, who may have a certain image of engineers as pure technologists in mind, may not immediately recognize their importance.

To ensure students recognize the value of such learning and develop the necessary motivation to hone their competencies, it is imperative that their disciplinary of professional relevance is *explicitly* clarified by the educator [10]. Many of the educators we spoke to had clear ideas and motivations behind the assignments they gave to students, particularly in terms of communication and collaboration, but did often assume the students' understanding of these benefits rather than being explicit about these goals. Moreover, if global competence learning is to be integrated with regular disciplinary learning, an additional factor to consider is authenticity. An effortless way to achieve authenticity is to let students work with real-world cases or issues, or let them relate what they are learning with potential areas of application. Showing students the potential and importance of course contents for real life contexts is not only great for motivation, but also enables them to look at the bigger picture and work on their systematic thinking skills. Regardless of whether students have to analyze or work themselves on case studies, they can provide wonderful examples for good – or problematic – implementations. By actively reflecting on the processes or decisions leading to final outcomes, they are a great opportunity for working on critical reasoning skills. Similar to case studies are also critical incidents, potential real life situations characterized by misunderstandings or conflicts, which can be used for reflections and discussions on how such situations could be handled appropriately.

Another simple way to convey relevance and create authenticity, while simultaneously offering the students another perspective, is the invitation of guest speakers. Depending on what makes sense regarding course contents, these may be researchers or experts from industry or other institutions for rather theoretical subjects, or industry partners, stakeholders, or alumni for the more practical subjects. The topics these guest speakers address may even be subject for later follow-up assignments or exercises. The educators we spoke to that did incorporate some kind of industry partners did typically have guest speakers, primarily for motivational purposes, or used their connections to provide case studies for the students to work on, the output of which would later be presented to the industry partners. In some cases, industry partners also took up supervisory or mentor roles. However, it was also pointed out that forming and maintaining relationships with such external partners was very time-consuming for the educators.

An approach we took in our own global competence course for students was to have themselves identify, approach, and then interview a person that could function as a mentor for them. While something like this might not be a common assignment within engineering subjects, it gave students a chance to reflect on their future professions and what type of person could function as mentor, to get out of their comfort zone, gain relevant insights into questions they had about professional life, and at the same time network and form connections for their future.

3.3 Theory and practice need to be integrated

The third lesson is that theory is a good starting point for much learning, but students should also have the opportunity to practice what they are learning. While hearing that certain competencies are invaluable in professional settings can be useful, experiencing their merit firsthand is even better. Related to this is experiential learning theory, originally proposed by Kolb [17], which rests on the idea that “learning is a continuous process grounded in experience” (p. 27). With the undeniable advantages of integrative learning through experiences, it is not surprising that also the CDIO guidelines for engineering education [18] are strongly informed by such an approach. By actively applying their knowledge, small issues that may otherwise be undetected come to the forefront, and the students are eased into using a holistic perspective to make theory work. The approach of having students apply their theoretical knowledge to projects was very common amongst the educators we spoke to. Only one of them, teaching a very fundamental theoretical science course, emphasized difficulty doing this due to their course contents being based on theoretical models with “little direct connection to application.” After reflecting on the issue and the feedback of other educators taking the global competence course with them, this educator did however propose emphasizing links to sustainability, i.e., how concepts could be used to solve problems, in order to show students potential areas for practical application.

A special tip related to competence learning is to also balance discomfort with support – students should have a chance to break out of their comfort zone, but at the same time do so in a safe environment where they can try, fail, and learn from failure. In the real world, mistakes can have costly consequences, but the engineering classroom can be a safe space to learn from trial and error. As a matter of fact, it has been pointed out that mistakes may be very valuable for learning [19] – assuming that they are properly introduced as a learning experience rather than a failure. This experiential approach does not necessarily mean students really have to go out of the classroom and practice engineering – several of the examples mentioned before, such as case studies, roleplays, or critical incidents – may function well for gaining such experience. They even have the advantage that they can be specifically targeted at common or extremely challenging situations that can be used as learning experiences. As soon as practice is involved, peer or teacher feedback or self-reflections can be used to revisit the learning experience and potentially gain an even deeper understanding of the subject. However, as stated earlier, it is crucial for the students to understand this reasoning in order for the exercises to fulfill their full potential. Many of the students we talked to saw their grades as important for getting a good job, hence the frustration with team colleagues potentially dragging their grades down. In an attempt at self-serving comradery, they might also for this reason be tempted to be overly positive when giving each other feedback in front of the teacher, which both runs counter to the idea behind the exercises and can easily be interpreted by the teacher as a lack of critical thinking.

3.4 Global competence cannot be taught, but it can be learnt

Our final lesson is that global competence cannot be taught, but that it can be learnt. Becoming globally competent is a lifelong, continuous process, which requires the learner to actively hone their competencies. A simple course, yet alone one only seeing competency development as additional informal learning outcome, will hardly be able to lead to globally competent students. It can, however, create the basic knowledge, skills, and attitudes – and the motivation – needed for students to continue the path to become globally competent individuals. The prior points have already hinted at the fact that the student – and not the teacher – should be the focus of such activities. Indeed, in creating globally competent students, educators should act as facilitators supporting their students – they can show them the basics, but the students have to do the work themselves. In a similar regard it is also important to view the educators as learners themselves. Every engagement with diverse perspectives can support them in becoming more globally competent educators, which in turn allows them to create more globally competent students.

4 SUMMARY

Addressing the great industry demand for globally competent engineers, universities have begun to look for ways to foster those competencies in their students, and the engineering educator is an essential key player in those efforts. With global competencies appearing foreign to traditional hard science teaching, there is always a risk of institutional efforts meeting hesitation or resistance from educators feeling top-down pressures to having to redesign their well-tried courses without seeing additional value in doing so. Connecting the insights from our own background as global competence educators with those of engineering educators and students, we have shown that technical and global competence can easily be integrated in a way that also mirrors professional practice without putting much additional strain on educators. We identified four key lessons for the integration of global competence in engineering courses; these related to the identification of vast opportunities for global competence development, the importance of emphasizing relevance and authenticity, the integration of theory and practice, and the fact that any approaches to global competence learning need to be centered around the learner. The latter lessons show obvious overlaps with what can be seen as good pedagogical practice in general, which also highlights how a good educator should – given the right training and support – be able to effortlessly tweak their course contents to increase the potential for global competence development. While our lessons are a first starting point for those educators wanting to do so, the institutional support given them for such endeavors – both in the provision of relevant training opportunities as well as encouragement and other incentives for redesigning their courses for additional global competence learning – will be the deciding factor to whether a *comprehensive* institutional approach to global competence development can have the desired effects.

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INTEGRATING SUSTAINABILITY AND SOCIAL COMMITMENT (S&SC) COMPETENCES IN THE CURRICULUM AT THE BARCELONA SCHOOL OF CIVIL ENGINEERING

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ABSTRACT

The importance of integrating the Sustainable Development Goals (SDG) in the curriculum of all the bachelor and master degrees at UPC has been legally and institutionally recognised. At the Barcelona School of Civil Engineering, issues such as professional ethics, environmental impacts of infrastructures, respect for cultural diversity and gender perspective are currently cross-cutting competences highlighted and stated in the study plans as a transversal competence on Sustainability and Social Commitment (S&SC). However, its effective implementation requires significant teaching efforts in order to adapt academic curricula, so far limited to individual non-coordinated initiatives.

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The launch of the “ODS-Camins Toolkit” project (Toolkit for the Promotion of SDG in the Civil and Environmental Engineering Fields) seeks to encourage the implementation of teaching innovation practices that contribute to the deployment and assessment of S&CS competences. The aim of the project is to exchange experiences, develop new practices, and draft a common pathway for the promotion and implementation of the SDGs in the field of civil and environmental engineering studies.
The paper will explain the experience of this one-year project, highlighting barriers, challenges, and sharing the lessons learned with the final purpose of involving all the community in the years to come. It will also present the Toolkit for the Promotion of SDGs in the Civil and Environmental Engineering Fields

1 INTRODUCTION

Education for Sustainable Development (ESD) facilitates the acquisition of knowledge, skills, attitudes and values needed to forge a sustainable future. It seeks to provide students with professional and personal abilities necessary to work and live in a way that protects environmental, social and economic well-being, for present and future generations. Applying ESD principles to engineering education involves working under an integrated approach, incorporating social and humanities disciplines, encouraging work in multidisciplinary teams, stimulating creativity and critical thinking, and promoting self-learning.

In Higher Education, the pathway to integrate the Sustainable Development Goals (SDGs) in the curriculum has started through a legal recognition that pushes towards this direction. Specifically, in the fields of civil and environmental engineering, issues such as professional ethics, environmental impacts of infrastructures, respect for cultural diversity and gender perspective are currently cross-cutting competencies included in the study plans as a transversal competence on Sustainability and Social Commitment (S&SC). However, its effective implementation requires significant teaching efforts in order to adapt academic curricula. This is not always easy, due to a lack of recognition by academic institutions.

At the Barcelona School of Civil Engineering (BSCE), several projects have recently been carried out on this topic. So far, these were individual initiatives with a certain degree of internal coordination but with low institutional leadership. These previous experiences, the recent legal enforcement and new institutional priorities have led to a change, and facilitated the launch of several initiatives promoted at different UPC levels. On the one hand, a bottom-up initiative called ODS-Camins Toolkit led by the Barcelona School of Civil Engineering, which aims at producing accessible educational resources to help lecturers integrate sustainability in their courses. On the other hand, UPC at higher institutional levels is leading a pilot initiative to guide and give support to different UPC schools on this endeavour. These coordinated actions aim at assessing the current situation and foster a planned deployment of the integration of S&CS competences in the context of the civil and environmental engineering studies.

Conceptually, this experience feeds from the on-going research projects Edinsost I & II [1,2,3] which have created the Engineering Sustainability Map (ESM), a tool that contains the ESD-related learning outcomes that any engineering graduate should have acquired upon completion of the studies.

There are previous academic research works [4] and institutional contributions [5] that identify and describes competences that engineers should acquire to deal with SDG challenges. However, in this paper the classification used is that recommended by the Working Group of the Sectorial Commission CRUE-Sustainability (Conference of Rectors of Spanish Universities) which should be integrated in the curricula of all Spanish university degrees. It stablishes four sustainability competencies units:

- CU1: Critical contextualization of knowledge establishing interrelationships with social, economic and environmental issues, local and/or global."
- C2- Ho: Holistic. Identification and analysis the environmental, social and economic impact of their professional activity and to propose, design, organize and carry out sustainable actions.
- C2-En: Environmental: Identification and analysis the environmental impact of their professional activity and to propose sustainable solutions."
- CU2- So: Social. Identification and analysis the social impact of their professional activity and to propose sustainable solutions."
- CU2- Ec: Economic. Ability to manage material, economic and human resources of projects in their professional field, in order to ensure the economic viability while taking into account the sustainability.
- CU3: Participation in community processes that promote sustainability.
- CU4: Application of ethical principles related to the values of sustainability to personal and professional behaviours.

The objective of this paper is to assess to what extent the ESM is fulfilled in the curriculum of Bachelor Degrees at the Barcelona School of Civil Engineering and discuss strategies to improve the level of integration of S&SC competences. This is embedded in a wider project called Toolkit-ODS Camins with the goal of creating an engaged "Civil and Environmental Engineering community" with a high commitment with SDGs.

2 METHODOLOGY

The following coordinated tools and activities have been implemented in order to achieve our objectives. Firstly, the ESM was shared among a group of lecturers to identify and assess their learning outcomes, competencies and SDGs integrated in a representative set of courses.

Then, based on this previous experience, an on-line survey adapted from [1] was addressed to all teaching staff to gather information on the SDGs addressed, methodologies used and learning outcomes and competences present in each of the Bachelor Degree in Civil Engineering courses. The survey included a table with the learning outcomes and competences and the teachers addressed were asked to recognise which were the 5 top ones addressed in their course. A total amount of 40 responses were collected, representing almost 50% of the courses. Based on this initial assessment and together with all involved parties (coordinators, lecturers, students) learning strategies will be suggested and planned to embed all the SDGs in the curriculum

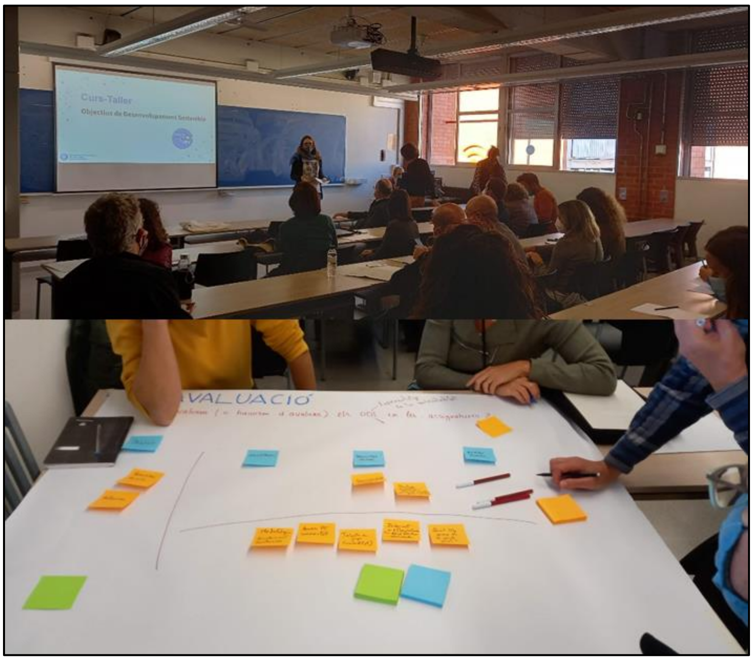

Fig. 1 Images of the workshop held in November 2021.

Finally, parallel activities to promote community involvement were undertaken such as workshops, meetings and a video recording. For instance, the workshop “Team building for SDGs engagement in the Civil and Environmental Engineering Field” was held in November 2021 (Fig. 1). More than 40 participants were informed on the institutional strategies and projects to embed SDGs in the curricula, and invited to discuss teaching and learning activities, their main barriers, challenges and needs. Moreover, a course on “Inclusive non-sexist language in teaching and research” was organized in March 2022, to address the SDG 5 on Gender Equality

3 RESULTS

Data from the surveys helped assessing to which extent the SDGs and sustainability competences are addressed in different courses of the Bachelor Degree in Civil Engineering.

Figure 2 shows how this Bachelor currently involves more than half of the SDGs. This is in line with the institutional goal of getting students to know the SDGs and their importance for society. It can be observed how the SDGs related to infrastructures, water, cities, climate and production, are among the most studied, while those related to education, inequalities, peace, hunger and poverty are barely introduced. The reason for this is the curriculum of the very same Bachelor, where socio-political competencies are barely included as learning outcomes.

The analysis has also shown that lecturers have been introducing the SDGs by their own, as individual actions lacking institutional support and funding. However, an institutional change is currently taking place both at the Barcelona School of Civil Engineering and UPC, who have fostered a coordinated strategy to integrate sustainability competences in the curricula.

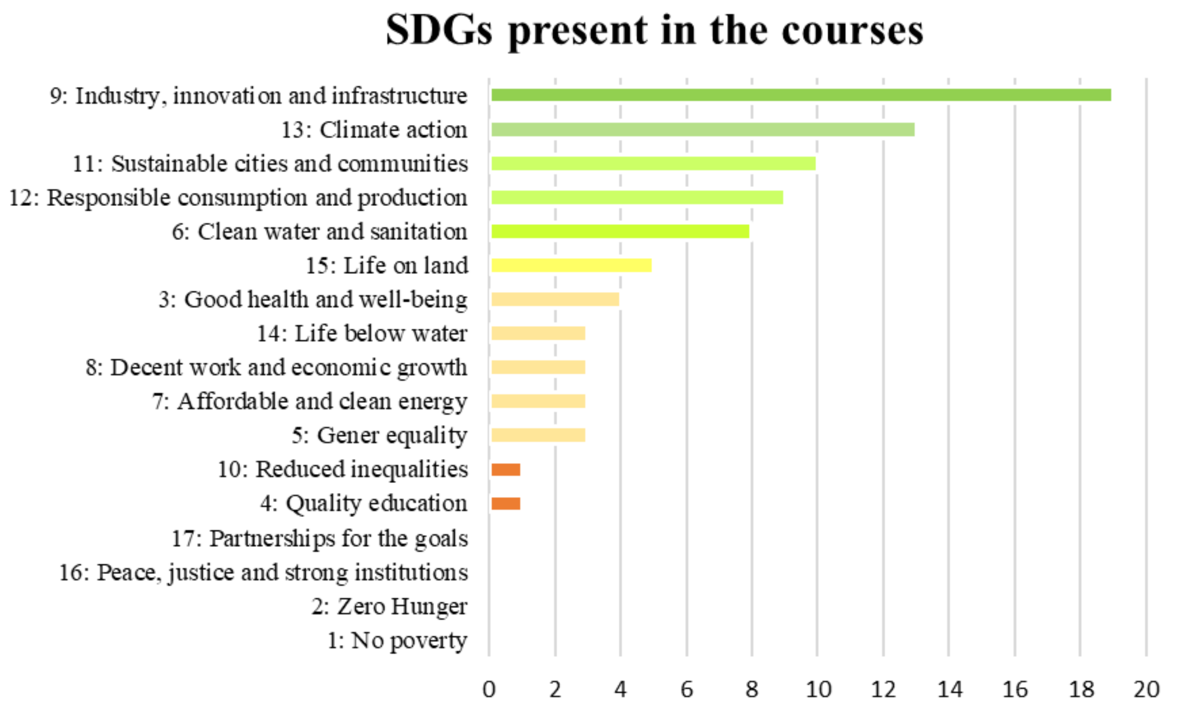

Fig 2. Number of courses that deals with each SDG in the Bachelor Degree in Civil Engineering.

A more detailed analysis on the four sustainability competence units (Figure 3) shows how they are deployed to a different extent. The graph divides the holistic unit (C2), in which the student achieves the capacity to prevent negative impacts, into four dimensions: holistic, environmental, social and economic. Competences related to the sustainable use of natural resources (C2) and critical contextualization (C1), which are the most closely related to technical aspects of civil engineering, are developed to a higher extent in the courses. Among them, social and economic aspects seem to be beyond the scope of many courses, as they are less present. However, civil engineers are responsible for planning, constructing and managing infrastructures that should be aimed at improving human well-being.

Competences dealing with C3 are placed in a medium position, meaning that the participation in community processes that promote sustainability seems to be reasonably accounted for. However, effort should be made to encourage transforming teaching-learning processes and include active methodologies and service-learning. The students will be better prepared to face complex problems if they learn how to collaborate and understand the local context and society.

Finally, the Bachelor Degree in Civil Engineering appears to invest more time at teaching negative impact assessment than addressing ethical aspects, as shown by the poor presence of C4 competence. Lecturers should discuss the risks, uncertainties and ethical implications that their future projects or professional activities will eventually have.

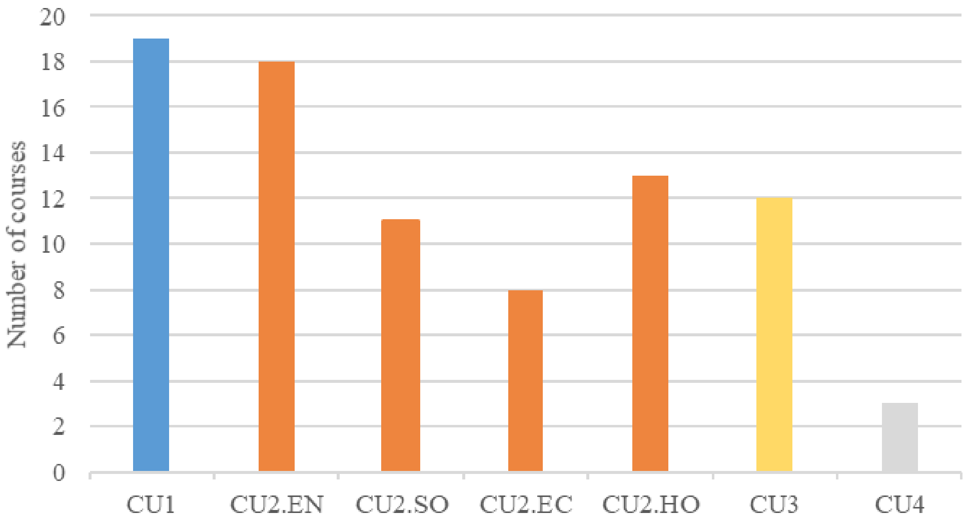

Fig 3. Presence of each competence unit at the Bachelor Degree in Civil Engineering.

Once the SME was completed, lecturers participating in the innovation project Toolkit-ODS Camins were encouraged to prepare a teaching activity to introduce the SDSGs in the curriculum. To this end, they were provided with a template and asked to fill in information on their activity, such as the SDG addressed and sustainability competences level acquired by the students.

These activities were included in the web site “Toolkit-ODS Camins”, which proposes a pathway to implement the SDGs in 4 steps:

1) Get familiar
2) Evaluate yourself
3) Prepare your own activity
4) More info

It shows a simple, straightforward way to learn and implement the SDGs in our courses. The web site will be launched soon, along with a promotional video.

4 CONCLUSIONS

The aim of this paper is to explain to which extent sustainability is present at the Bachelor Degree in Civil Engineering of the Barcelona School of Civil Engineering (UPC). It has been shown how competences dealing with C1 and C2 are present to a higher extent than C3 and particularly C4, which is still missing. These results are consistent with previous analyses of other Bachelor Degrees in Engineering at UPC.

However, some limitations should be considered. The assessment of the sustainability "presence" is based on the information provided by the lecturers' self-assessment. Considering the qualitative dimension and open-to-interpretation nature of some concepts, an external validation would be required. Thus, a more in-depth analysis should be done, and feedback from students ought to be included to increase the robustness of the results.

This initiative also seeks to encourage the implementation of teaching innovation practices that contribute to the deployment and assessment of S&CS competences and evaluate their learning outcomes. The aim of the project was to exchange experiences, develop new practices, share and disseminate them, learn and draw a common pathway for the promotion of the SDGs in the field of Civil and Environmental Engineering. For this reason, the results of the project will be disseminated in a video and web called Toolkit-ODS Camins, that will be used as guideline to integrate S&CS in other courses.

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STUDENTS' EXPERIENCES WITH SHORT VIDEOS IN A FLIPPED CLASSROOM DESIGN IN PHYSICS

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Keywords: *Flipped classroom, Short videos, Teacher collaboration, Physics, Multicampus*

ABSTRACT

We have implemented a methodology for using short videos as a part of a flipped classroom design in an introductory, multi-campus physics course for engineering students. These pre-recorded videos introduced theory and concepts to students ahead of in-class sessions, which enabled a reduction in the time used for traditional lectures. The time spent in classes puts emphasis on student activities, such as quizzes, Q&A sessions with the lecturer answering student-submitted questions, and problem solving.

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The physics course has a modular design for customized delivery to a multitude of study programmes and is coordinated by a team of teachers who provide localized classes at several campuses. Although teachers manage individual classes, the course uses an open learning environment which allows enrolled students access to all study materials published by any teacher.

We present results from a questionnaire investigating student experiences with the use of short videos, by measuring the overall level of satisfaction with the videos, as well as collecting students' comments to the videos. We investigate correlations between student satisfaction with the videos and the comments they make, and whether students whose teacher is featured in the video are more satisfied than students without a personal relationship with the featured teacher.

Students report overall satisfaction with video length and level of precision, while requesting more worked examples and detailed calculations. We identify a set of good practices for flipped classroom designs, based on the students' feedback.

1 INTRODUCTION

Active learning is found to promote students' performance in science, engineering, and mathematics compared to traditional lecturing [1]. A controlled study comparing students' self-reported perception of learning in an active learning environment with a traditional one showed that the students attending the active learning classroom learn more, but feel they learn less [2]. One way to implement active learning is through a flipped classroom design where students watch videos introducing new content before class and in class students are engaged in activities such as quizzes, Q&A sessions with the lecturer answering student-submitted questions, and problem solving. A recent study of students' perception of videos in introductory physics courses for engineering study programs showed that including videos in physics increases the probability of passing the course [3].

The focus of this paper is students' self-reported experiences with "low-budget", short videos used for introducing theory and concepts in an introductory physics course for engineering students, using a flipped classroom approach. The videos were "low-budget" in the sense of using a basic setup of recording a teacher writing notes on an interactive display. Furthermore, preparation time could be minimized because the teacher was intimately familiar with the course curriculum, being a member of the team of teachers delivering the course, and having taught the course earlier.

In our investigation we posed the following research questions:

How do students perceive the videos and what is the correlation between students' reported satisfaction with the videos, and the comments they give as feedback?

What is the effect of having your own teacher producing the videos, as opposed to a video produced by someone else?

2 BACKGROUND

The focus of this paper is a compulsory introductory physics course for engineering students, which is taught in parallel across three campuses by a team of six teachers (subsequently anonymized as teacher A-F) for a total of approx. 1000 students. The inaugural run of the course coincided with the outbreak of the COVID-19 pandemic in 2020, which enforced a digital transition of the course delivery. Building on experiences gained during the “emergency remote teaching” phase [4], a flipped classroom design was implemented in 2022. In this design, students watched short videos ahead of sessions, which introduced physics theory and concepts. The in-class/synchronous sessions (i.e., digital, physical or hybrid) briefly recapitulated key points from the videos, before proceeding to active learning activities like quizzes and problem solving.

The videos were 5-10 minutes in length and were produced by one member of the teacher team. The videos used a simple, inexpensive format which enabled rapid production: The teacher filled in partially pre-written notes on a table-mounted interactive display, with audio narration - only a small number of videos showed the teacher. A screenshot of one of the videos is shown in Fig. 1 below:

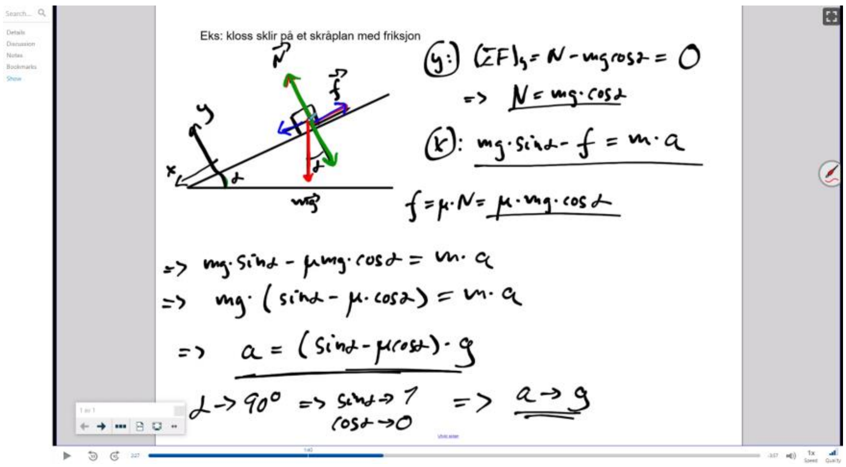

Fig. 1. Screenshot of one of the videos

Although all the involved teachers covered the same curriculum using the same set of videos, there was some variation in how in-class sessions were conducted: Some classes were given digitally; some in medium-sized classrooms; some in large lecture theatres. Furthermore, individual teachers had considerable autonomy in choosing how to present or approach any given subject during in-class sessions.

3 METHODOLOGY

3.1 Data collection

Data was collected by means of an anonymous online questionnaire, as part of a course evaluation from which only the subset of the questions regarding the videos is addressed in this paper. The questions, none of which were mandatory, were formulated as follows:

- What was your level of satisfaction with the videos? (Likert scale 1-5)

- How have you used the videos? Options: Preparation ahead of sessions/ Repetition or recap between sessions/ Aid for doing assignments and exercises/ Not used videos/ Have you used the videos in other ways than listed above? (Text answer)
- Satisfaction with teacher instruction in synchronous sessions (Likert scale 1-5)
- What worked well/less well with the videos? Suggestions for improvement? (Text answer)

3.2 Analysis

Likert-scale questions were analysed to check whether means between different student populations differed significantly, using an Aspin-Welch t-test [5]. The qualitative answers to how the videos had worked were coded inductively [6]. Codes were derived from the data and afterwards gathered into the three categories: *Appreciating short and precise videos*, *Wishing for more structure and better legibility*, and *Wishing for more examples.* To make a systematic overview, these three categories were correlated to the students' Likert scale answers of their overall satisfaction with the videos.

4 RESULTS

4.1 Student satisfaction with the videos

This section details the students' answers to the questionnaire. A total of n=259 students completed the survey, corresponding to a response rate of approx. 26 %.

The distribution of scores awarded to the videos by the students, on a 1-5 Likert scale, is shown in Fig. 2 (n = 246):

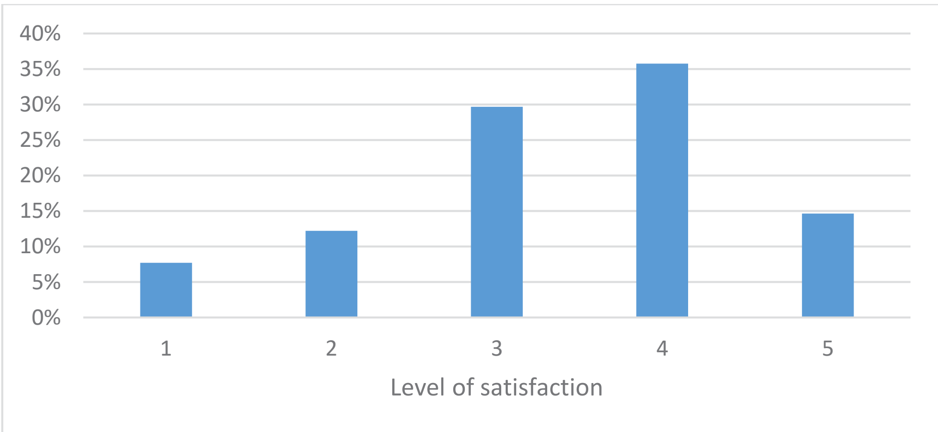

Fig. 2. Student answers to the question "What was your level of satisfaction with the videos?" (1-5 Likert scale; 1 = very dissatisfied, 5 = very satisfied)

The questionnaire did not specify which criteria the students should use to indicate the level of "satisfaction" with the videos, so implicitly Fig. 2 is a measure of "general student satisfaction", incorporating aspects like video and audio quality, clarity of the presentation, and the perceived learning effect. With an average score of 3,4 and a standard deviation of 1,1, students were generally satisfied with the videos.

4.2 Students' usage of the videos

The flipped classroom approach was presented to the students at the beginning of the term, with particular emphasis on how the students were expected to use the videos to prepare for sessions.

The various usage scenarios for the videos are summarized in Fig. 3 below:

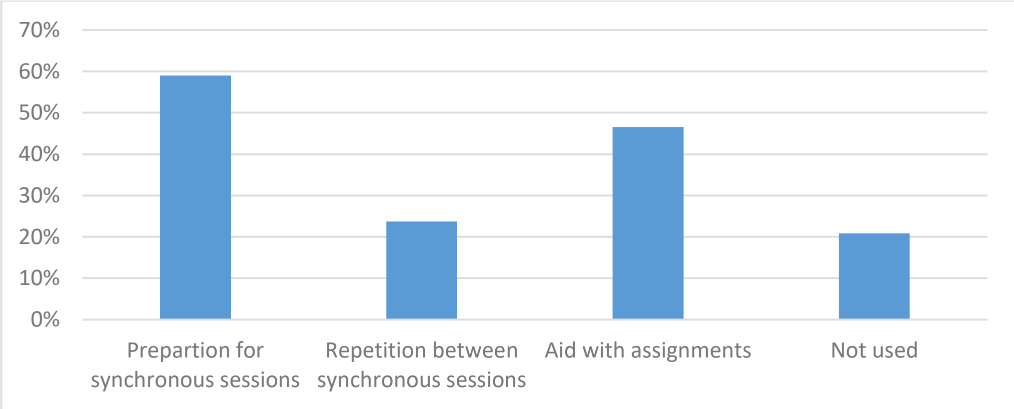

Fig. 3. Student answers to the question "How have you used the videos?"

In this respect, Fig. 3 above shows that some 60 % of the students used the videos "as intended".

Additionally, a significant proportion of students used the videos for repetition between synchronous sessions, and as an aid with assignments. No additional use cases were identified by the open question.

4.3 The effect of having your own teacher producing the videos

Of the six teachers in the teaching team, only teacher A was featured in the videos. Teacher A also gave synchronous sessions like the rest of the team, and was thus a "familiar face" for a subset of the students. The respective levels of satisfaction with the videos of teacher A's students vs. students taught by teachers B-F are shown in Table 1 below:

Table 1. Student level of satisfaction with videos: featured teacher (A)'s students vs. students taught by other teachers (B-F), as well as teachers B-F combined

Teacher	A	B	C	D	E	F	B-F
Student's level of satisfaction with the videos (1-5 Likert scale)	4,1	3,0	3,0	3,4	3,1	3,3	3,2
Standard deviation	0,9	1,2	1,2	1,1	1,2	0,9	1,1
No. of students	48	36	14	30	42	76	196

As shown in Table 1, teacher A's students and B-F's students have average levels of satisfaction of 4,1 and 3,2, respectively. Employing the Alpin-Welch test to compare averages, assuming independent populations with unequal population standard deviations, the observed difference is indeed statistically significant (p-value = $1{,}3 \cdot 10^{-7}$).

To investigate possible origins of the observed difference in level of satisfaction with the videos, data for the reported levels of satisfaction with teacher instruction in the synchronous sessions were compiled into Table 2 below:

Table 2. Students' level of satisfaction with teacher instruction for teachers A-F, and B-F combined

Teacher	A	B	C	D	E	F	B-F
Student's level of satisfaction with teacher instruction (1-5 Likert scale)	4,1	2,9	2,6	4,0	3,6	4,2	3,7
Standard deviation	1,0	1,2	1,1	0,8	1,0	0,9	1,1
No. of students	50	39	16	30	44	80	209

While teacher A was indeed highly rated, teachers D and F were given similar high ratings by their students – and so perceived teaching ability does not explain the difference in student satisfaction with the videos in Table 1.

The physics class consisted of both 1st-year and 2nd-year students, the latter of whom were familiar with a flipped classroom approach in an earlier course. The Alpin-Welch t-test found no statistically significant differences in the level of satisfaction between 1st- and 2nd-year students (p-value = 0,66).

4.4 Students' comments to the videos

The students' comments to the question, What worked well/less well with the videos were categorised into the three categories, *Appreciating short and precise videos, Wishing for more structure and better legibility*, *Wishing for more examples.* These categories are described in the following.

Most students who write comments appreciated the fact that the videos are short and precise: "*The videos are concrete and give an overview of the most important things, I like that very much", "Nice introduction to the topics",* or *"I like that the videos are short".* Students considered the videos "information-dense" and would sometimes pause the videos: *"A lot of learning in a short time".* The students also appreciated that the videos *"Are right to the point and explain the content in a good way".* The students favourably compared the short videos with much longer videos used in other courses, in which the length (from 25 minutes up to 2 hours) would make students lose focus and induce boredom.

Students were ambivalent about the teacher narrating and writing over pre-written notes: It was appreciated that this helped keep the videos short, but negative student comments to this approach were gathered into the second category: *Wishing for more structure and better legibility.* Students in this category commented on a lack of structure in the videos, and the use of handwritten notes: *"It is very nice that the* *videos are so short, but it is difficult to follow when the text is already written, and the teacher only explains what is written".* The handwriting itself was criticized by some: "*The handwriting is messy".* Other criticized the structure of the video: *"I do like the concept of flipped classroom, …, I find the videos chaotic, and they are overwhelming when you do not know the content. I feel the videos are more suited for repetition after the live sessions, not as preparation"*. Students who were focused on applications rather than understanding of physics commented e.g., *"It is difficult to follow the short videos, and it is unclear which of the formulas that are useful"*.

Comments in the last category, *Wishing for more examples,* opined that videos should contain more worked problems and examples: *"I think the videos should contain calculation exercises as well as more thorough explanations",* and *"It would have helped with more practical examples"*. These comments indicate that students would have liked to see worked problems and calculations in the videos, contrary to our intentions of using the videos to introduce the theory, while using the synchronous sessions to work on problem sets.

Correlating student comments within the three categories with the level of satisfaction with the videos, gives the distribution shown in Fig. 4:

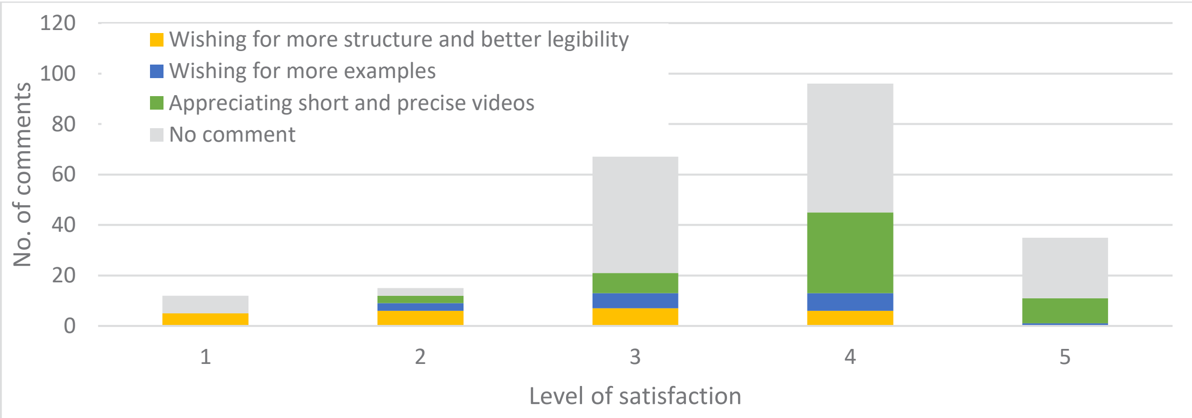

Fig. 4. Students' comments categories grouped by answer to the question "What was your level of satisfaction with the videos?" (1-5 Likert scale)

Dissatisfied students (score = 1) all belong in the category Wishing for more structure and better legibility, whereas "reasonably satisfied" students (score 2-4) are present in all three categories. Higher levels of satisfaction correlate with greater appreciation for short and precise videos. Note: A single student's comment can contribute to more than one category.

4.5 Students' suggestions for improvements

Students felt that structure could be improved by *"Handwriting text and calculations live instead of using pre-written text"*, and that the tradeoff in terms of *"It takes a little more time"* would be worthwhile.

Some students suggested that videos contain a list of recommended textbook exercises, relevant to the theory presented in the video, at the end.

A few students reported a dislike for the flipped classroom approach altogether, in favour of traditional lectures – in line with findings in [6], where flipped classroom is found to be less advantageous for certain groups of students.

5 DISCUSSION

5.1 General analysis

Overall, the students were satisfied with the videos, highlighting their short duration and precise, to-the-point presentation. Except for the students most satisfied with the videos, students across all satisfaction levels suggested improving the video structure, to make it easier to understand the logic of the learning material.

Comparing Tables 1 and 2, we conclude that familiarity with the teacher featured in the video, rather than exceptional instructional skills, is key to student satisfaction.

5.2 Suggestions for good practice in video-led flipped classroom designs

Based on Fig. 4 and the students' comments on the videos, we can suggest certain good practices for flipped classroom designs:

- A simple, low-cost setup with a digital writing surface (e.g. interactive display or tablet) is enough to produce videos of adequate quality.
- Video length vs. legibility: Keep videos short, but avoid static slides. Spending some extra time to write live text will increases legibility and makes it easier for students to follow the logic of the presentation.
- Video structure: Give a very brief overview of the video at the beginning, and point the students towards further study material (e.g. exercises) at the end.
- If the students are unfamiliar with the methodology, the teacher should demonstrate how to work with the videos by showing the first few of them in the classroom. Additionally, students need to be repeatedly reminded how they are expected to work outside the synchronous sessions, and the rationale behind the chosen approach.

5.3 Study limitations

The authors are aware of several methodological limitations to this study:

- The 26 % response rate is low.
- 20 % of the students participating in the survey, reported not using the videos.
- Even though the research questions focused on the videos and pedagogical approach in which they were used, it's difficult to decouple the significance of individual teacher performance during the synchronous sessions.

6 ACKNOWLEDGMENTS

The authors are grateful to all students who participated in the survey, and they also wish to thank all the members of the teacher team for their cooperation. We also thank reviewer 2 for providing constructive feedback that helped us clarify the last point in section 5.2.

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Challenges for engineering students working with authentic complex problems

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ABSTRACT

Engineers are important participants in solving societal, environmental and technical problems. However, due to an increasing complexity in relation to these problems new interdisciplinary competences are needed in engineering. Instead of students working with monodisciplinary problems, a situation where students work with authentic complex problems in interdisciplinary teams together with a company may scaffold development of new competences. The question is: What are the challenges for students structuring the work on authentic interdisciplinary problems? This study explores a three-day event where 7 students from Aalborg University (AAU) from four different faculties and one student from University College North Denmark (UCN), (6^{th}-10^{th} semester), worked in two groups at a large Danish company, solving authentic complex problems. The event was structured as a Hackathon where the students for three days worked with problem identification, problem analysis and finalizing with a pitch competition presenting their findings. During the event the students had workshops to support the work and they had the opportunity to use employees from the company as facilitators. It was an extracurricular activity during the summer holiday season. The methodology used for data collection was qualitative both in terms of observations and participants' reflection reports. The students were observed during the whole event. Findings from this part of a larger study indicated, that students experience inability to transfer and transform project competences from their previous disciplinary experiences to an interdisciplinary setting.

1 INTRODUCTION

1.1 Section 1

Engineers are expected to be important participants in solving the grand societal challenges [1]. These aspects create new demands for engineering education in the future [1,2] and new ways of students' collaboration in more interdisciplinary situations across disciplines and faculties [3]. This paper describes the experience from a 3-days Hackathon event that took place at a large Danish company where 7 students from AAU (Aalborg University) and one student from UCN (University College North Jutland) worked in two project groups solving authentic complex problems. Students from AAU are used to project work on problems in teams with participants from their own discipline. At the Hackathon event students work with complex problems in an interdisciplinary group. Research shows that students have difficulties with collaboration on complex interdisciplinary problems [4,5]. The aim of this research is to answer the question: What are the challenges for students structuring the work on authentic interdisciplinary problems? Initially the paper introduces the theoretical framework used to interpret the data collected, then presents the methodology and finally describe and discuss the results.

1.2 Theoretical framework

There are different interpretations of the concept interdisciplinarity. However, this study uses the definition by Keestra & Menken [6] where interdisciplinarity is defined as a range of degrees from multidisciplinarity to transdisciplinarity. Multidisciplinarity is defined as a situation where disciplines work together in parallel. Interdisciplinarity is a situation where disciplines are integrated and finally transdisciplinarity is a situation where interdisciplinarity is integrated with non-academic domains. To extend the definition of interdisciplinarity the typologies described by Klein [7] are used. Klein [7] distinguishes between narrow and broad interdisciplinarity. Broad interdisciplinary collaboration teams are teams working together with very different understandings of ontologies, epistemologies and methodological approaches, whereas narrow interdisciplinary teams are teams that are closer aligned in relation to ontology, epistemology, methods and understandings. In relation to interdisciplinarity, boundaries and boundary crossings are very important. Carlile [8] defines three levels of managing knowledge across boundaries in relation to the differences, dependencies and novelty, see figure 1.

The first level – Syntactic transfer: When novelty is minor the knowledge between Actor A and Actor B can be transferred without problems and the category of the boundary object can be represented by a repository [9]. **The second level – Semantic translation**: With increasing novelty, the differences and dependencies can become unclear or there can be different interpretations of meanings. At this level, transformation of knowledge is not enough but translation of meanings or negotiations may be needed and the boundary objects can be categorized as

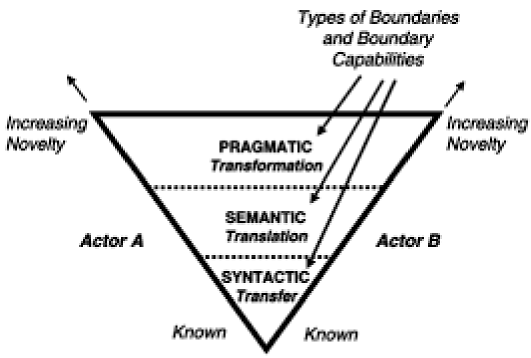

Fig. 1. An integrated framework for managing knowledge across boundaries [8, p.558]. Actor A and Actor B represent actors from different disciplines with differences and mutual dependencies. Increasing novelty entails increasing effort to manage the boundary.

standardized forms and methods. **The third level – Pragmatic transformation**: When novelty increases to a level where it affects the interests of the actors a transition to the pragmatic level occurs. The pragmatic level needs knowledge to be transformed from domain specific knowledge to a mixture of knowledge domains and the boundary object can be categorized as objects, models or maps [9].

2 METHODOLOGY

2.1 Research context

This study, which is part of a larger study, is based on a 3-days extracurricular event arranged by AAU in cooperation with a large Danish company. 7 students from four different faculties at AAU and one student from UCN participated in the event that was structured like a Hackathon. The students came from four different countries. The event took place at the premises of the Danish company, where the students stayed during the whole event together with three employees from the company and three researchers from AAU. The content of the Hackathon was a combination of round tours at the company, supporting workshops and group work. The group work was divided in four sprints with inspiration from a guide concerning PBL and Entrepreneurship [10]. Each sprint finalized with a pitch from the two groups. The overview of the Hackathon is shown in figure 2.

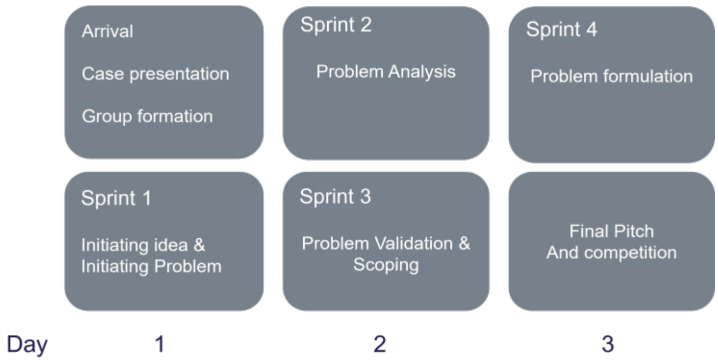

Fig. 2. Overview of the Hackathon event divided in four sprints finalizing with a pitch.

After students' arrival and accommodation at the company, employees from the company presented two different cases for the students. The first case - Case #1 belonged to a problem area familiar for the company whereas Case #2 was regarded as a new problem area. After lunch two groups were formed based on student competences and interest in the two cases. After group formation the students worked in four sprints finalizing with a pitch competition on day 3. The jury for the competition consisted of one jury member from the company and two jury members from AAU. The winning group was awarded with a cash prize.

2.2 Empirical data

The methodology used for data collection was a qualitative research design. Three researchers from AAU participated in the event. Two of the researchers conducted the workshops and structured the event. The third researcher was assigned the role as an observer during the whole event, without participation in the workshops. This researcher used an observation protocol [11, p.190] for recording the observations during the whole event. The observation protocol was divided in a descriptive part, supplemented with columns for details concerning participants, objectives, means and tools, messages and findings and a reflexive part with room for observers own thoughts and comments. The header of the observation protocol contained information about the current project phase. At the registration to the Hackathon event, the students were asked to give a short-written justification for participation and at the beginning of the event the students were asked to make a competence profile. The competences were parted in two: the professional competences and the PBL competences which worked as baseline for the final reflections and edition of competences gained at this event. After the Hackathon the students were asked to reflect about their experiences with the Hackathon event and give inputs to improvements for the future.

3 RESULTS

3.1 Students justifications for participate

From the students' justifications for participation, it is clear that it is very motivating for the students to participate in an event like this, especially when it is possible to relate the themes to their own studies and backgrounds. *"I would like to join this event because I think that the challenges sound really exciting and the themes fit very well together with my studies".*

Two of the students directly mentioned one of the themes as very important for their participation. The students also mentioned their own backgrounds as important and the experience of how they could contribute*: "With excitement I look forward to see what I can contribute in the context of Your enlightened themes and in the collaboration with other professional groups during the teamwork sessions…..".*

"Additionally, with my knowledge of [……..] together with a background in [……..] and experience in problem solving in a group, I feel I would be able to really make a difference and contribute to the workshop".

Collaboration and problem solving in groups was mentioned too. *"I want to participate because I see it as a great opportunity to work creative and innovative with other students on solving problems"*.

Moreover, reflections about the future about own career and their own role was mentioned: *"Events like this allow me to establish my professional qualities as I have to be a specialist in my area, aware of the fact that my input really matters".* And: *"The possibility to broaden my horizons and challenge my creativity is the reason for my participation"*. At a more meta level a student wrote: *"Furthermore, I am interes-ted in design processes, innovation and the human consequences from implement-ting smart technologies"*. Finally making new relations also mattered: *"And most importantly, challenging events are the place where amazing friendships start :)".*

3.2 Interdisciplinary team formation

After the presentation of the two cases the students were asked to write down their professional and PBL competences on post-it notes. Subsequently the students shared all the post-it notes on a large white board and presented their personal competences to the other students. With support from the researchers the students formed two groups, based on individual interests in the cases and based on the knowledge from the competence clarification. Group #1 working on Case #1 consisted of four students from four different faculties at AAU (Technical Faculty of

IT and Design (TECH), Faculty of Engineering and Science (ENG), Faculty of Social Sciences and Faculty of Humanities). This case was familiar to the company and the students were able to get information from employees from the company. Group #2 working on Case #2 consisted of three students from AAU (two from ENG, one from TECH) and one from UCN – (Energy management). Case #2 was a case the company had no experience with.

3.3 Working process

The analysis of the working processes for the two groups is based on the information from the observation protocol.

Group #1: The group used written material from the company as basis for communication and for developing the idea together. Trying to decide an idea – discussing pros and cons. They also were inspired by the round tour at the company. They had difficulties with a common platform for communication, but after some time they began to use a white board. The first pitch was not well organized – they had no plan for speaker and content and no agreement on idea and no project management. After the pitch, the group began to work individually to find a problem. They chose an idea and discovered it was already realized. Then changed the idea and discussed who the customer is. In the first sprint retrospective they agreed that they lost their focus and talked past each other. However, they have developed a concept that help them communicate. An employee from the company gave input to the group concerning the problem context, which made it easier for the group to clarify the problem. During the problem analysis the group was still unsure about the problem. This situation changed in the problem validation sprint, where the group used the Business Model Canvas (BMC), they were introduced to in a workshop. The BMC created a structure for the work and became a steering tool for the group. The group created a good understanding of the customer. Still there were no project manager in the group. The group used the white board to define the hypothesis and used a drawing as focal point, however they had problems concerning consensus for the work. In the preparation for the final sprint one student took the lead. The time pressure was evident, however, there was a consensus concerning the result. The final pitch presentation showed good understanding of the customer, the problem, market potential and the opportunities for the company.

Group #2: They started with expectation clarification and worked individual on own ideas. They used the white board to present many ideas to each other and discussed limitations. They had no specific project manager. The time pressure was very clear. They were ready for the pitch, but the problem was still open – they needed to narrow it down. After the first pitch the group used the white board, writing down what they agreed on. Despite disagreements they acknowledged their differences. In the sprint retrospective they agreed that they often end in circular discussions, that they need to be better to ask for help and to realize when they are agreeing. In the problem analysis sprint, it was clear for the group what the essential problem was. However, the group had difficulties delimiting and clarify the problem.

They struggled with identifying the customer. In the problem validation sprint, they started out with individual drawings, but joined using the drawings as focal points. One member of the group stood out as leader. The group rejected to use BMC, instead they used many different methods mixed together. Language was observed as a barrier sometimes. The group worked individual within own discipline, calculating system performance or sketching the solution, resulting in many drawings and calculations. Working systematically, two by two or individually. The time pressure was evident, however, there seemed to be a consensus concerning the result. The final pitch presentation showed a well-structured and well-designed presentation with technical details and a systemic approach. However, there was less determination concerning the customer and hence the problem understanding and possible opportunities for the company.

3.4 PBL competences

Before the group formation the students were asked to reflect on their professional competences and PBL competences. Some of the PBL competences mentioned before the group formation were: *Team collaboration, planning of the process, task delegation, project management, time management, work structuration, conflict management, problem identification and problem analysis.*

After the final pitch, the students were asked to reflect on their new competences acquired during the event: “Shorter time for handling selection [decisions]”, “Awareness of incorporation of “in-house” knowledge that is outside the group”, “Not being blind to externals”. “Acceptance of concepts from all of us”. “See the value in my collaboration skills in ‘the real world’ not tacit”. “Agreements in the group”, “Good team player”, “Value oriented”, “managing time”, “reflective”, “focus on finishing task”, “solution oriented”, “make room for every one to be heard”, “change management”, “giving presentation”, “take responsibility for initiating tasks”.

3.5 Students’ reflections

The students were asked to reflect on the Hackathon event. Some of the observations are described for the two groups below.

Group #1 reflections: Were not used to use all the technical resources present at the company. There is a lot of new tacit knowledge, which mean they need to be more explicit. The communication was a barrier, they used a lot of time because they talked past each other and needed to repeat the information to identify and set a common scene. Commented that it is important to identify the main problem and know the core problem to solve.

Group #2 reflections: Need to be more critical and to say “No”, especially when narrowing down the problem. Identify more soft skills and be able to reflect and identify on the process. The setting was familiar for one of the group members, however, the domain specific competences came only to a little extent into play. Learned new business skills and how to apply it in a company.

Besides the students own reflections, they were asked a question about their expectation to the event. One student answered: "*Learning the new form "Hackathon", "Getting to know [company name] better", and "Getting experience in the processes and in presenting new stuff".* Another student answered, "*Challenge myself with innovation and new concepts"* and a student answered, "*To use my competences, to work interdisciplinary and to hopefully find a solution to the problem".* Furthermore, the students were asked to elaborate on the experience from the Hackathon. One student answered: *"The Hackathon was a great event. The 'lectures' facilitated the development of the project, however I felt the introduction of the topics was not specific enough and left me wondering what we are actually supposed to do. The teamwork was very easy due to everyone being so open to forming new work relationships."* Another student answered *"The social aspect only benefited the teamwork, and I felt that it was very important"* and a student answered *"I think it was great, everything happened at [company name], and we were able to ask them questions. I think it was an experience both socially and professional. And I think it was good motivation".*

Concerning outcome of the event some of the student answers were: *"Knowing new things about myself, found my good presentation skills. getting better at listening".*

"It showed me how I work in interdisciplinary teams, where none actually knows each other beforehand. I also learned the importance of questioning my choices and not agreeing to everything that is brought up in the discussion."

"I experienced a new environment, where I found a new professional part of me. I have learned a lot about myself, and working together with people I don't know".

Students' ideas to improve the Hackathon were: *"Less time in pitching. Let people know a little time earlier that you had to present your own skills, I missed a lot."*

"A more thorough presentation of what the topics are and what is expected would be beneficial. Specifying whether the end result should be a business concept, a product or what would guide the groups in a good direction. Overall, loved it, so thank you for organizing it :) hope to take part in it again"

"Shorter pitches. Maybe we from the beginning could limit our pitches to 10 min. And maybe present, what it a good pitch?". "It was a great experience, and something I will recommend to others"

3.6 Discussion

The two groups performed differently. Group #1 was a broad interdisciplinary group working on a case the company had worked with before and where an expert was available for further in-dept knowledge. The group had a solution early in the process. The group had troubles with finding an agreement, structuring, managing, communicating and understanding each other. However, when they were introduced to Business Model Canvas, they used this model as a boundary object to structure the process and the project. They created a good understanding of the customer in relation to the case and used the guided company round tour to get inspiration for their solution. Group #2 was a narrow interdisciplinary group working on a case unfamiliar to the company, therefore they could not get any expert knowledge. They were all used to work with technical problems and they had many ideas to solve the technical challenges. Each group member worked in a structured way and they used the white board intensively in the whole process. Communication was difficult and they disagreed about scope. They had troubles identifying the customer and the real problem, but very early focused on the technical part, from different angles, making calculations and drawings. The drawings were this groups boundary objects, as they did not want to use the Business Model Canvas. Referring to Carlile [8] the novelty for both groups were high. The problem areas were new for the students, the time frame very short and the team composition different from what they are used to. Both groups had difficulties with transferring their previous experience and knowledge concerning project work to the new situation. The participants forgot about their experience of how they used to do and needed more support and steering from the facilitators. The general lack of management affected their process and management of time. It was difficult to use knowledge developed in a monodisciplinary setup in the interdisciplinary setup and decide how to work together in the new situation. More time to strengthen their relations could help the process. It was difficult to keep the time in the pitch presentations, more training could help. Moreover, it is difficult for students to express their competences without preparation. They may need more time for that and for creating the necessary relations in the groups. The winning group of the Hackathon event was Group #1, basically because this group had the best understanding of the problem and the customer. Group #2 was more focused on the technical aspects and on a technical solution. At this event the two groups worked with two different cases – the broad interdisciplinary group with the most familiar problem area and the narrow interdisciplinary group with the less familiar problem area. In future Hackathons it will be preferred to present only one case for the students in order to create more even criteria for the competition.

This Hackathon, which is part of a larger study, shows difficulties for students to transfer their monodisciplinary knowledge and experience to an interdisciplinary situation, without guidance and preparation. However, the students' reflections and comments after the Hackathon show that the step from monodisciplinary project work to interdisciplinary project work is difficult, but events like this Hackathon in Engineering Education can help students to experience the challenge of interdisciplinary boundary work and experiment with coping strategies. One step may not be enough but events like this used in different contexts can scaffold the students' interdisciplinary competence development.

4 ACKNOWLEDGMENTS

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Departmental seminar series and journal club with enhanced learning outcomes

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Keywords: Seminar series, journal club, paper reading, active learning, feedback driven

Abstract
Listening to scientific presentations and reading scientific literature are core activities of any scientist, and frequent components of students' curricula. When employing these activities in teaching, finding the right balance between student instruction and autonomous learning is important for best learning outcomes and teachers' workload. We here present our course design for a coordinated lecture series and journal club, that finds this balance by leveraging modern learning concepts in a digital environment. Participating students were tasked to read a landmark scientific paper every week ahead of a lecture by a scientist with practical experience on the topic of that paper, often an author of that week's paper. Students then had to hand in written answers to three questions probing their understanding of the topic and the paper. In a subsequent seminar, activating questions were discussed by the students in break-out rooms and then answered by randomly chosen students in class, followed by a broad discussion that included the homework questions. Students gave weekly feedback on their learning progress and experience, and the course was then dynamically adapted accordingly. This yielded a course with largely increased course capacity, reduced teachers' workload, and substantially enhanced learning outcomes, qualitatively and quantitatively compared to previous implementations of the course.

1 Introduction
Scientific core activities include listening to presentations, discussions, literature research and writing, and critical appraisal of each of these [1]. While University level teaching generally considers these skills to be important, they are not taught comprehensively, with only few courses focussing on these skills specifically [2,3].
A contributing factor might be the high time consumption of scientific reading formats for both students and teachers. First contact with scientific communication needs a high degree of instruction and supervision. This is contrasted by tight teaching

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resources [4] and increasing numbers of student enrolments [5] that make it difficult to realise small scale formats like journal clubs or expert discussions.

Progressive teaching concepts like active learning and peer-teaching could overcome such limitations. Solutions could include topic rather than paper-specific journal clubs [6] or active teaching [7], peer-mentored learning [8], which proved to increase student engagement and learning outcomes; this could potentially be further enhanced by restructuring a course into problem-solving and instruction phases [9].

Furthermore, science-related classes feature a huge variety of topics, which creates challenges and chances alike. Being confronted with expert-level knowledge from different fields can be overwhelming and discouraging, however it can also be utilised to make students profit even more. Studies showed that interleaving different topics enhanced memory and problem-solving ability [10] and that translation between different research fields greatly improved metacognition, which consequently increased active learning success [11]. Another point to consider when covering different topics in an iterative manner is the frequency of testing or feedback on learning status. Meta-analysis showed no significant correlation between test frequency and academic achievement but also suggested that topic associated, frequent assessment outperforms centralised assessments (e.g. midterm or final exams) regarding learning outcomes [12,13].

Our previous “student peer teaching” concept [14] for the presented course included many of these considerations already. Each week, a student presented a scientific paper and its associated topic to the class in a full lecture, supported by us in the preparation and during Q&As. This, however, limited the number of attendees to the number of weeks and students complained that only the topic they themselves presented was really mastered.

We here present a course and its first test that builds on these considerations to enhance learning outcomes in an open participant number format. We combined a departmental lecture series of expert talks with an active learning journal club in a digital environment. Initially introducing topics by experts from the field sparks interest, translates the research into different contexts and defines objectives (educational trajectory phase) [15] for the subsequent active learning & problem-solving phase, which is rounded by a seminar including peer-teaching and teacher instruction phases.

2 Methods

2.1 The current course concept was created in a three stage process. The first stage consisted of conception sessions of a professor and two teaching PhD students similar to the curricular spider web [16] following the rationale of increasing the participant number, whilst decreasing teacher time expense and most importantly enhancing the learning outcome for students. This step included reviewing the structured student feedback and teacher notes from running the previous course format for seven years, followed by literature research on formats like lecture series and journal clubs and concepts like active learning [7], peer-teaching [8,14] and problem-solving [9]. The resultant plan of the course was further refined in the following two ways:

2.2 The second stage included the acquisition of speakers for broadly predefined topics in the area of modern biological mass spectrometry, based on the content of the previous iterations of the course. The scientific publication to focus on was suggested by us and in some cases adjusted based on feedback from the speaker. External speakers were all chosen from the list of authors of the scientific papers we wanted to cover and approached proactively. In our experience, scientists have a general interest in propagating their field specific knowledge and techniques, especially to students. Besides altruistic reasons, the aspect of recruiting potential new master or PhD students can be compelling and is far from being a one-way road, as this also offers the students career options.

2.3 The third stage took place whilst running the course and based on student participation. We collected feedback and ideas for improvement at the end of every week, screened that immediately and categorised it into: unfeasible (ideas/wishes restricted due to e.g. limited expert availability, university regulations, time etc.), potential long term goals (ideas for next year's course) and potential immediate implementations (ideas that seem short term viable and potentially add value). Third category ideas were implemented and followed by feedback at the end of that week, so that we could decide if changes would be solidified or dropped again.

It took about six weeks into the course to find the right balance between student instruction and autonomous learning. The resulting final course concept is presented in the following section.

3 Results

3.1 Goals

When planning the course, we defined three main goals, elaborated in the following passages. To facilitate critical reading of scientific literature, we followed an active learning strategy. We used paper examples and tasks to emphasise certain caveats and foci when reading a scientific publication.

A second aim was to enhance general paper reading skills. Next to the natural progression by regular reading and discussing, two weeks into the course (after students read the first couple of papers) we discuss with the students how to approach a paper and mutually developed a reading strategy. This strategy suggested getting an initial overview of the papers' main points by perceiving the graphical content first, then understanding the abstract and figures, and finally reading the paper with a focus on the critical parts [17].

Thirdly, at the end of the course we want the students to be equipped with a large toolbox full of bioanalytical methods, problem-solving skills and an individual compartment for their own ideas, including the courage to think big. By giving them the opportunity to pre-familiarise themselves with these topics in a flexible environment, bringing them into contact with experts from these fields and finally encouraging them to apply the gained knowledge into new contexts every week, we expand their long-term skill set and strengthen their confidence in applying these.

3.2 Implementation

To achieve these goals, we developed a weekly schedule (summarised in **Supplement Figure 1)**, which is further explained in the next paragraphs.
The weekly paper and corresponding homework questions were uploaded on the universities' moodle based platform each Friday morning of the preceding week. To profit most from the expert session on Monday, students read the paper beforehand.
The expert's session consisted of a 45-min talk and a subsequent 15-min discussion with the students via Zoom. The talks included an introduction into the technology, examples of its application, personal side notes from the expert scientist and an inaugural part on the week's paper. The latter was especially important as it helped students to understand the paper's premise and set the objective (educational trajectory phase[15]) for the subsequent active learning phase. Students liked to hear these personal side notes and hands-on experiences, as it makes technical content more approachable and imaginable.
Students were then asked to re-read the paper and answer three questions regarding the paper until Wednesday night. Answering the following topic-related questions, across all twelve topics, made up 72% of the final mark.

1. "What is the core idea of the technology and how is it applied in the paper?"
2. "What application of the technology intrigued/inspired you and why?"
3. Examples for *general or topic-specific* third questions:
   "Explain the principle of the technology and what it is used for in easy words (like for a 12-year-old) preferably supported by metaphors or picturesque explanations". (*general*)
   "It is 2030, how did the technology used in the paper develop? How does it influence science and maybe even society? Write a brief future scenario!" (*general*)
   "What are differences between protein and mRNA coexpression data?" (*specific*)

The first two questions stayed the same, whereas the third question varied across each week and was more translational. According to student feedback, this seemed to give the right balance between consistent expectation and motivating variety.
Each week was finalised with a seminar (**Supplement Figure 2**) that started with an anonymously answered multiple choice activation question, usually a seemingly basic question on the paper's fundamentals. However, the polls consistently showed ambiguous outcomes, with substantial proportions voting for the wrong answers. We find this especially noteworthy, as even after reading the paper, listening to an expert on it, being able to ask questions and then having to provide written answers, these students frequently did not get the underlying core concepts. The results were shared uncommented with the students, which were then sent into 30-min breakout sessions with five to six students. They were instructed to discuss the activation question (peer teaching) and the answers to their homework questions. Back in the plenum, the activation question was then polled again. Interestingly, the vast majority now answered correctly! Subsequently, the pre-discussed homework questions were

shortly presented by randomly chosen students, complemented voluntarily in a discussion and rounded through additions by teaching staff. This further deepened the understanding of the core concepts. Student feedback steered the course towards more time within the breakout sessions and a concise plenum afterwards. So also the students became clear about the value of peer interaction.
Seminar participation was marked following a “points remain unless you abstain” system, meaning everyone gets full points from the start, only being lost when a participant is chosen by a randomizer tool and does not answer at all (most basic answers were accepted and used as discussion starters). This being communicated clearly at the course’s start created a seminar discussion environment without competition for speaking times (when participation would equal points), hence less overlapping content. This also encouraged preparation, and appearance of each student, and allowed the discussion to evolve more naturally and autonomously.

3.3 Feedback

Finally, students were asked to give their weekly feedback on the course structure, and the content and to evaluate their knowledge of the topic before and after the topic’s week. Students also commented on implementation of their suggestions.
Students viewed time requirements as demanding, but very fair. The course required regular time investment throughout the week, however the consistent structure with flexibility in-between helped to learn efficiently and plan their weeks in advance. The weekly time needed to access a paper fully and to answer the homework questions was very individual to each student, ranging mainly between 2-8 hours (**Figure 1**); however, oral feedback indicated that the time expense declined throughout the course progression due to improved paper reading skills.

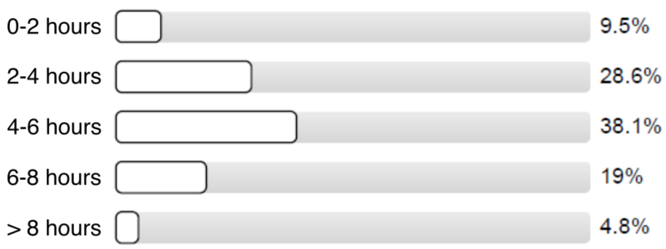

Figure 1: *Weekly time investment for students (acquired by the systematic university’s evaluation system at the end of the semester)*

This also applied for the teacher’s time investment; with growing experience, especially marking the homework questions became more efficient. One major workload on the teacher's side was the course preparation; guest speakers needed to be acquired, fitted into a suitable schedule, briefed on the concept and a suitable paper had to be proposed and/or mutually agreed on. Including the usual tasks like online course setup and material collection, one to two full-time weeks should be considered as preparatory work (however this should decrease on reiterations with the same guest speakers). Weekly time investment was necessary for the course

maintenance including paper reading and content generation (~1-2 h), moderation of the talk (1 h) and the seminar (2 h), feedback assessment and organisational matters (~1 h), and examination of the homework questions (~4-6 h) adding up to a weekly time expense of around 9-12 h. With 45 students in the course, this equated to ~15 min/student per week, with an improved learning outcome and student satisfaction compared to the previous concepts (~1 h/student per week).
We assessed student progress across all topics through weekly evaluation shown in **Figure 2**. We could observe a substantial increase of self-assessed knowledge levels from prior to afterwards across all topics. The ratings (x-axis) span from 0 (absolutely no knowledge) to 10 (expert knowledge).

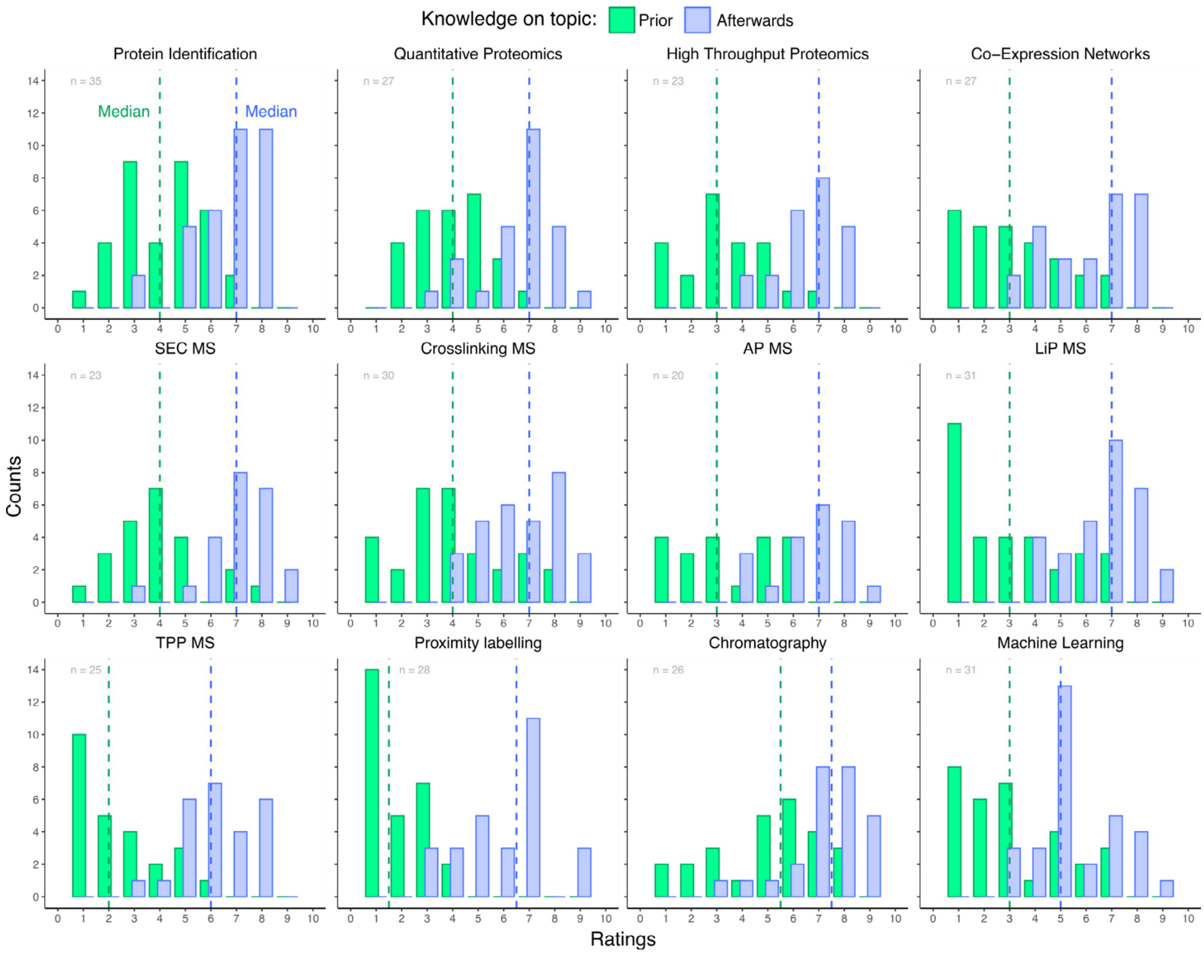

Figure 2: *Self-assessed knowledge level of students prior to (green) and after (blue) a topic-specific week, with medians given as dotted lines*

For the majority of topics, we observe an increase by 3 or 4 of the median knowledge level (dotted line) from 3-4 (prior) to 7 (afterwards). This is a marked improvement over the previous years, when students consistently complained about achieving limited progress. We also noticed increased precision and depth of answers given in homework and seminars as the course progressed. The average mark improved from 1.7 (WiSe 20/21, n = 12, old format) to 1.3 (WiSe 21/22, n = 45, new format) (*1.0* being the best and *5.0* being the worst possible). Overall, this data

supports the assumption to have enhanced the students' learning outcomes and skill set sustainably across all topics.
This assumption is further supported by the university's systematic final evaluation system, marking the course quality on average with *1.1* . Providing the course content in the format of a lecture series in combination with a journal club seemed very useful for students' learning success (*1.2*) and gave them confidence in having understood these (*1.6*), even though the overall content was perceived as more complicated than in other courses (**Figure 3**).

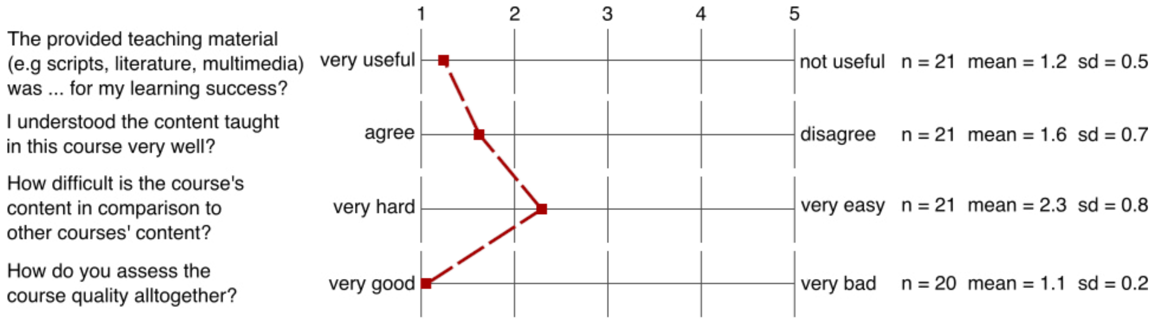

Figure 3: *Overall course feedback at the end of the semester (acquired by the systematic university's evaluation system)*

Lastly, it is also the students' qualitative feedback that shapes the course evaluation and its further development. Feedback like *"Thank you for all the Input! I learned a lot and will definitely recommend this course.", "This course is pretty much the first in which the possibilities of e-learning have been properly exploited"* or *"One of the most interesting and informative courses I have ever had"* encouraged us to consolidate this concept and to make it available for others through publication.
To outline some of the most frequent feedback we got (supported by frequency analysis [**Supplementary figure 3**]), most students were pointing out their interest and content ("interesting topic/discussion", "everything …[fine, good, great etc.]") and they were positive about the variety of content and formats ("new things/information", "good way", "different aspects", "third question"). Additionally, the majority affirmed adequate course pace or time expense ("enough time") and in the beginning, many pointed out a wish for smaller discussion groups ("many people", "smaller group"), which was complied by refining the seminar structure ("break out session", "small group discussion").

4 Discussion

The entirety of collected feedback suggests us having enhanced the learning outcomes across all topics considerably by remodelling the course into a departmental seminar series and journal club. We here rely on an extensive collection and interpretation of regular student feedback and the experience of our teaching perspective. However, we are aware that our study lacks a long-term comparison and a standardised learning outcome assessment. Such measures are currently being developed.

Furthermore, it has to be considered that the remodelling from a topic-centric "student peer teaching" concept towards a lecture series and journal club shifts the focus of trained soft skills from presentation towards paper reading, critical assessment and discussion. All of these are essential skills for scientists, though, our experience and received feedback indicate that we could achieve greater improvement within the literacy skill set, than previously in presentation skills. Note that the latter is being trained from elementary school on, whereas for most students, scientific reading and assessing is only a part of writing up their theses. We see a great necessity to help students approach scientific literature confidently. Many of them, even when close to finishing their studies, still feel demotivated or overwhelmed when researching literature [6].

Apparent improvements we could work out already refer mainly to the need of weekly summaries. The in-depth discussions and topical excursion in the seminar made it hard for some students to remain focused on the essentials, so that they asked for more frequent summaries. This could be achieved by ending a seminar by collectively defining e.g. the three most important points about the technology or answering the same summary questions for each topic. This would refocus the natural flow of the discussion into a digestible take-home message. From the teaching side, we identified as the main caveat the time needed for marking the homework questions. In the next course iteration, we will experiment with students having increased responsibility, to answer non-assessed topical questions and use the seminar discussion to evolve their answers. We will then use part assessments (e.g. every 3 papers) consisting of a mixture of multiple choice (similar to the activation questions) and partly free text questions (as described in 3.2).

In conclusion, the revised course achieved the defined goals. The now scalable, more student-autonomous concept enabled us to lift the participant restriction whilst showing substantially improved learning outcomes across the range of very specialised content. Instructors' absolute time investment decreased only slightly, however with student numbers quadrupled and learning outcomes increased, we consider this a great success.

5 Recommendation

Our course concept might serve as a blueprint for a departmental lecture series in combination with a journal club. We see this concept as being highly transferable, as the structure evolves around weekly building blocks that could be filled with any topic and corresponding speaker and literature. We happily encourage any educational team or lecturer to adopt the here presented concept and would in such a case just ask to reference us and, more importantly, to give feedback to us on its performance and potential improvements.

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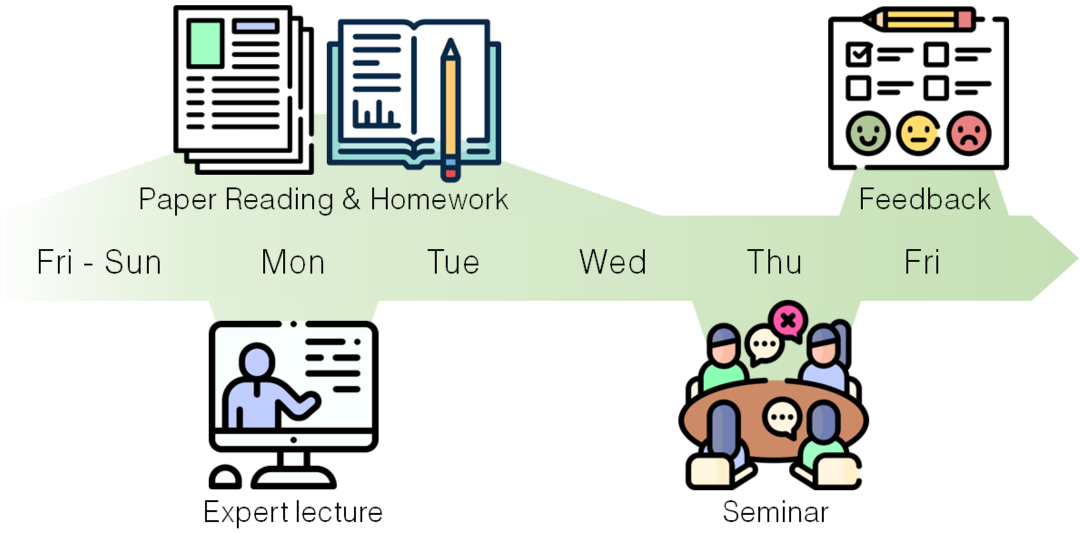
Graphical sources

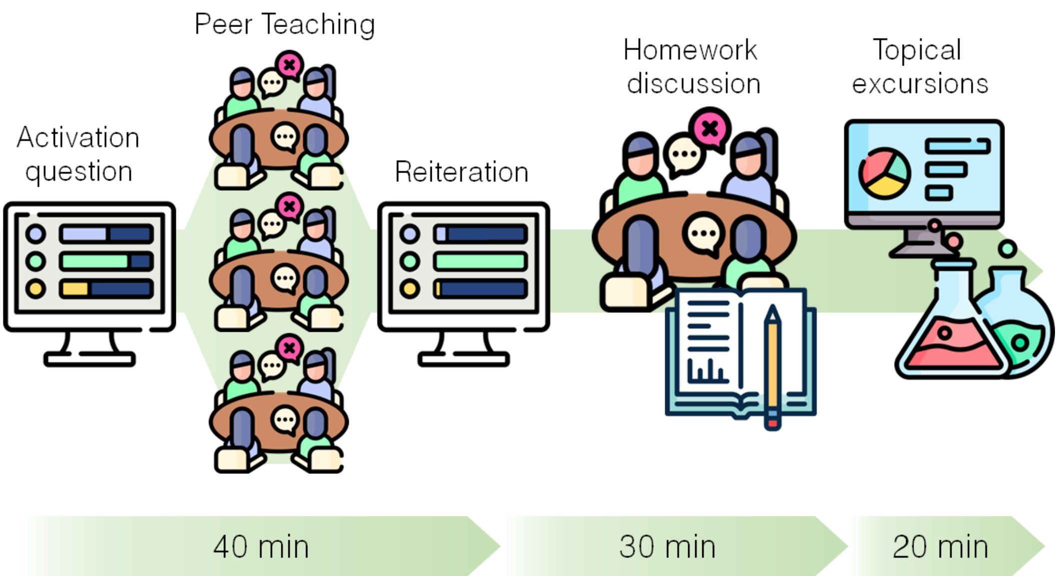
Icons used in Supplement figures 1 and 2 were downloaded from https://www.flaticon.com/

Word cloud in Supplement figure 3 made at https://monkeylearn.com/word-cloud

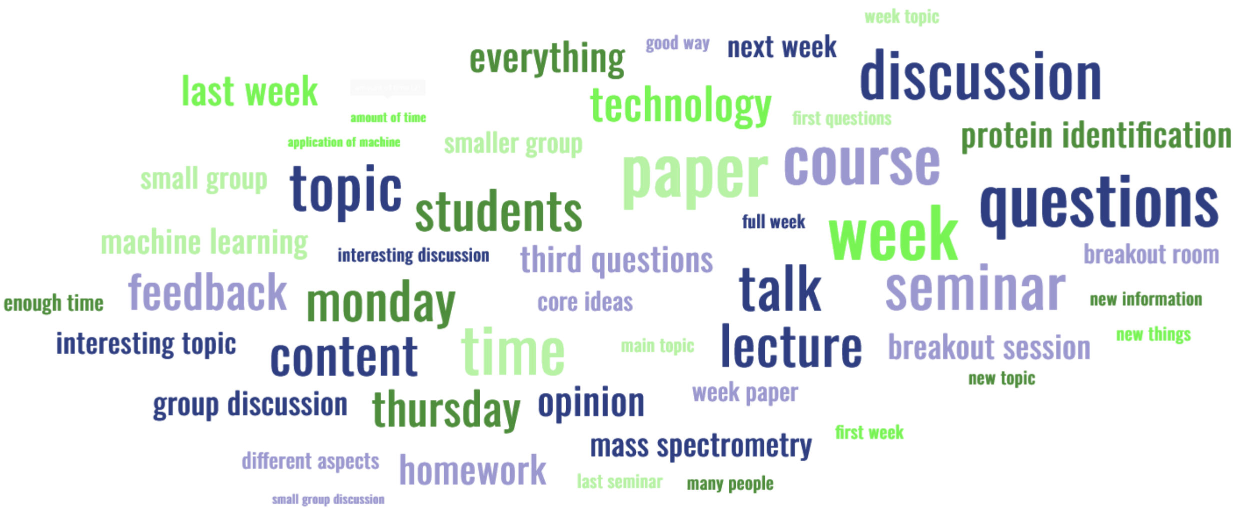
Supplement:



Supplement figure 1: *Weekly plan of the departmental lecture series, consisting of reading a paper, listening to an expert's talk, answering homework questions, discussing these in a seminar and finally giving feedback*



Supplement Figure 2: *Seminar structure, consisting of a paper related activation question, peer-teaching breakout sessions, re-iteration of the paper related activation question, discussion of the homework and excursions on related topics*



Supplement figure 3: *Word cloud of 50 most relevant word (groups) within a total of ~380 written weekly feedback on "Do you have general feedback and/or comments on the course?"; created with [Free Word Cloud Generator – MonkeyLearn]*

LEARNING JOURNEYS FOR SCALABLE AI EDUCATION: AN MIT - USAF COLLABORATION

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ABSTRACT

In 2021 the United States Air Force (USAF) and the Department of Defence (DoD) entered into a collaboration with multiple units within the Massachusetts Institute of

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Technology (MIT) to develop a new academic program focusing on Artificial Intelligence (AI) training. Given the size and the diversity within the body of USAF employees, the goal of this collaboration is to design and implement an innovative program that will achieve maximum learning outcomes at scale for learners with diverse roles and educational backgrounds.
This program is now piloting and evaluating three different learning journeys addressing three different groups of USAF employees (USAF leaders and decision makers; technology developers; and daily frontend technology users). The learning journeys were designed based on each group's specific professional needs and academic backgrounds, and they include combinations of online synchronous and asynchronous courses and face-to-face activities. The program's pilot is currently underway and evaluation research findings are informing the next program iterations. The ultimate goal of this program is to formulate general recommendations on how to serve large numbers of diverse learners at scale in an optimum way. In addition to an evaluation pilot study, MIT experts on AI and the Science of Learning have been asked to review the program and their feedback will be integrated into the next program iteration.
This paper presents the three learning journeys as originally designed to serve the three first diverse cohorts of learners, as well as the plan for future improvement and implementation of the program.

1 INTRODUCTION

Artificial Intelligence (AI) is a rapidly growing field expected to change the way organisations and businesses operate, as well as how grand challenges of the future will get tackled [1]. As the AI field progresses the number of jobs in or in conjunction with this sector is also growing. Industries need upskilling programs for their employees, "universities are clamoring to create curriculum that can meet the demand for computer scientists with AI expertise", and governments are working to find ways to best educate the general public [2]. Approaches to AI education vary significantly. They include topics ranging from understanding of fundamental concepts, applications and solutions, to development of hard-core technical knowledge like machine learning, robotics and big data analytics. Technical knowledge is guided mainly by the engineering and computer science world, but there is an urgent call for timely discussions about societal and ethical implications of AI development and use [1]. Despite the urgent need for State-of-the-Art AI education, this field is at a nascent stage and there is still a lack of understanding regarding what the optimum ways would be to approach different professionals with different needs, along with the education of the general public.

Within this context the US Department of Defence (DoD) decided it is absolutely crucial to harness the potential of AI to positively transform all functions of the Department, while also supporting AI education related research and development targeting a broader body of learners. Realising this vision requires identifying appropriate use cases for AI across DoD, rapidly piloting solutions, and scaling successes across the whole enterprise [3]. The Joint Artificial Intelligence Center (JAIC) was the focal point selected for carrying out this vision [3]. As careful AI adoption in all operations would require both State-of-the-Art technology and a highly educated and trained body of employees it became clear early on that the DoD would need to closely collaborate with academia or other centers of innovation providing expertise on AI education, to design the appropriate educational resources and training programs [4]. Given the size of the United States Air Force (USAF) workforce (~680.000), the difference in employees educational (high school diplomas to graduate degrees), age (18-60), cultural backgrounds, and the difference in the nature of their daily working needs and operations (full spectrum of officer and enlisted ranks), in 2020 DoD decided to collaborate with multiple units of the Massachusetts Institute of Technology (MIT) and fund an AI Education research project that would explore the development of a set of different AI learning journeys targeting subgroups of diverse learners (for this paper each group will be called an *archetype*). Goal of this mixed-method research approach is to understand the learner experience regarding content, pedagogy, and educational technologies engaged in the learning process. Findings are expected to guide further iterations of the program as the number of learners will be scaling up. This concept paper will present the development and implementation of the first 3 learning journeys that started in the summer of 2020, and a plan for future improvement.

2 AI EDUCATION PROGRAM DEVELOPMENT

2.1 Background

To start this endeavour JAIC engaged in a primary analysis of the USAF body of employees and presented a set of 6 archetypes (see Table 1), as well as desired AI related needs, skills and competencies for each one of them. A description and analysis regarding desired AI competencies and learning outcomes per archetype, as well as expected levels of understanding can be found in greater detail at the 2020 DoD AI Education Strategy [4].

Table 1. Learner archetypes (Modified from [4])

Name	Descriptions
Lead AI	Decides policy and doctrine, including how AI tools can or will be used; builds AI vision and plan
Drive AI	Ensures appropriate AI tools and capabilities are developed and delivered
Create AI	Creates AI tools to meet current and future needs
Embed AI	Embedded with Employ AI, establishes AI systems and provides end-user support at tactical edge

Facilitate AI	Represents user to ensure appropriate AI tools are developed and delivered to address use cases
Employ AI	End-user of AI tools, provide feedback on and requirements for AI tools.

2.2 USAF - MIT AI Accelerator

In 2019 the Department of the Air Force (DAF) signed a cooperative agreement with MIT and jointly created the Artificial Intelligence Accelerator, hosted at MIT. In summer 2020 the USAF-MIT AI accelerator, involving staff from MIT Campus, MIT Lincoln Laboratory, the DAF, along with STEM education researchers from MIT Open Learning and the MIT Media Lab, launched the “Know-Apply-Lead” project, to design, implement, and evaluate 3 separate AI-focused learning journeys particularly targeting the aforementioned archetypes.

3 THE LEARNING JOURNEYS

3.1 Content

In the summer of 2020, a group of MIT faculty and staff, with an expertise on AI and STEM education, collaborated with JAIC to develop the first set of learning journeys. Three cohorts were formed including learners representing two archetypes each, who appeared to have similar working needs, interests and backgrounds, and would equally benefit by attending the same courses. First cohort includes learners from the Lead AI and Drive AI archetypes (L/D) traditionally focusing more on management and leadership of the organisation, second includes learners from the Create AI and Embed AI (C/E) being mostly technology developers and facilitators, and third includes learners from Facilitate AI and Employ AI (F/E) who are mainly AI technology end users. After examining the needs of each cohort, the MIT team proceeded to explore what appropriate AI related courses the group could leverage on from MIT’s online catalogue of resources, along with what would be the most meaningful development of custom-made exploratory courses and accompanying educational experiences. Discussions led to the design of 3 different learning journeys employing a variety of pre-existing, adapted, and new educational resources.

3.2 Pedagogy and Educational Technology

Educational research has already shown that online courses where students can access educational resources at their own pace and master topics and concepts before moving on to more advanced levels is an effective way to learn [5]. Hands-on authentic project-based and problem-based learning is another established way to master technical skills and applied practices [6]. However, existing online learning platforms often fall very short when needing to support automated personalised tutoring or collaborative hands-on projects. Considering the program scope and technological restrictions, the team decided to employ, study, and evaluate a combination of technology-enabled pedagogies and experiences, while combining online and in-person learning contexts for AI [7]. Furthermore, state of the art teaching and learning practices and theoretical frameworks have been employed in several aspects of each learning journey, such as active learning, memory retrieval practices, employment of low-stake quizzes, and presentation of worked/faded examples. Number of learners is also expected to significantly scale over time. Given the opportunity to leverage existing MIT resources while also developing new content, the group ended up offering 3 learning journeys that combined 5 learning modalities, that are now getting separately studied and evaluated (via 4 learner surveys spaced throughout the program, interviews to program staff, and "gap analysis" performed by MIT-USAF AI experts) to guide our understanding about optimum AI teaching approaches:

- *online asynchronous self-paced* courses about AI fundamentals were available to learners throughout the duration of the whole program
- *online asynchronous instructor-paced* courses (about 3-months in duration, each)
- *experimental courses* (online or in-person project and team-based courses, particularly designed to interweave technical and ethical content about AI, with a 3-5 days duration)
- *live online events* about AI offered by MIT to a greater audience (1-2 hours long webinars)
- *curated supplementary materials* available to learners to read or watch (spanning 30 hours of material)

Table 2. Learning modalities employed in the 3 learning journeys

Cohort	Learning Journey courses and activities (# of offerings)				
	Online asynchronous self-paced	Online asynchronous instructor-paced	Experimental Courses Online	Experimental Courses In-person	Live Online Events
L/D (N=100)	2	1 (select out of 2 options)	1*	1*	6
C/E (N=30)	2	1-3 (select out of 3 options)	N/A	1	6
F/E (N=100)	2	N/A	N/A	N/A	6

*learners could choose between one online or one in-person experimental course

To better support the program, and given that the learners had to enrol in different platforms to participate in various pre-existing online courses, the team proceeded to develop an access portal for learners. Through this portal the learners were directed to their own personalised learning path and could keep track of their progress, while the development team could also keep track of learner's progress and course completion status (using a self-report tool).

3.3 Learning journey content and timeline

Figures 1-4 present the 3 learning journeys along with the planned timelines showing various offerings to each cohort. The learning journey for the L/D cohort was offered to 100 learners and designed with an emphasis on AI business strategy, ethics and policy. The learning journey for the C/E cohort included 30 learners and had a greater orientation towards development of deep technical knowledge and the know-how of AI tech solutions with an emphasis on probability, statistics, and machine learning. The learning journey of the F/E cohort aimed to provide fundamental knowledge about AI to an end user of AI solutions. This cohort included 100 learners.

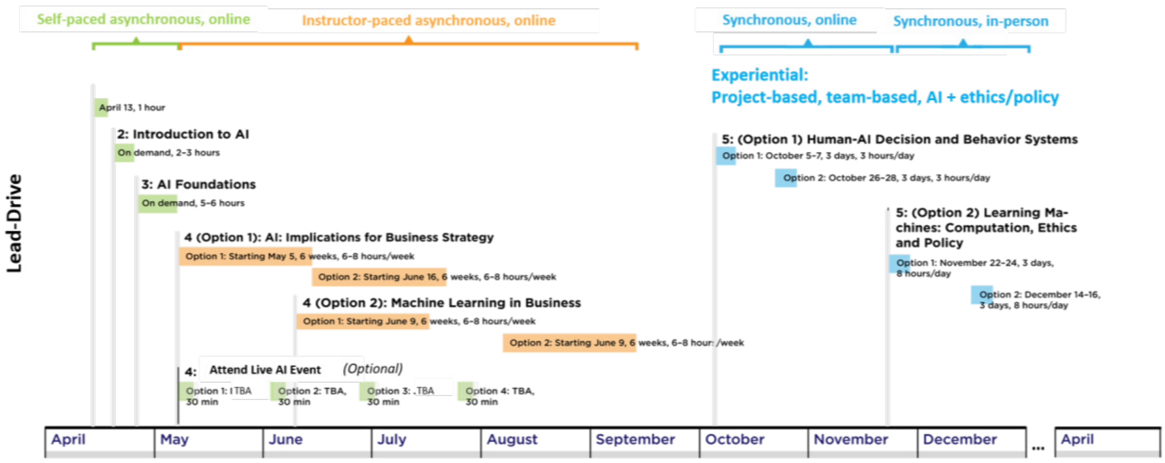

Fig. 1. Lead/Drive Learning Journey with an emphasis on AI business strategy, ethics, and policy

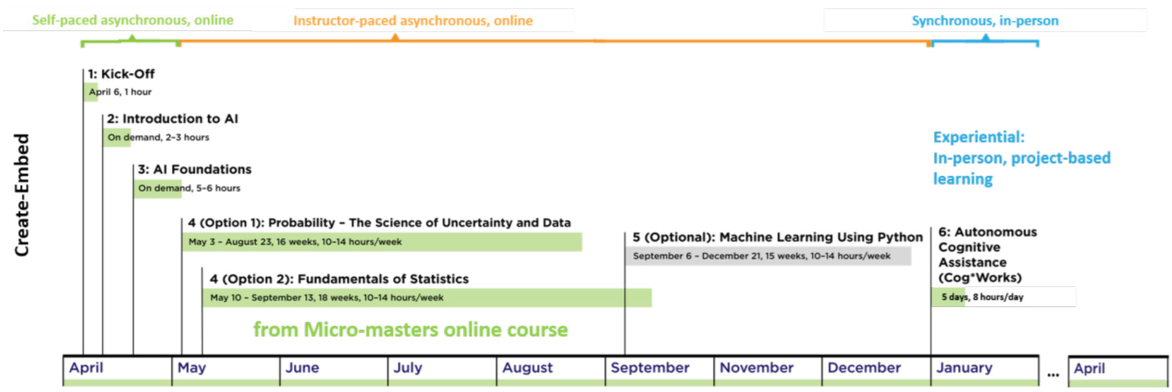

Fig. 2. Create/Embed Learning Journey with an emphasis on technical knowledge and know-how of AI solutions

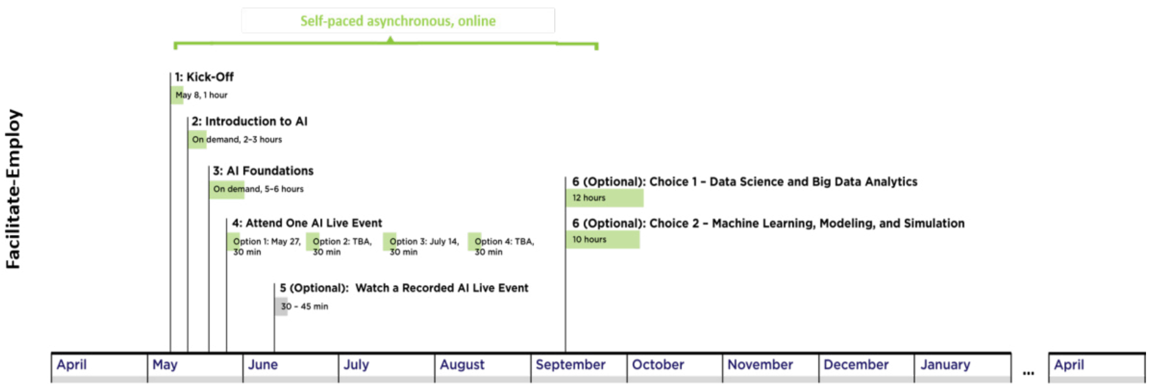

Fig. 3. Facilitate/Employ Learning Journey with an emphasis on developing fundamental knowledge about AI

Fig. 4. Screenshot of the 3 learning journeys as presented to each cohort in our AI Education Research Portal

4 CURRENT STATUS AND FUTURE ITERATIONS

4.1 Program completion and certification

April 15th, 2022 was the completion date for the first 3 cohorts participating in the program. Some activities were delayed due to COVID restrictions being imposed to in-person courses/workshops. Figure 5 presents the completion rate per cohort. Learners receive a certificate of completion if they have completed over 90% or the required tasks, videos, readings and low-stake quizzes (knowledge check-ins) of their learning journey (based on their responses in the AI platform self-report tool). Our team noticed that there were many optional tasks that had also been completed.

Fig. 5. Percentage of completion of all required tasks as of March 15, 2022.

4.2 Future Plans

Based on an initial first pilot evaluation study, described in great detail in [7], and also guided by recent findings from the Science of Learning field, plan for future improvement suggest work on the following areas:

- **Technology:** Improvement of accessibility and developing a program that will support single access to all courses.
- **Content:** Develop case studies and examples directly related to the learner organisation to provide better context and raise interest and engagement.
- **Pedagogy:** Redesign knowledge check-ins used in the asynchronous self-paced courses, to better support retrieval learning practices and enhance learning retention. Provide the F/E cohort with opportunities for live mentored sessions. Provide and better support community building and opportunities for peer-learning for all cohorts. Consider more opportunities for cross-cohort interactions, as well as interactions with learners from other military units.

Furthermore, a small group of the program staff will be interviewed to understand the logistical hurdles experienced by learners, and a group of MIT AI experts have been commissioned to perform a gap analysis on current curriculum and provide an additional set or recommendations about additional content and appropriate pedagogy. Overall, research findings will further inform updates to the future learning journeys.

Scope of this program is not just to evaluate various learning modalities but also to understand if and how they would best serve the program as the number of learners will keep on scaling. The group is now working on the aforementioned improvements and has also proposed two larger cohorts to start within the next year.

5 ACKNOWLEDGMENTS

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ACTIVE LEARNING IN MATHEMATIC FOR STEM: REAL-LIFE ENGINEERING APPLICATIONS

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***Conference Key Areas**: Mathematics at the heart of Engineering, Physics and Engineering Education.*
***Keywords**: Engineering Education, Active Learning, Problem-Based Learning, Real-life Applications, Interdisciplinary.*

ABSTRACT

An opinion piece in Scientific American [1] discusses how a fraction of students ultimately complete a STEM degree and cites research [2] that disengagement with traditional calculus courses as one of the causes. It goes on to highlight examples of several promising calculus reforms and recommends that STEM faculty take the lead in introducing changes by collaborating and co-creating across disciplines to make mathematics more relevant and interesting to students.

Feedback from module surveys indicate that students learn much better when the link between theoretical and practical knowledge is captured and echoes pedagogical literature.

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The author introduces past experiences of active learning approaches to enhance the teaching of mathematics to first-year engineering students. Class discussions incorporate real-life engineering applications highlighting example problems from a wide variety of core engineering modules such as Fluid Mechanics, Vibration, and Mechanics of Materials.

The impact of this approach has not been directly measured and documented for the module being discussed here and is motivated by encouraging student feedback where they shared that they find the teaching interesting, fun, engaging, and interactive. The present concept paper therefore outlines how past pedagogical practice have influenced the enhancements in the delivery of engineering mathematics with a particular focus on interdisciplinary approach. It then goes own to demonstrate some examples of implementation and offers initial reflections based on student feedback. Finally, the author proposes future steps of detailing the effect on student learning experience via class surveys, interviews and making comparisons to comparably taught modules.

1 INTRODUCTION

1.1 Motivation

Galileo wrote: "*Philosophy is written in this grand book, the universe… [But the book] is written in the language of mathematics*." The study of engineering requires a substantial grounding in engineering principles, science, and mathematics. The gradual development of students' critical thinking and analytical ability to solve real engineering problems is the key to their future success [3]. A strong foundation in mathematics is therefore necessary to produce competent engineers who can confidently analyse and solve problems, employ analytical tools and techniques, design and innovate, and communicate their results.

Research about why students abandon degrees [2] suggests that traditional calculus courses are one of the main reasons. This tallies with anecdotal observations of declining competencies of mathematical ability in senior undergraduate students, with several engineering students struggling to do simple calculus in higher levels of studies, based on discussions and comments from academic colleagues. And alarmingly, a recent report, '*Charting a New Course: Investigating Barriers on the Calculus Pathway to STEM'* [4] adds that traditional approaches to calculus are partly responsible for the large proportions of women and students from minoritised backgrounds getting discouraged from pursuing STEM careers.

It's generally suspected that one underlying factor to these issues can be attributed to the lack of engaging and relevant material in describing, solving, and understanding the significance of mathematics in an engineering context. A publication recommends that STEM faculty prioritise collaborations and co-creation across disciplines to transform math classes [1]. The same article concludes by proposing that "math learning is fundamental to all STEM fields, but the opposite also appears to be true: the STEM fields may be central to making math learning effective for more students.

Student-centered pedagogies like problem-based learning, collaborative learning, process-oriented guided inquiry learning, and peer-led learning have been extensively developed and tested in response to the tried-and-test approaches to match the way we teach to the way students learn [5]. Studies have shown that active learning environments are more effective than traditional lectures [6]. And Mark Deakin [7] concludes that students value the link between teaching and research, placing particular weight on research led teaching and the bearing which it has on the quality of their learning experiences.

With these in mind, the present concept paper first briefly describes prior successes of employing CDIO framework in the design and delivery of engineering modules such as Computational Fluid Dynamics and Solid Mechanics. The positive impact of the past implementation motivated the use of the CDIO approach in the teaching of the current mathematics module. The paper outlines how this method has been adopted in the existing engineering mathematics module to make it more relevant, attractive, and interesting to learners and reports early results from observations and module surveys. Finally further work is proposed to structurally measure the effects of the introduced enhancements on students learning and progression.

1.2 CDIO

The paper will start with a summary of the CDIO approach and its benefits. CDIO is an educational framework that stresses engineering fundamentals set in the context of Conceiving, Designing, Implementing and Operating (CDIO for short) real-world systems and products. CDIO advocates active learning techniques such as problem-based learning to equip engineering students with technical knowledge as well as communication and professional skills. These techniques collectively promotes active and integrated learning experiences. The core philosophy of CDIO is to prepare engineering students who can engineer. Readers are encouraged to visit www.cdio.org to find out more. This has a bank of useful resources including standards, syllabus, and case studies.

1.3 Past Implementation and Student Feedback

The author has experimented with and implement different educational frameworks and has continuously adapted and refined his teaching on reviewing class performance and feedback. He has received very encouraging student feedback over the past decade such as *"The only enjoyable class throughout my studies is Solid Mechanics Class. Additionally, we were given the opportunity to work on an assignment in which, for the first time, I was able to apply my engineering knowledge to design a given task. This has never been done in any other Engineering classes and should strongly be taken into consideration"* referencing the CDIO approach employed. Another student from a subsequent cohort agreed: *"He's very good in explaining the theory behind each mechanics applied in engineering as well as in real life situation. He makes us think out of the box which is very good and indeed challenging. Keep up the good work!"*

The author's colleague attests: *"I believe his plan for assessment strategies proved very effective in motivating the students to develop and apply their techniques…and to act as real engineers in a way that would be sought by future employers".*

The knowledge, skills, and experiences gained over the years backed by positive student feedback and observable improvements in class performance helped refine the author's teaching practice and build his confidence. The next section describes how the past implementation and experience of CDIO principles influenced the teaching of mathematics. Then goes on to reflect on the impact on student learning initial feedback received from the cohorts.

2 ACTIVE LEARNING IN MATHEMATICS

2.1 Adopting CDIO in engineering mathematics

Pedagogical literature, student feedback and discussions with colleagues have highlighted the benefits of integrating theoretical knowledge with practical application which is the underpinning principle of CDIO. Drawing from cross-discipline research and engineering subject expertise the mathematic lessons are updated with real-life applications to introduce mathematical concepts, solve class examples, and demonstrate applications of the new contents being presented and discussed. The intention is to help learners relate to the subject matter, appreciate the relevance of mathematics in the wider engineering context, and in the process excite them to discover more and transfer knowledge.

2.2 Outline of the engineering mathematics module

The mathematics module (titled 'Engineering Analysis 2') is taught to 1st year undergraduate engineering students in their second semester and covers:

- Vectors
- Complex Numbers
- Ordinary Differential Equations
- Multivariate Functions
- Series and Sequences

The module's main aim is to provide the essential grounding in mathematical analysis techniques for engineering students with a focus on calculus which is the mathematical study of change.

2.3 Delivery plan

In the very first lesson students are introduced to the Navier-Stokes Equations as one of the unsolved Millennium Prize Problems by the Clay Mathematics Institute[2]. This is followed by discussion about various ways of solving engineering problems: analytical, experimental, and computational and the class finally go through the use of the Navier-Stokes Equations in the context of Computational Fluid Dynamics (CFD) with some real-life examples from senior student projects over the years. The intention of this is to encourage the first-year students to see the bigger picture and appreciate the end goal of learning all the mathematical techniques and how it will gradually equip them with the tools and skills to analyse and solve engineering problems in later level of studies.

The beauty of the Navier-Stokes Equations - which are fundamentally the conservation equations of mass (continuity), momentum (Newton's second law) and energy - are that they are multidisciplinary, and learners will come across them repeatedly in various forms and iterations in the other core modules of Thermodynamics, Fluid Dynamics, Solid Mechanics and so on, throughout their engineering studies.

As we progress through the 10 weeks of classes, we revisit the different aspects of the Navier-Stokes equation and relate them to the mathematic concepts we are learning thus threading all the topics together.

Two examples are presented below:

[2] https://www.claymath.org/millennium-problems

Example 1: Vectors (Chapter 1)

Fig.1. is a screenshot of the material hosted on Microsoft OneNote presented to the class when introducing the ‘Vectors’ topic. It includes example of student projects using CFD and linked to the Navier-Stokes Equations. The left image is of a student modelling the ventilation in a lecture theatre to evaluate the indoor air quality in response to the covid outbreak. The other two are simulations of a previous intake manifold used by the Formula Student race team and their proposed design change to enhance the volumetric efficiency. This gets the students interested, motivated and encourages them to appreciate the reason they are learning vectors.

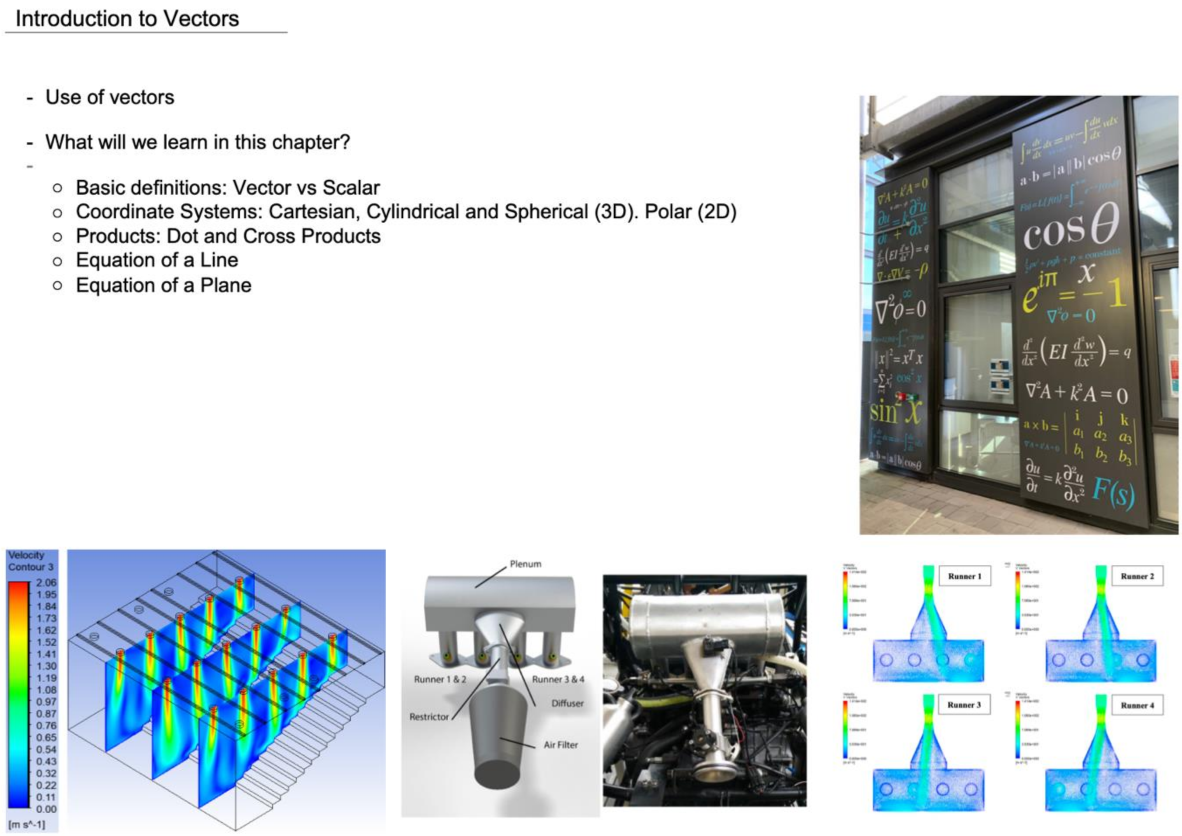

Fig. 1. Introduction to Vectors

Example 2: Multivariate Functions (Chapter 4)

Half-way through the ‘Multivariate Functions’ topic, we revisit the Navier-Stokes equation to demonstrate that acceleration (in $F = ma$) is a multivariate function of x, y, z and t and we proceed to employ the chain rule to derive the material derivative. This also links well with ‘vectors’ topic where we come across the dot product again. The other example to the left illustrates the conversion between cartesian and polar coordinate systems also covered in vectors and discusses composite functions and the chair rule.

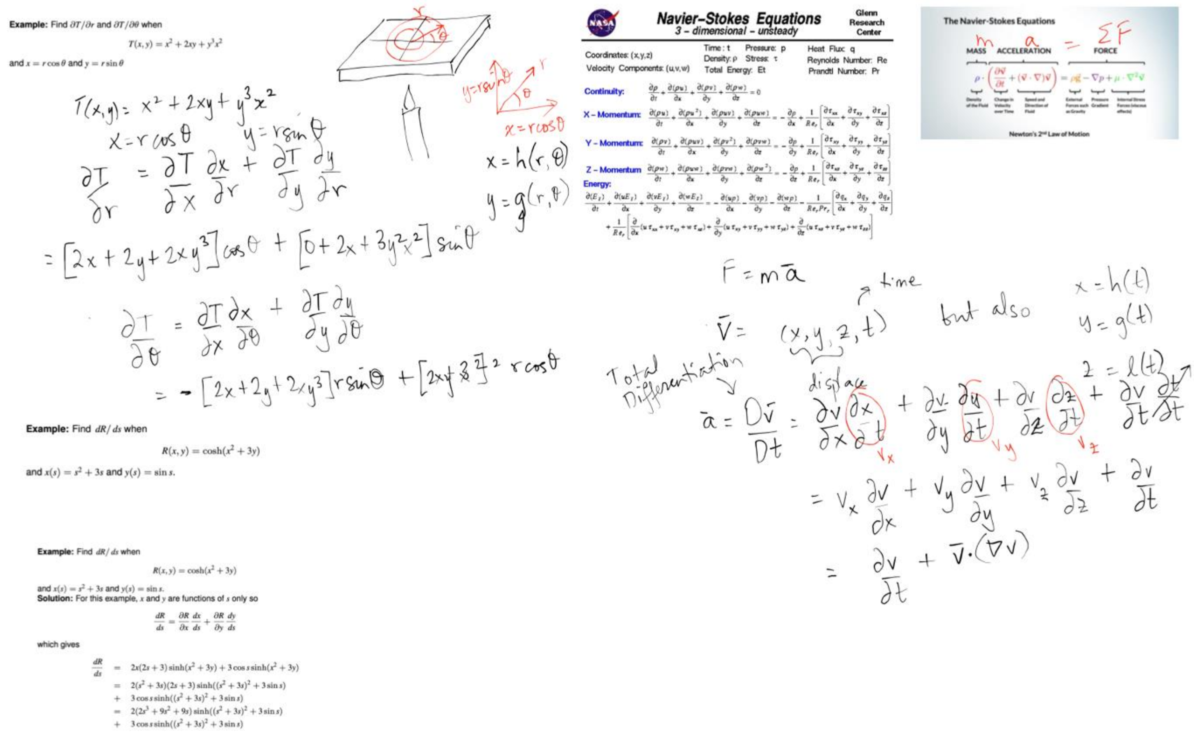

Fig. 2. Chain Rule for Differentiation of Multivariate Functions

3 REFLECTIONS

I've included student comments collected as part of the formal module feedback exercise from the past and current academic year for the module. This was obtained via a standardised survey deployed across the faculty using evasys+ tool (https://evasysplus.co.uk/). The comments below are in response to the open-ended question:

Q: Please name the one thing in the module which had the most impact on your learning.

I enjoy these lectures I feel like the lecturer has a passion for mathematics and it shows through his teaching.

I like the variety of ways he teaches his lectures (example classes, quiz classes, polls etc) as this helps me stay engaged and focused.

I like the use of the class notebook [Microsoft OneNote], it makes it easier to go back and revise some of the example problems covered.

I think sir is quite interactive. I understand very clearly and when I am stuck, he supports us.

Lecturer is very likable and approachable, and this shows in his lectures. Everyone pays more attention because he also makes the lectures more interesting and fun to attend.

Really enjoying the module so far. Good level of teaching and good structured live zoom lectures!

The lecturer is very engaging. He makes the lectures interesting and his passion for the subject is very clear, making lectures more enjoyable. The lectures are very interactive.

Love coming to this module. The lecturer is really enthusiastic and passionate about what we are being taught. The content is being taught at a good pace. I really appreciate the chances to ask and answer questions throughout the lectures and the fact it is made sure everyone understands before we move on.

The keywords: passion, interactive, engaging, fun, interesting and of course the best compliment: love reassures me that students are benefiting from and enjoying the teaching approach. The author attributes these positive comments to the use of real-life engineering examples to explain and bring to life the mathematical techniques. He draws in content and applications from other engineering subjects and research activities making the module truly inter- and multi-disciplinary.

The positive student feedback support the opinion piece in Scientific American [1] which suggest that “math education researchers consider more relevant and engaging curriculum to be an important strategy for increasing persistence rates particularly among students traditionally excluded from STEM fields, such as Black, Latinx and Indigenous students, as well as women.” The same article gives an example from Wright State University’s where academics focused on preparing students for calculus by emphasising ‘engineering motivation for math’ rather than changing the module content.

4 FUTURE WORK

The Scientific American publication continues by arguing that “the shift toward more practical applications of calculus is missing one key academic endorsement: publication in widely-read journals, if the success of the courses is examined academically at all.”

One can deduce from the student feedback that the adopted teaching approach of incorporating material from other core engineering subjects and emphasising real-life applications very likely contributed to the positive satisfaction with the currently discussed module. It will therefore be interesting to conduct more pedagogical research via surveys and interviews and comparing against similar modules (the teaching of the engineering mathematics is split in to 3 separate cohorts due to large numbers of engineering students – over 600 in total).

The author also proposes to investigate to what extent the revised teaching delivery plan has had an impact on the students learning by interviewing completed cohorts as they progress to their next level of studies (Year 2 and 3, respectively) and will include questions that draws comparisons to related modules, particularly the preceding engineering maths module delivered in the previous semester and to pre-university maths studies such as A-levels and/or Foundation programmes.

There will be specific questions related to the inter- and multidisciplinary approach and real-life examples, and whether this has better prepared them for modules such as Fluid Mechanics and Mechanics of Materials that they have encountered in the later years of studies.

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Experiential learning: integrating learning and experience in shaping the future of the engineers

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ABSTRACT

The industry demands skill-equipped engineering graduates who could be efficient enough to adapt to face the challenges of uncertainty posed by a lack of skills and resources. Accreditation boards have identified problem-solving, teamwork, communication, etc. as the workplace required skills. However, industry/employers feel that the engineers seem to lack problem-solving, teamwork, etc. To groom these skills, experiential learning (EL) platform provides hands-on practice. Thus, the study aims to gain insights into the need of experiential learning to integrate learning and experience. The study, qualitative in nature, focuses on the essential skills, specifically problem-solving skills, against the applicability of experiential learning. Experiential learning allows engineering students to get a hands-on approach to practise their acquired skills to understand industrial needs and constraints. In the given context, problem solving helps in knowing what is learnt and what needs to be learnt.

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1 INTRODUCTION

In 2018, the Organisation for Economic Co-operation and Development (OECD) raised two well-reasoned questions: what knowledge and skills future engineers require; and how instructional systems can help develop that knowledge and skills? This being an unavoidable issue tends to seek attention on multiple facets. Employers and various agencies, after having understood the essentiality of such skills, give high importance to problem-solving skills (86%) followed by teamwork (79%) among the key future skills (Hristov, Minocha & Sreedharan, 2018). Only 33% of employers feel that graduates possess the necessary higher-level skills and knowledge that they are looking for in their industry. Supposedly, engineering programmes must prepare engineering graduates for the practice of engineering at the professional level (IEA, 2021). However, employers and industrial representatives seem to be congruent in their understanding that the graduated engineers lack specialised knowledge as well as employability skills, the expected learning outcomes of engineering education.

Some of the assumptions associated with skills are: the skills develop on their own during the learning phase; their understanding and acquisition is implicit; explicit efforts are not needed; and only technical aspects need attention. Various stakeholders are making conscious efforts to draw attention to skills, their finer aspects, implementation, urgency, and benefits Accreditation boards (IEA, 2021) have identified twelve skills: engineering fundamentals, knowledge of a particular domain, environment and sustainability, design, problem-solving, the engineer and society, independent work settings, lifelong learning, teamwork, communication, conflict management, and ethics.

Engineering education seems to address essential life and career skills to deal with financial pressure, career opportunities, time management, workplace etiquette, and other necessary skills. Engineering education, being technical in nature, needs to be more practice oriented. Learning-oriented involvement (to observe, analyse, interpret and solve) of students in experimental data, a case study, a complex real-world problem, etc. (Prince & Felder, 2006) makes students active agents. Theory-based teaching, outdated curriculum, academic environment isolated from industry work (Hristov, Minocha, & Sreedharan, 2018), etc. lead to lack of skills. Various benchmark and policy statements emphasise creative and critical problem solving skills. Problem solving skills, recognized as one of the key concepts of the learning framework (International Engineering Alliance (IEA), 2021) (https://www.ieagreements.org/assets/Uploads/IEA-Graduate-Attributes-and-Professional-Competencies-2021.1-Sept-2021.pdf), is still a big challenge for Indian engineering education (Büth et al., 2017). The employees who can work in groups to identify problems, sift solvable unsolvable problems, understand causality, form problems, take calculated risks, and be resourceful enough to solve uncertain, ill-defined, and unthought-of problems, apparently seem to be an asset to any industry.

Learning seems to comprise a complete set of contextual skills. Experiential learning (EL), comprising active as well as reflecting learning, helps learners acquire knowledge, understand theoretical concepts, foster complex problem solving, develop other skills, apply previous knowledge to current problems, and attain superior performance. EL techniques (theory-practice integrated), such as problem based learning, project based learning (Savery, 2015), make learners realise that problems are valuable; difficulties and problems lead to learning; and knowledge is applied in real life. Thus, the study aims to gain insights into the need of experiential learning to integrate learning and experience. The questions addressed are:

- Which skills are required the most by industry?
- What are the types of experiential learning techniques?
- Does the curriculum of premier institutes of India give space to EL?
- How experiential learning enables developing the skills in the Indian context?

2 METHODOLOGY

The study, qualitative in nature, focuses on the development of problem-solving skills against the applicability of experiential learning. Deductive approach was used to extract skills and EL from literature review. Inductive approach was used to analyse curriculum documents of the two leading premier institutes (higher education) of India, based on the pedagogical approaches: teaching techniques, learning environment, content, and assessment.

3 SKILLS OF ENGINEERING GRADUATES

94% of employers termed problem-solving and teamwork as the two top skills urgently required in their sector (Hristov, Minocha & Sreedharan, 2018). There is an improvement in teamwork but problem solving still remains a challenge (Sting, 2016). Problem solving is a complex yet systematic process with criticality to address a dynamic issue and seek multifaceted and open ended solutions (Priemer et al., 2019). Problem-solving skills is not only about process (stages and strategies) but also about problem (nature and context) and solution (types) (Sangwan & Singh, 2021).

The process has two to five stages; each stage has specified strategies. Reflection is one of the important stages in the process. Learners should be able to describe, explain, design, and produce with what they know, understand, think, and believe. The complexity and difficulty of problems are relative, depending on the learner's own existing knowledge, strategy application, and situated context. Thus, the approaches and teaching-learning techniques need to be explored to find their effectiveness in improving problem solving skills.

4 ROLE OF EXPERIENTIAL LEARNING IN ENGINEERING EDUCATION

Despite intense focus on multifaceted aspects, students seem to lack exposure to practice-based higher education curriculum and pedagogies (Hristov, Minocha, & Sreedharan, 2018). The challenge is not only to infuse domain specific and disciplinary insights but also to make the learners competent. Skills (and outcomes) comprise three concepts (problem solving process constituents): head (intellectual development), hand (skill development), and heart (modes of thinking, habits of mind). Intellectual development enables engineers to analyse and evaluate; skill development eases tools usage to manipulate the knowledge; and thinking habits sharpen motives and strategies for learning and performing.

All three elements (teacher, learner and environment) impact skill development. Real work environment/practical experience must comprise active and interactive actions in teaching-learning. An integrated framework of problem-solving, addressing domain-specific, complex, and interdisciplinary problems (Priemer, et al., 2019), can equip the learner not only with the theoretical knowledge (concept of 'what' - deductive approach); but also with the situated knowledge application ('how and why' - inductive approach).

Conducive environment encourages students to re/construct knowledge through metacognition - the process of assessing their own understanding and performance through reflection - a stage of EL cycle (Venugopal, Singh, & Devika, 2019; Kolb & Kolb, 2017). Metacognition corresponds to problem solving. Next, heterogeneity of learners changes the role of learners and teachers; same instructions and same environment cannot check performance variance. EL (student-centred pedagogy) provides a platform to learners to realise and assess their own learning, errors and improvements, and changes the role of teacher as a mentor and the role of learner as a performer.

EL theory (Kolb & Kolb, 2017) has four stages: experiencing, reflecting, thinking, and acting. Experiencing is necessary for learning. EL involves both active and reflective learning (learning by doing, experiencing, discovering, and exploring). Reflecting, an iterative learning experience, develops self-awareness, a part of the problem solving process. In the EL curriculum (like PBL), projects enable students to identify and analyse multidisciplinary problems and problem-solving processes, develop critical thinking skills, and experience deep learning (a comprehensive grasp on the meaning) (Edström & Kolmos, 2014). Prior knowledge, knowledge organisation, motivation, skill development for mastery, goal directed practice and feedback, interaction between learner development and course environment, and approaches monitoring and adjustment are the principles of EL. The EL techniques - problem based learning (PBL), Project based learning (PrBL), Research based learning (RBL), Inquiry based learning (IBL), Case based learning (CBL), and Discovery based learning (DBL) - cater to engineering education particularly (Camacho, Valcke, & Chiluiza, 2017; Savery, 2015; Prince & Felder, 2006). Subsequent to the identification of types of EL, the study compares these six techniques (see table 1) in the context of suitability of engineering education and problem-solving skills. The comparative analysis is based on the four parameters such as role, encouragement, practice and hands-on-experience, and learning outcome (skills) (Hristov, Minocha,

& Sreedharan, 2018). Besides these four, one more parameter (discipline applicability) was identified through literature.

4.1 COMPARATIVE ANALYSIS OF EL TECHNIQUES

Abducitve (mix) approach, learner-centred pedagogy, and active learning are predominant in all EL techniques. PBL and RBL contribute to the development of problem solving skills to the maximum followed by PrBL. These three learning techniques do contribute to the development of problem solving skills to a higher level (Singh et al., 2019; Winarti & Waluya, 2019; Efstratia, 2014). PBL (being engaged, hands-on experience) makes learners challenge things, develop a deeper understanding of the subject, and enhance deep learning. (Hristov, Minocha & Sreedharan, 2018). Learners become more active, self-dependent, and owners of the learning process in PBL and RBL than PrBL; facilitator guides the students with ideas, methods, and tools in PBL (Edström & Kolmos, 2014).

Teacher acts as a facilitator (student centred - contemporary) than a conventional lecturer (teacher centred - traditional). In EL techniques, learners receive sufficient scaffolding (both support and supervision followed by gradual withdrawal of the support and feedback (multidimensional, non-evaluative, timely, specific)) as a powerful driver.

PBL is not a simple application of the methodology that may be transferred to the classroom without making structural changes. Implementation of EL techniques like PBL needs consideration at all three levels: teacher/learner, course, and organisation. This represents the shift in classroom culture. Implementation of EL into engineering education helps achieve the learning outcomes, as it leads to the development of problem solving skills required at the workplace. Overall, it has been found that EL provides a platform to the teacher/learner to develop and improve problem solving skills.

Table 1. Comparative analysis of EL techniques

EL techniques: Types → Parameters ↓		**PBL**	**PrBL**	**CBL**	**IBL**	**RBL**	**DBL**
Role	**Teacher**	Facilitator	Coach	Instructor	Facilitator	Facilitator	No guidance
	Learner	Very Active	Less Active	Active	Active	Very Active	Active
Encouragement		Very High	Moderate	Low	High	Low	Moderate
Practice and	**Product oriented**	Low	High	Low	Low	Low	Low

hands-on experience learning	**Process oriented**	High	Low	High	High	High	High
Learning Outcome (skills)	**Analytical**	High	High	High	High	High	High
	Decision-making	High	High	High	High	Moderate	Low
	Team work	High	High	High	High	High	High
	Problem solving	High	High	High	High	High	High
	Self-directed learning	High	High	Low	High	High	High
	Self-awareness and management	High	Moderate	Low	High	High	High
Applicability in disciplines		Education	All areas of education	Law, medicine, business management, teacher education	Science education	All areas of education	School education

4.2 Analysis of Curriculum of engineering education in Indian context

The analysis of curriculum of Indian institutes of engineering education would help in developing basic understanding about the concept of graduate attributes development holistically. For this, the curriculum of high ranking, fully government universities such as Indian Institute of Technology (IIT) and private university such as Birla Institute of Technology and Science Pilani (BITS) were analysed based on the documents available in the public domain as well as interacting with the past and current students of these institutes. The analysis was performed on parameters of teaching techniques and learning environment, content, and assessment.

Teaching techniques and learning environment: Both universities have classroom environment and industry internships within the curriculum. The internships provide the opportunity of a real work environment to the students for a very short period. The Indian engineering graduates are taught based on input-output orientation (PrBL approach). Most of the core courses have laboratory classes but unfortunately these laboratory classes have input-output orientation, which does not foster real life environment problem solving skills. Though the faculties in these universities are highly qualified but lack industrial exposure, a probable reason for the gap between theory and practice in teaching-learning. Theoretical basis of Indian teachers is very strong but they fall short of new developments (Hristov, Minocha & Sreedharan, 2018). BITS Pilani, known for innovation in teaching and learning, particularly in India, provides full semester project courses (study, laboratory, design, special projects, etc.) to cater to the students' learning in newer or advanced areas. BITS Pilani also has a minimum seven-month internship with industry while IITs have short duration internships.

Content: The curriculum includes foundation courses (engineering, mathematics, sciences, humanities, technical arts, and application oriented courses), core (compulsory disciplinary), discipline electives, and open elective courses, indicative of content rich curriculum to develop the required skills among engineering graduates. Core courses develop strong fundamental knowledge in particular domains forming the part of theoretical knowledge. Also, the students admitted in these institutes have highly competitive entrance examinations, ensuring high quality students.

Assessment: The assessment is done majorly through written examination (mid semester, end semester, continuous assignment, quiz, etc.) and practicals (experiments, viva-voce, quiz, etc.). The written examination at BITS Pilani is both open book and close book. The questions in the open book are application oriented, with more flexibility to construct prior experience based knowledge. Open book examination develops application oriented learning and knowledge transforming ability.

The analysis also reflects that with the current teaching approach the Indian engineering graduates are likely to lack problem solving skills. The Indian higher education institutes have to redesign their laboratory classes based on open ended experiments rather than input-output based experimentation. Overall, it can be stated that current pedagogy, predominantly PrBL, is not solely sufficient to develop problem-solving skills. Based on the analysis of the lack of problem solving skills, the study recommends integration of EL aspects in the teaching-learning techniques and environment to develop and improve problem-solving skills.

- More exposure to practice and problem solving along with self-awareness
- Engagement of learners in an authentic environment
- Need to bring familiarity with the cultural aspects of EL techniques in comparison to traditional teaching-learning
- Need to arouse interest and motivation among learners to solve the problem with an emphasis on reflection

The present study recommends an experiential learning integrated teaching-learning for problem-solving skills development and improvement.

5 SUMMARY

The accrediting boards, academicians, and practitioners have acknowledged the importance of good problem-solving skills along with adequate knowledge of self-reflection and self-awareness. Problem solving skills, found lacking in Indian engineering graduates, tops the set of skills needed for survival and success in industry/workplace. EL techniques sharpen problem solving skills through authentic learning situations such as learning factory, virtual laboratory, simulation, etc. Linking learning approaches and strategies with a real work environment empowers engineering training, research, and education.

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DEVELOPING FUTURE ENGINEERS WITH BROAD VIEWS AND DEEP SKILLS – THE EMERGENCE OF A NEW T^2-CAPABILITY PROFILE

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ABSTRACT

Companies are increasingly stressing their need for recruits and employees who can understand the company strategy and operations on a wider scale and with an integrative mindset, as opposed to siloed departments, jobs, and people possessing those jobs.

With new digital technologies, new organizational forms such as team-based organizations and virtual teams as well as Human Resource Management practices like job rotations, there are increasing opportunities for cooperation and integration of people with different backgrounds and skillsets, as the interplay between marketing (business function) and R&D (engineering function).

However, having the company practices and infrastructure "right" for holistic and cross-disciplinary work does not suffice. The professional preparedness of the practitioners has to support this new paradigm as well. The solution has been proposed to be T-shaped capabilities, where the vertical line represents the deep expertise in one area, and the horizontal line overview expertise to better understand processes outside one´s domain. This is an improvement to I-shaped capabilities, where the connecting horizontal integration is missing.

The paper propagates for a prospective upgrade to the T-shaped capability model, the T^2 capability profile. The core idea - derived from interviews with industry managers - is that two horizontal lines differ in scope. The societal/business megatrends demand a set of non-contextual understanding of issues such as sustainability, quality as well as basic technical and financial literacy, and the other horizontal line is made of company-and industry-specific processes. To conclude, the opportunities to foster T^2-capabilities in (engineering) education get discussed.

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1 INTRODUCTION

1.1 The concept of capability profiles

Capability profiles in the realm of human resource management (HRM) and knowledge management (KM) are not a new issue of discussion and research. The early stages of capability profile discussion were centered around depth (of expertise) vs. width. People were assumed to possess either the vertical capabilities that lead them into a deeper and deeper knowledge of their area of expertise (like a business function like quality management or a branch of science/engineering, such as software engineering or artificial intelligence. This deep yet now wide capability profile (that has reach only in the vertical dimension) got a symbol and name of the I-shaped capability profile. Some people and jobs were claimed to ask more for a horizontal view, i.e. ability to act across business functions and knowledge areas. This integrative capability profile with just horizontal reach was labeled as a "hyphen"(-)-shaped capability profile, also called generalist (vs. specialist). Typically these capabilities were seen to be of demand in the higher ranks of the organization, where the responsibility areas of managers grew to cover multiple business functions.

Lately, the developments arising both from organizational evolution as well as from changes in job markets and younger generations' values about work and careers have risen into discussion the need to re-look at the capabilities needed and achievable. Some proposals have propagated a professional profile standing on two pillars, the so-called π-shaped (Greek letter "pi") capability profile [1]. The essence of the construct is well visualized in its name carrying the symbol of two vertical expertise and in addition ability to see the organization's processes and linkages between expertise areas (the horizontal bar in π). Logical reasoning for the new profile is the intrusion of technology and digitalization into all corporate functions, so, to act successfully as a digital marketing manager, one must master both the technology ("digital") and well as its domain of usage ("marketing"). Likewise, a technology developer like a software engineer should understand not only technology (like Artificial Intelligence=AI) but also its intended usage cases and areas, like digital marketing powered by AI.

Another proposed model is the V-shaped professionality, where the two expertise areas are more permanently intertwined, connected, and even converged. In his 2022 paper [2] Oerther describes the need for this new model as a call for "humanitarian technologists", who are better equipped to solve complex societal challenges e.g. in areas of sustainability.

1.2 The shift from I- to T-shaped capability profile and its evolutions

The most common depiction of an ideal capability profile for a modern professional is the T-shaped capability profile. The fundamental idea is well readable in the name of the profile: A T-shaped professional has got deep expertise in one area to offer to

the organization, but can also disseminate that knowledge to experts in other domains for common benefit as well as acquire knowledge from other areas. The need for a T-shaped professional has been studied and theorized in many different areas ranging from the medical sphere, entrepreneurship, innovation, and engineering education [3], [4].
Due to the presence of the T-shaped capability profiles in the discourse since the 1990s, it is understandable many modifications and enlargements to the base construct have been proposed. Many of them have focused on adding to the model capabilities parallel to both vertical and horizontal dimensions (Figure 1), stating e.g. how in the vertical reach an individual should possess expertise on more than one domain or system and in the horizontal reach be able to apply that knowledge to more than one context (industrial and/or socio-cultural).

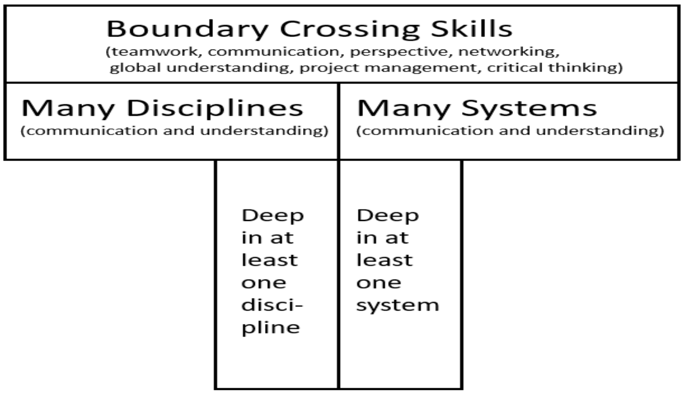

Fig. 1. Example of extensions to the T-shaped capability model [5]

This paper aims at evaluating the models proposed in terms of their relevance to the current and anticipated operating environment of engineering professionals. The paper also proposes a new improvement on the T-shaped capability model and discusses the role Higher Education Institutions (HEIs) can have in the development and supply of the new T^2-shaped professional to industries.

2 METHODOLOGY

The paper at hand relies on its arrival to conclusions on various pathways of inquiry. To start with, a brief synthesis of prior research and conceptualization is offered as well as its merits and possible shortcomings get discussed. Secondly, the author utilizes the constructional pathway, where a new model is introduced as derived from logical reasoning that relies on the author´s observations of societal, organizational, and technological change. Finally, the identification pathway pre-tests the model with thematic discussion with stakeholders in a) technology-based companies and b) educators in HEIs. The participants in the thematic interviews were selected with purposeful convenience sampling. The experts were chosen to represent both the technology and business point of view – both in the case of the company as well as

HEI participants. The industry stakeholders represented the following industries and positions in them: ICT-development/CEO, Energy Technology/Senior Quality Expert, New Materials/Business Development Director, and Machinery/Chief Financial Officer. The education stakeholders with whom the discussions were held operate in the programs of Logistics Engineering and International Business Management, on top of which the author has done observations when acting within a program of Technology Business and Futures Foresight. The author´s dual role as a designer of the model and observer of the reality is a potential bias. However, this selectiveness characteristic of conceptual and interpretative qualitative research is all-natural in the early stages of the development of a framework. In the further stages of validation, further development of the model and its practical instantiations more rigorous methodology, sampling, and implementation will be applied.

3 RESULTS

3.1 Overview and assessment of the prior work on capability profiles

The current discourse on capability profiles strongly propagates widened area of expertise as a plausible characteristic of an employable and successful employee of today and the future. However, the ideas of multiple areas of deep expertise – like in the case of π-shaped and enlarged T-shaped capability profiles contradict the trends of continuing specialization and technological development that force the companies and the professionals in them to focus their efforts to gain a competitive edge. The concept of multiple or boundaryless careers suggests that the Y- and Z-generations will not only change the company they work for multiple times on their career journey or just move up the corporate ladder, but will also make notable horizontal moves and leaps in their career trajectory. This will over time lead to multiple expertise profiles for an individual in some cases where a person moves to a different field of action (e.g., from production to procurement) or from one industry to another (e.g., from consumer electronics to aviation industry. This type of double expertise is however a result of a long career rather than a valid requirement for all let alone young recruits. Likewise, it is not a realistic target for education, since the birth of two or more true expertise areas would mean a substantial lengthening of study times. The societal pressure and demands for education efficiency are pushing the development in the opposite direction.

Furthermore, the capability profile models in hand do not make a claim on the layer in which the “wide” combinatory capabilities should be applicable. In reality, the processes in which one’s special areas connect to the expertise of others are context-sensitive, i.e. dependent on the industry or even a specific company where work takes place. Looking at the issue from the engineering angle, the same expertise of software engineering connects to other functions and professions in different ways in the case of medical technology vs. in the e-commerce platforms.

Finally, the models are rather unspecific in what counts as a capability. Also, the concepts of system, culture, and process are quite fuzzy, just like the boundaries between them.

3.2. The new T²-capability model to elaborate on and its implications for HEIs

The findings of the previous work as reviewed in Section 3.1. were based on logical reasoning. The utility of the models proposed in prior literature was mirrored by the other trends and challenges for modern organizations as introduced by research. In the principle of Socratic dialogue, the tensions between the models (thesis) and findings of current and foreseen forces for organizations and jobs (antithesis) in them, a new prospective model combining the findings gets proposed in this paper (synthesis).
The T²-model borrows its name from the main structure of the model, where the reality-bounded view of one true expertise (the vertical line of the letter T) is enriched with two layers of combinatory/generic capabilities (see Figure 2). The horizontal layers differ in two ways: 1) The contextuality of the capability, and 2) The level of expertise required in those layers.

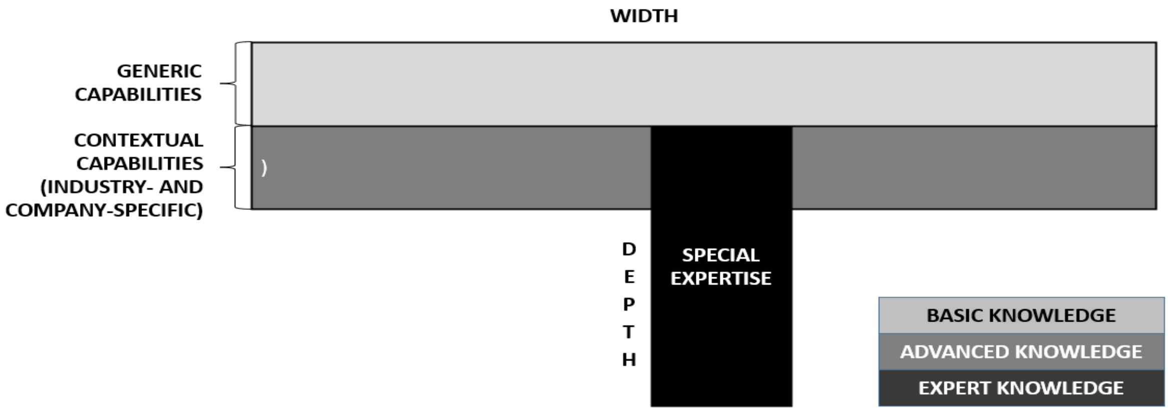

Fig. 2. Structural model of T²-capability profile

The T²-model suggests that the truly relevant combinatory capabilities e.g. in engineering jobs are made of the ability to understand and communicate the connections between one’s expertise and function to other fields of knowledge *within context.* Context refers to the application area and operating environment of the organizational knowledge, that tends to be specific to both industries (“clock speed” of an industry, value/supply chains, the role of standards and regulations, etc.) as well as to companies (different business models within an industry utilize different pieces of knowledge and in different ways). This context-dependent layer that goes for wider understanding does not need the match the depth of the specific professional expertise one possesses.
The upper and more generic, i.e. non-context dependent knowledge is needed for basic understanding of key concepts, their definitions, and relationships. This type of knowledge on issues such as quality, sustainability, etc. serves for one´s ability to

participate in discussions on the subject area and forms a base on which one can deepen the use of this generic knowledge in the context and further into their field and profession.
Based on the discussions with industry experts and engineering education practitioners, the following instantiations of T^2-capability profiles for software engineering capabilities as they manifest in two different context domains of digitalization were ideated (Figures 3 and 4) to test the feasibility of the model proposed. The stakeholders in the industry represented differing business functions (quality management, procurement, logistics, strategic management, financial management) just as the higher education stakeholders came both from business and technology faculties (and from different streams in them). Both the context-dependent as well as generic capabilities introduced were sourced from these stakeholders and applied to the framework with a manufacturing company in mind.

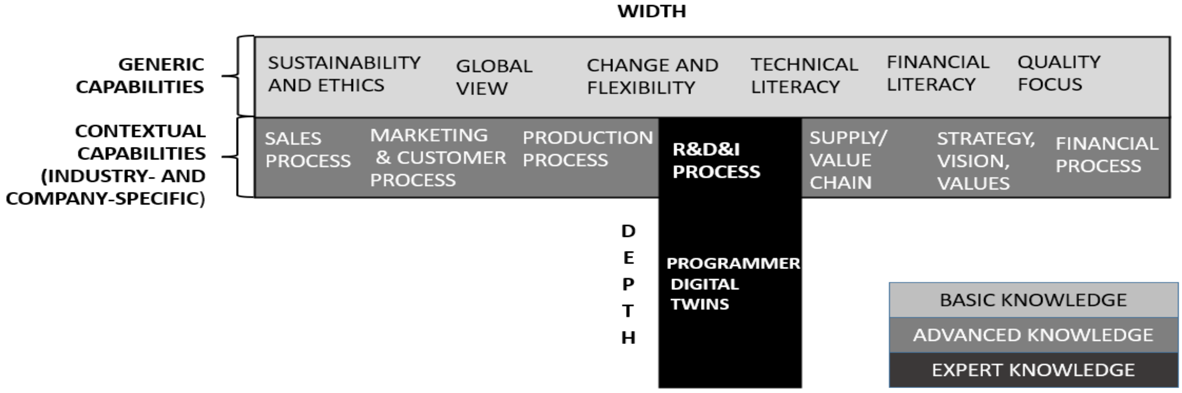

Fig. 3. T^2-capability profile for software skills in Research and Development

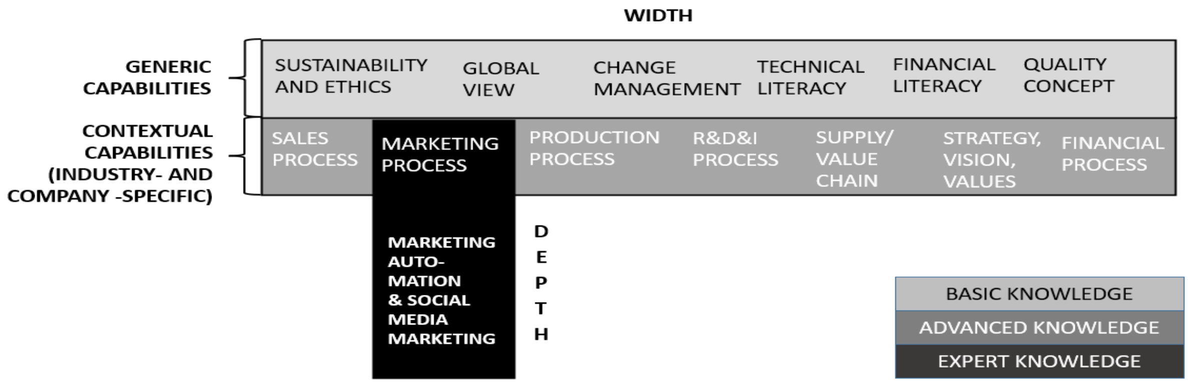

Fig. 2. T^2-capability profile for software skills in Marketing

Ironically, higher education institutes (HEIs) have traditionally been well equipped to contribute to both the most generic and most specific capabilities. In the early stage of the studies, learners across domains get introduced in their basic courses to the fundamental principles and key lexicons of multiple domains, after which the move to specialization studies aiming at narrow but deep professional skills takes place. The structure of HEIs divided into faculties, schools, and further study programs reflects

this specialization and siloing of knowledge. Depth and deepness in an inherent nature of top-level research – the other main function of HEIs – but serves badly the needs of the cross-disciplinary nature of the world of work. Furthermore, due to practical issues of scheduling and premises (separated campuses), even the generic skills are often taught in a way that does not bring people (both teachers and students) from different domain areas together.
Hackathons, case competitions, business simulations, and entrepreneurial (when team-based) incubation are some practices that HEIs and even some companies have deployed to foster the "T^2-mindset". However, these events and learning spaces typically involve a limited total student cohort and the ones engaged are often self-selecting themselves to these learning instances due to their T^2-mode already existing. For the remaining ones the horizontal, combinatory capability building is left to companies, who promote width of knowledge by trainee and talent onboarding programs and by job rotation. It is worth noticing that the contributing stakeholders from business organizations and education saw both technical and financial "literacies" – basic knowledge in key concepts and processes in the fields of technology and economics – as generic capabilities needed across functional domains and thus attached to the capability profile of any expert. This finding proposes to open up the educational offerings of business and engineering schools to a wider variety of students to enhance future collaboration and shared knowledge within organizations. Likewise, internationalization should be a knowledge possession of each individual in a modern networked world of work.

4 SUMMARY AND ACKNOWLEDGMENTS

To conclude, the new model once deployed by joint planning between HEI departments as well as between HEIs and companies would prepare and motivate the HEI learners better for their careers and add to their job market value and flexibility. In addition, altering the HEI learners early on to the combinatory views and experiences would create benefits for employers by the wider usability and mobility of the workforce, thus increasing resilience to changes in the operating environment and allowing lower (re)training cost of the employees. The author aims to continue the work by creating more industry- and job-specific models and empirically testing the feasibility of the model both in HEI and industry settings.

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4I4U CONCEPT CITIZEN ENGAGEMENT OF ENGINEERING STUDENTS AND HIGH SCHOOL STUDENTS

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Keywords: Innovation, Entrepreneurship, International Education, Citizen Engagement, Urban Mobility

ABSTRACT

The 4I4U project[2], which runs through 2022, aims to engage the community of citizens made up of students between the ages of 15 to 23 in the urban mobility of the future while empowering them to become actors of change who can participate in the development and evolution of their city. Led by a European Consortium composed of two cities, Barcelona in Spain and Toulouse in France, as well as education entities from high school to universities and clusters of companies in the field of urban mobility, and co-funded by the EIT Urban Mobility, the main objectives of 4I4U focus on raising awareness among young citizens in the context of urban mobility, developing their capabilities to become actors, highlighting their needs and finally creating a

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methodology and an environment that help students from ideation to action for the mobility of the future. The objectives of 4I4U are achieved by planning a set of seminars, round tables and brainstorming sessions to raise awareness or understanding of different aspects of urban mobility. To move from ideation to action, small groups of students design and produce a first ideation to understand and be able to project themselves into the proposed solution. This activity will be carried out under the mentoring of cities and industrialists, using the means of training institutions.

1 INTRODUCTION

1.1 Citizen Engagement of young people

The aim of citizen engagement is to ensure that users are part of the ideation process by achieving social and gender inclusion and stakeholder engagement, creating an opportunity to experiment and share information on urban mobility. 4I4U focuses on students aged 15 - 23 as they are rarely involved in the ideation process. Moreover, one of the added values compare to previous experiences for example in India-ICT standardization European project [1] on the smart city part is that they do not just experiment new products, system of services and try to create a new one by themselves as done in cities of Delhi, Kanpur, Bangalore, Chandigarh, Pune, Goa. In 4I4U, they not only try to develop an idea, they also have a phase of improving skills and exchange ideas in urban mobility with a strong connection with researchers, city services, and mobility companies. This allows them to advance in urban mobility and feel included.

1.2 Context

Partners of the project in both cities were willing to involve young students in the area of urban mobility, including university students, not necessarily from the civil engineering field, and high-school students. The common goals are to rise awareness and empower them as citiziens to act and be part of the solution for future mobility in our cities. Barcelona and Toulouse have some historical ties in both sides of the Pyrenées, also a common focus in teaching students who could work in the automotive or urban mobility sector with a sustainable mindset.

1.3 Goals and Scope of the 4I4U Project

The community of citizens made up of students aged 15 to 23 has and will have a growing impact on urban mobility. Making students aware of this issue as early as possible will have an important effect for the future, both in everyday life but also in the following generations.
We believe that young citizens are not involved in this issue because they think they cannot have an impact on the city. They do not master the process that goes from the awareness of a need, the formalization of an idea, the integration of the right actors and contacts to finally have impactful results. However, it is necessary to adapt the tools that are put in place to interest them and put them in a position to be protagonists of the necessary changes and innovations.
More specifically, the objectives of 4I4U are:

- OB1 Raise awareness of young citizens on the context of urban mobility with the help and expertise of teachers and trainers, city services and industrialists in this field.
- OB2 Develop the capacities of students to become actors of future urban mobility with the creation of networking between students, city and industry on this topic.
- OB3 Be able to highlight the needs and hope of this class of citizens.
- OB4 Create a methodology and an environment to help students from ideation to action in this field.

The scope of the activities focus on

- Propose, implement and evaluate a methodology based on a set of tools (seminars, round tables, workshop) addressed to the student population between 15 and 23 years old in a co-creation process tutored by city services, industrialists and academics. The use of these tools and, above all, the fact that they are part of the ideation process, will allow students, not only to be informed about science and innovation with different classes, but to be empowered and feel actors of urban mobility projects.
- The proposed methodology and activities are developed in two cities with specific and common events. The development of skills through access and exchange with experts, the identification of levers through the presence of city services and industrialists in this field, the networking to bring together all the players around the same approach should enable this population of citizens to understand and change their thinking and behavior in terms of urban mobility.

1.4 Towards a new future in engineering education

The 4I4U project includes some elements that can contribute to the future of engineering as it tries to engage engineering students in city challenges by involving them in the ideation of solutions and at the same encouraging younger students, who are currently in high school, in this design thinking approach. The focus is on citizen engagement and urban mobility and bringing together two cities close enough but from two different countries. The methodology of the process is explained below.

2 METHODOLOGY

2.1 Implementation of the Project

The project is divided in three tasks. The first task aims to understand and increase students' competencies in the field of urban mobility. It creates transdisciplinarity groups of students. This task specifically addresses objective OB1. The second task aims to create, produce ideas and think about their implementation. It addresses objective OB2 of the project. Finally, the third task creates a synthesis of the methodology implemented and the results in terms of ideas and proposed actions. This task integrates the dissemination of the events and the results of the activities. It addresses objectives OB3 and OB4 of the project.

Task 1. Networking debate and problem finding

This task concerns the sharing of information and the networking of the various participants at the beginning of the project. Its objective is to share information on the existing situation and the solutions envisaged around the world, but also to report the problems perceived by people in each partner city. The goal is to have well-informed and motivated students. It takes the form of events with focused seminars, discussion forums that can be shared or specific to each partner city. The events require of setting up the necessary structures, organizing the recruitment of external speakers, managing students and creating a space of physical and virtual conviviality conducive to exchanges. We rely in particular on a digital tool called DecidiUM and social networks to fuel and maintain exchanges. Seminars for example on the evolution of cities, the challenges of mobility, the city and the citizen, the industrial perspectives on mobility.

Task 2. Ideation phase and selection of proposals

This task is dedicated to the ideation phase by each group of students to propose a solution to an open problem that has been debated in the previous phase with citizens and stakeholders. The problem solved could be specific for Toulouse or Barcelona or for both/any cities. Educational establishments provide their equipment and fablab. The objective is to obtain a prototype demonstrating the philosophy of the proposed solution without having a level of operational maturity.
During a **final workshop at the** end of the year, each group will demonstrate their solutions and obtain various feedback to improve their proposal. They will present their idea and prototype in front of a jury bringing together different actors: users, cities, manufacturers, incubators, etc. The jury selects the best solutions. Each city together with the stakeholders decides about the future of the proposals.

Task 3. Assessment of the ideation and engagement process

During the beginning of the project, the program has been refined in terms of events and communication [2].
At the end of the project a summary of the process implemented and the results obtained will be made. CARNET experience in other projects [3] will help develop and assess the methodology for evaluating the ideation and the engagement of students in urban mobility. Partners will collaborate in the drafting of the good practices guide. This guide will produced and distributed on the Erasmus platforms, the EIT Urban Mobility community, and in the multiplier events organised by each partner for dissemination purposes.

2.2 Expected Impact

Environmental:
The methodology of working will raise awareness of young generations of students to the need that future urban mobility should be sustainable and active. The approach is to imagine that the project ideations that the students are going to be involved in are sustainable. We estimate that at least 3 of the ideas selected by the jury will have an impact on the environment. The change of scale in production will allow for the development of local employment but above all will avoid the transport of semi-industrialized parts around the world.
Economic:

The expected outcomes and impacts are the possible creation of products on the domain of the future mobility, an opportunity given to ideate in the city an innovative solution and help to argue for finding founds, the production of forms with easily shared techniques, the perception of which is easily understood by all thanks to a work of popularisation of information and maintenance and finally sharing new ideas with industry. We expect at least 2 ideas that have a real impact and economic potential for commercialisation.

Social:
We expect more than 200 students involved in 4I4U in different degrees of implication. So far around 21 posters and videos have been created by ISDAT students, as explained in section 3.5, and 10 telecom engineering students have develop an app, as explained in section 3.4. The hackathon organized in Barcelona in December will gather around 150 students from Toulouse and Barcelona. Activities with high-schools in Barcelona are planned for the fall semester involving engineering students as "ambassador" of the project. We have to add to this numbers other students that have attended the seminars so far.They will become well-informed and increase their capacity to become actors of the future urban mobility and more generally actors of the city. Moreover, connection will be made between the different visions of the city from: learners, citizens, city management, companies and teaching entities. Furthermore, common work for high school students, undergraduate and postgraduate students can encourage high school students to project their future as citizens engaged in sustainable activities in their cies. Finally, teachers will also increase their knowledge on this topic and be able to integrate this experience in their courses.

3 ON-GOING RESULTS AND EXPECTED RESULTS

3.1 Seminars shared between the two cities the First Semestrer

Twelve hybrid events are held simultaneously in Toulouse and Barcelona. These seminars, round-tables and brainstorming sessions have taken place in order to understand different aspects of urban mobility and raise awareness on the subject as it can be seen in the topics of the events that follow.[3]

1. "Draw me the Automobile of the Future for Urban Mobility" by Jean Luc Maté on February 15th 2022 4PM.
2. "Project Design from the perspective of city services for citizens" by Ángel López on March, 3rd 2022 5PM.
3. "Non-Financial Report of ICT projects" by Eva Vidal, on March, 8th 2022 at 2PM.
4. "Autofiction, a biography on the automobile object" by Olivier Peyricot on March 9th 2022 at a6PM

[3] All seminars could be found on the following link: https://engage.eiturbanmobility.eu/processes/Project4I4U/f/41/meetings?filter%5Bsearch_text%5D=&filter%5Bdate%5D%5B%5D=&filter%5Btype%5D%5B%5D=&filter%5Bactivity%5D=&filter%5Bactivity%5D=all

5. “The role of Technology Innovation in Urban Mobility” by Jordi Ortuño on March 17th 2022 at 5PM
6. “Challenges for sustainable urban logistics” by François de Bertier on March 24th 2022 at 4:30 PM.
7. “Smart mobility. Urban Mobility challenges” by Ángel López on March 31st 2022 at 5PM.
8. “When smart mobility means smart infraestructures” by Pierre Emmanuel Maire on April14th 2022 at 5PM.
9. “Female mobility patterns” by Imma Ribas on April 28th 2022 at 5PM
10. “5G technology and smart mobility” by Bruno Pouget, Frederic Gardes, Stéphane Vialle and André Bottaro on May 12th 2022 at 4PM.
11. “Mobility 4.0. and cognitive ergonomics: thinking about the human in an autonomous and connected environment” by Céline Lemercier on May 16th 2022 at 4PM.
12. “Urban mobility and Pollution Citizen Maps. Young Population study in Barcelona” by Universitat Politècnica de Catalunya on May 19th 2022 at 5PM.

3.2 Barcelona Activities (current and to be done)

A core group of 10 final year undergraduate students in the area of Telecommunication Engineering, not related to urban mobility, automotive or environmental studies, are taking a 12 ECTS challenge-based course during the first semester of 2022. The proposed challenge is to develop a product/service with the following requirements: to estimate the exposure to pollutants while moving around the city in their daily life, especially when they go to study; to raise awareness among the young population between 15 and 23 years old about the carbon footprint caused by the means of transport they use; finally, to use the knowledge in their own studies as a way to see that urban mobility is a transversal field where any professional can contribute. As a product they decided to create an app that shows three alternative routes to go from one place to another in the cities of Barcelona and Terrassa, that is, the fastest route and two alternatives with less pollutant exposure. The app also shows the carbon footprint generated according to the chosen route and depending on the mode of transport. The app contains projections of carbon footprint estimates for 1, 5 and 10 years. Finally, a ranking, as a game between friends from the same high school to see who is the "champion" generating less emissions in their daily mobility around the city. This project has required them, first of all, to become aware themselves of the environmental, social and economic impact of pollution through their own research study and by attending parallel seminars organized by 4I4U. Thanks to this awareness of the magnitude of the consequences of pollution, they are now ambassadors and together with 4I4U partners they visit high schools to show students younger than them their own experience in acquiring knowledge and on the other hand in their contribution by developing an application that can help this awareness and at the same time have fun. The university students also want to get feedback on the product they are developing.
Some results of their own work are presented to the university community at the last 4I4U seminar in Barcelona.

3.3 Toulouse Activities (current and to be done)

Following the networking phase, a first set of solution proposals in the form of posters and videos was produced by ISDAT. This material will be exhibited and shown to other students from other establishments to give them a first ideas of solution (idea0) and allow them to co-construct either from this first batch of ideas or from new ideas, their will propose their final proposal of idea (idea1) for the end of June. We will then begin the mentored implementation phase of the various ideas (idea1) by industrialists, city services and teachers. In December, groups will finalise their first prototypes (proto1). A jury will evaluate these prototypes and select those that can have a real impact and a possibility of deployment in the city. Students will then be able to gather around these few selected prototypes to improve them and move on to a prototype version (proto2) that can be deployed and used by a subset of citizens in real-life situations in the city.

3.4 Common Activities and Assessment for the Second Semester

Common Activities for the Second Semester

Beyond the sharing that takes place in the first semester, during the seminars, we wanted the students to also benefit from the richness of their different cultures between Toulouse and Barcelona. For this, a 2-day event will allow them on the one hand to attend together at a conference and exhibition on urban mobility in Barcelona and on the other hand to share the knowledge they have acquired during the project 4I4U on a one-day and night hackathon on short projects on urban mobility involving technologies of connected objects, communication and design (see for example A humanitarian technology hackathon [4] and some good practices in [5]).

Assessment

The 4I4U assessment of the ideation and engagement process includes the quantification of three main aspects: 1) Social impact 2) Environmental impact and 3) Feasibility .

1) Regarding the social impact the assessment will focus on how university students from 18 up to 23 years old understand and increase the transversal fields related to urban mobility. Considering the students of secondary school and University the assessment is focused on building the awareness of sustainable mobility for the youngest and increasing it for the oldest taking into account the effects of a non sustainability mobility.

2) Regarding the environmental assessment, for instance, in one of the projects it is based on pollutant parameter measurements of the students' mobility patterns. This is achieved by an app created by a group of students.

3) Feasibility assessment is based on how this project can be repeated in time or how the environment and the social impact can be reproduced through the outputs of the project and thanks to citizen associations which are aligned with 4I4U values.

4 CONCLUSIONS AND PERSPECTIVES

The first results of the project show that the choice to have developed an offer of face-to-face seminars, streaming and recording makes it possible to adapt to this audience of 15-25 year olds who consume information at their own rythm. The final conclusions will have to wait until the end of the project with the implementation phase done and the final feedback from the partners involved and the students on the whole of what they have learned and achieved. Nevertheless, the first presentations of the concept to college, and undergraduate school outside the project have aroused an interest in this type of approach with a desire to participate in future editions.

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BOOST I&E CONCEPT FOR URBAN MOBILITY EDUCATION

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ABSTRACT

Modern higher education needs to provide skills needed in working life, such as entrepreneurship, besides the more traditional technological competence. The Boost

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I&E Project[2] was developed in 2020 and 2021 with the aim of generating a set of guidelines for innovation and entrepreneurship challenge-driven projects for master's programmes. The added value was created by collaborating and exchanging best practices among higher education institutions in seven different countries, with the aim of developing students' skills with an international perspective and exposure to the knowledge triangle. The implementation of Boost I&E would allow learning about the advantages and disadvantages of different approaches in a practical way, while courses on urban mobility were provided. The activities involved more than 100 students over two years.
The experience concluded with the adoption of a set of guidelines based on best practices, covering several aspects. Most emphasis was placed on the methodology of the course, on sharing activities and on finding best practices and implications for stakeholders. Our experience can be useful for universities that want to open up their students to I&E.

1 INTRODUCTION

In the last 15-20 years, there has been a push to renew higher education, shifting from a technical knowledge-focused paradigm to a model that, without losing scientific and technological competence, also provides skills needed in practice. Students need to be trained to meet the demands of society at large. Students from all disciplines need to be trained in discovering the most relevant needs of their communities, defining alternative solutions, choosing the most impactful ones based on approaching users and other stakeholders and, finally, designing and developing the chosen solutions; this last step being the only one usually carried out in traditional curricula. There are many societal needs that can be addressed through this approach, such as all those mentioned in the UN Sustainable Development Goals (SDGs) [1], which are reflected in the EIT's Strategic Objectives for Urban Mobility [2]. Urban mobility is one of the themes best suited to this new approach, as the urban population as a whole is the target and many of the stakeholders are public institutions. It would therefore be reasonable to emphasise human- and user-centred design in the curricula, while promoting our students' skills in social innovation and entrepreneurship so that they become the drivers of change in our communities.
The Boost I&E project was developed with the intent to investigate such aspects in the context of urban mobility within various European universities. The consortium partners already had experience with different types of teaching and learning activities suitable for this purpose, but not with all of them and not to the same extent. A practical "learning by doing" approach was proposed:

- Each institution adapted a suitable existing course (or developed a new one), using different methods and a common topic on urban mobility.
- Teaching experiences and learning outcomes were shared through meetings, faculty exchanges, and joint events with the students from the different institutions.
- The results and process were analysed and a set of guidelines was proposed for designing appropriate teaching and learning methods for I&E education, mainly focused on Masters programmes.

[2] Co-Funded by EIT Urban Mobility

1.1 Existing alternatives to deploy I&E education

The more relevant alternatives that could be considered for develop I&E skills within a course or part of a course are the following:
- *The Case Method*. A set of cases are presented that have a real basis but are tailored to be useful for learning. Solving the cases forces the students to make decisions that can be compared to the decisions made in existing ("traditional") solution [3].
- *Project-Based Learning (PBL)*. Although it allows for different definitions and implementations, the most comprehensive is the replacement of part of the teaching methodology of one or more courses with a project that forces students to search for information, learn methods, and make decisions that will provide them with learning outcomes that are coherent with the objectives of the course.The cases are usually artificial and are defined by faculty members and not by external stakeholders. [4]
- *Product Development Project (PDP)*. A team of students carries out a project to develop a product or service to solve a challenge that is usually specified by an external organisation (e.g., from the industry or public sector). Although this modality is more suitable than the previous one for the objectives of this project, most PDP carried out in engineering schools start from requirements and even specifications based on decisions already made by the external entity. The user approach is thus limited and part of the creative phase may be lost. [5]
- *Challenge-Based Learning (CBL)*. In this case, usually, a very open challenge is provided to the team by the external organisation. Usually a Design Thinking methodology is used. The team of students must carry out an in-depth research to discover the users' needs related to the challenge, choose the most relevant ones, define different solutions, and choose the most appropriate one, developing a proof-of-concept prototype. Decisions in all phases should be based on feedback from users and other stakeholders. [6]
- *Hackathons and Intensive Courses*. They are shortened versions of a CBL course, with more or less open challenges. The hackathon carries out the whole process in a short time, for example two days, and the intensive courses can last 1-2 week(s), which can be separated over the semester. [7]

1.2 Context

Most institutions within Boost I&E implemented one or more of the learning modalities described in the previous section, although in most cases students from the same or closely related disciplines were included.
The most relevant features in relation to Urban Mobility are:
- following a user-driven environment;
- defining the challenges together with actors from the urban mobility sector;
- developing innovative ideas that can result in a start-up or that can be transferred to existing development platforms;
- training graduates with a set of skills suitable to transform innovation into a socially driven paradigm according to the EIT's overarching learning outcomes.

1.3 Goals and Scope of the Boost I&E Project

The purpose of the Boost I&E Project was to experience and recommend New Guidelines for an I&E Challenge-driven Academic Activity for Master's Programmes with the added value of boosting performance through collaborating and sharing best practices across institutions, focusing on developing students' I&E skills with an international perspective and exposure to the Knowledge Triangle.
The following objectives were effectively addressed to achieve this goal:

- Objective 1 - Propose initiatives for I&E challenges at academic level. Most universities participating in the project already had some experience of 'learning by doing' approaches, presenting open challenges to their students. Some institutions had specific I&E rooms to develop innovative solutions to real challenges with the participation of local stakeholders.
- Objective 2 - Real challenges for urban/urban mobility actors. One of the main points of this initiative was to add an extra value to the courses by making challenges faced by the Urban and/or Urban Mobility Actors occurring at European level.
- Objective 3 - Innovation and Business Mindset. The challenges presented were real-life and therefore the solutions had to be approached from a business perspective. The whole process had to be guided by observers from the business world.
- Objective 4 - Share best practices. The best way to improve the performance of the challenge project was to share methodologies and best practices to improve the project courses in each institution.
- Objective 5 - Sustainability and Scalability Mindset. As cities may face similar problems, the proposed approaches should focus on deploying sustainable and scalable solutions in a global market.

So far, there have not been many examples of international experience sharing among I&E spaces. Most challenges are usually identified and developed locally and with local stakeholders [10] or if they are international, are not embedded in courses [9]. By sharing challenges that are similar but have a different context in each city, students develop skills to better cope with global markets. Moreover, this experience helps to enhance the capacities of faculty members who lead academic I&E activities and disseminate this way of teaching in their own institutions in the framework of courses included in the curricula.

The intention is to extend the results of this project to other academic units within the consortium, and once the guidelines are well established, they can serve as an example for other higher education institutions. One of the particularities of urban mobility compared to other fields is its multidisciplinary perspective and the participation of cities, which propose to work on challenges that are very close to the needs of citizens.

2 METHODOLOGY

2.1 Implementation of the Project

Figure 1 shows the different phases of the project with regard to the activities in 2020 and 2021. The projects had a duration of one year and two editions were implemented. During the second year, additional partners joined this initiative, which can therefore start from the experience gained in 2020.

The **Kick-off Meetings** were held in early January 2020 and early January 2021, respectively, with representatives from all academic partners in order to establish the academic framework for the development of the project.

Train-the-Trainers events were intended for university teachers and managers of educational programmes involved in entrepreneurship education. The Train-the-Trainer sessions were based on experiential learning principles and were designed as a short entrepreneurship course, using teaching approaches and methods previously tested by Aalto Ventures Programme. In 2020 it was held at the beginning of the year, in 2021 in mid-March and with a different focus.

I&E Challenge Development, during the first semester of the year from the beginning to the end of the course in each institution, student teams worked on their solutions

Their work was not only supervised by academic staff, but also by representatives of companies and cities. Each institution could also integrate lectures on different aspects of I&E and relevant topics related to the problem to be solved.
Exchange of faculty observers, the original aim was to visit other institutions face-to-face. Because of COVID-19, this was changed to online meetings to share experiences, virtual visits to the courses, student presentations including final presentations, and partner questionnaires to gauge the opinions of the other institutions.

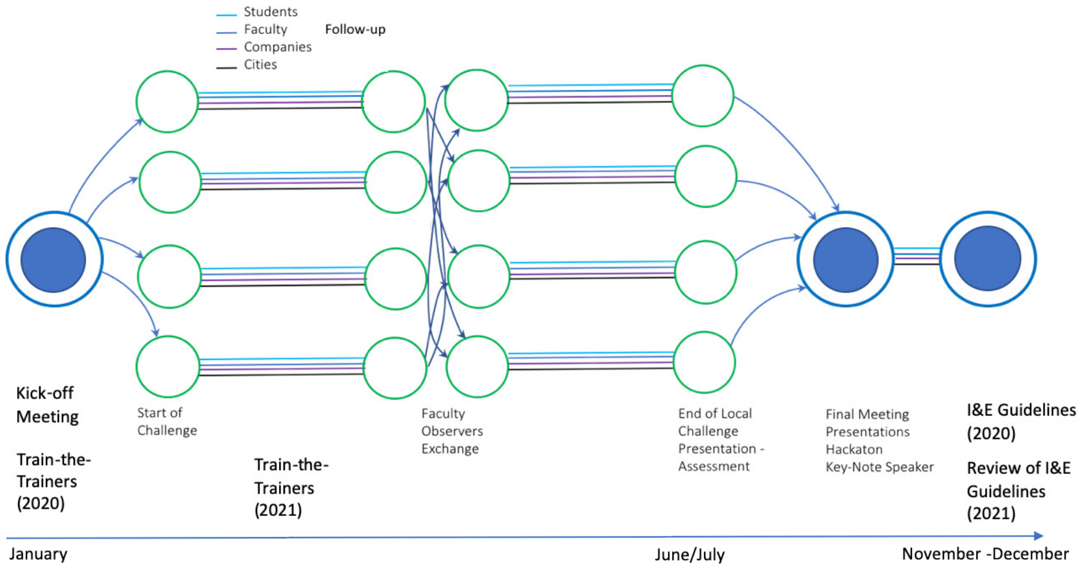

Fig. 1 Implementation Process of Boost I&E. Circles represent milestones, whereas lines development of activities and arrows relationships

At the end of the Local Challenge, students presented their solutions and the evaluation was carried out. At the final presentation of the students' projects, representatives of cities and local businesses were also invited in order to provide first-hand feedback on the innovation potential of the proposed solutions. The learning outcomes were evaluated. The best team from each university was selected to go to the final meeting.
The **final meetings** were held online in 2020 and face-to-face in 2021. The following activities were devised:
- Invitation of relevant keynote speakers.
- Presentation of the results of student teams from each institution. Prizes for the best teams. Invitation of a representative of the cities and representatives of companies.
- Hackaton, named "Urban Mobilithon", where mixed student teams were assembled to work on a challenge to be solved in the host city. Invitation to Representatives of the City and Representatives of Public and Private Stakeholders.
- Academic meeting of representatives to draw final conclusions

Guidelines for the I&E Challenge-Driven Academic Activity for Master Schools. After the activities, the partners worked on defining best practices. Therefore, Guidelines for International Cooperation I&E Challenge-Driven Projects in Urban Mobility were drafted.

2.2 Observed Best Practices

The activities carried out at each institution were assessed by the other partners, with the goal of identifying the most relevant best practices, ranking them by affinity

and included in some way in the general guidelines of Boost I&E. These practices are as follows:
- Planning for a good balance of technical and I&E skills
- Working with strong links to stakeholders
- Creating multidisciplinary teams
- Including sufficiently broad challenge topics to encourage creativity and autonomy
- Breaking up the challenge into sub-challenges, when many students participate in the course and the challenge allows it
- Challenging students to conduct interviews with many users and stakeholders
- Pushing students to get a good understanding of customer needs
- Pushing students to work out a rationale behind each decision
- Inviting relevant guest lecturers
- Performing intermediate checks of the challenges
- Visualising other teams at universities solving similar challenges
- Promote the achievement of a result that is ready to be piloted
- Sharing best practices with other partner universities
- Getting the support and encouragement of the leaders in the academic institution and making the links with other courses and the curriculum in general

3 SUMMARY OF GUIDELINES

The guidelines include features identified on the basis of lessons learned from implementation and exchange of best practice between institutions. It is strongly recommended to follow CBL projects. These features are summarised in the following subsections. For more information, the full version of the guidelines can be downloaded from [8].

3.1 Teaching and learning activities

Challenge-Based Education is mainly based on cooperative and experiential activities. The student teams have to carry out field research and conduct interviews with users, customers and experts. This requires time of autonomous work between sessions and in some phases a period of a week is not enough to collect and process the information.
Regular short presentations in the classroom, to get feedback from the teachers/coaches and from the classmates play a big role in the learning process.
On the other hand, it is also useful to share ideas in a different environment than the classroom and look at different solutions in similar processes. Hackathons and inter-institutional activities offer the chance to get to know different points of view and learn different tools.

3.2 Time distribution of the activities

Courses spread over a full semester are preferred. There is also a trade-off between breadth (scope) and depth. For example, courses of 5 or less ECTS allow for a reasonable range of I&E learning outcomes, but are limited to concept-level developments (need-solution-business idea). For deeper results, larger courses (10-12 ECTS) are a better choice. Combinations between an ideation course and a technical development project course with the same challenge is also an option.

3.3 Multidisciplinarity

Multidisciplinarity and diversity are essential in CBL and Design Thinking education. The possibility of including truly multidisciplinary students in the teams (i.e. not only different engineering disciplines but also architecture, business, design, arts or social sciences) adds tremendous value to the innovativeness of the courses, but it is usually not easy to organise because it requires cross-school or cross-university collaboration. It is also about having different ways of thinking. Multidisciplinarity can include diversity (gender, age, culture, nationality, etc.) and organisational complexity.

3.4 Challenge Selection

In urban mobility, many stakeholders are public institutions or public transport operators. Common projects involve a request for a public tender. The I&E possibilities in this framework are therefore limited.
To work on CBL, we need to ask stakeholders to propose more open projects. It is advisable that the challenge belongs to a live or near-future project of the stakeholder. If challenges are generic, they need a lot of time to converge. Therefore, challenges should be open, but not excessive. Another possibility is to work on campus-based challenges with their advantages and limitations.

3.5 Role of the external stakeholders

The role of the representatives of the external companies or institutions is essential. They have less effect if they only act as guest lecturers or external observers. The effect is greater if they behave like clients or contractors. A similar effect is achieved if part of the I&E training workshops is given by staff from the knowledge transfer unit of the university or by external innovation consultants.

3.6 Assessment of CBL Projects

Team rating seems to be the main tool for assessing CBL projects. Several institutions use it without individual assessment, while others include an individual modulation in relation to the team rating. External stakeholders give an opinion but do not participate in the assessment.
The individual modulation can have up to three contributions: Supervisors/coaches collecting evidence (participation, effort, value); assessment by the team leader (if any); and peer assessment, via a rubric. Apply peer assessment only if there is no agreement in a team negotiation.
It is difficult to give an absolute mark to all activities.

3.7 IP, Sponsorship

In most universities, the intellectual property of the project results belongs to the students. Conflicts may arise when an external institution or company sponsors the project. There is a trade-off between giving the student an incentive and getting relevant challenges and implications from the companies. Sponsorship of CBL ensures more involvement on the part of the company. The case for UM may be simpler, as public stakeholders in this field do not ask for IP ownership. Open projects proposed by public institutions may provide more opportunities for students' initiatives. Intellectual property is just one potential benefit for an external partner. The cooperation between sponsors and students during the CBL project is a competitive advantage in talent recruitment. Additionally, sponsorship can also be part of the companies' social corporate responsibility initiatives.

3.8 Sustainability and Engineering Ethics

UM is suitable for training socially oriented engineers. Seminars on sustainability, with specific reference to the UN SDGs, are also recommended. Sustainability analysis of their projects is a must, including social, environmental and economic aspects.

Business and Engineering Ethics should also play a role in I&E courses. Not only for the implications arising from the use of technology, but also for the mission, governance model and value chain of the business models developed by the student teams.

3.9 International Perspective

The possibility of cooperation between universities from different countries makes it possible to observe course development and share best practices. When the challenges are similar, it is easier to compare methodologies and activities and take note for current or future editions. Students observing students from other universities, with the practical solution of sharing this online in the middle of the semester, allows them to observe directly and possibly apply different perspectives to improve their own projects. They also get an idea of cultural issues and different legal structures. Sharing presentations from stakeholders or other invited speakers gives them a chance to broaden their international and triangular exposure. Organising Hackathons (Mobilithon) as a final activity, preferably face-to-face in a particular city and facing different challenges, boosts their motivation and establishes their I&E skills.

3.10 Self-assessment of I&E skills

We delivered surveys for self-assessment of the students' I&E skills, both before and after the courses at some universities. The comparison shows an overall slight improvement in the perceived level of I&E skills of students. For instance, one of the universities surveys results show that the number of students who think they can present creative ideas has increased.

3.11 Additional Features

Learnings from COVID-19 confinement

There were limitations to the lessons from the COVID-19 pandemic restrictions: difficulties in conducting user interviews and testing prototypes in the field and no possibility to visit other courses face-to-face (F2F) to observe practices. However, there were learning points that may be useful even if face-to-face returns: mastery of online meeting platforms (Zoom, Meet, ...); remote user interviews and surveys; prototyping and testing based on multimedia representations of the ideas; etc

Opportunities for Master Students to pursue an Entrepreneurial Career

Challenge solutions are usually not ready to be marketed. Some students have shown interest in going beyond the project. We can offer them support and information: by introducing them to the university's incubators; the cities' incubator programmes; and, in particular, the EIT Urban Mobility Accelerator Programme.

4 CONCLUSIONS AND EVALUATION OF RESULTS

Most emphasis of the project focused on the sharing of activities and looking for best-practices and finding stakeholder implication. Although all elements were discussed, in the future, we have to focus on some issues, as sharing best practices for evaluating I&E skills before and after students have taken the course, sharing how assessment was carried out, or even to increase stakeholder implication and sharing talks by experts.

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THE EDINSOST2-SDG PROJECT: INTRODUCING SDGs IN HIGHER EDUCATION

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ABSTRACT

The main objective of the EDINSOST2-SDG project is to introduce sustainability and the Sustainable Development Goals (SDGs) in Higher Education. The project focuses on Engineering degrees, Education Degrees, and the Business Administration and Management degrees of the Spanish university system. The project has four main objectives: (O1) Identify the SDGs in the EDINSOST sustainability competency maps

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(SCM); (O2) Improve the learning outcomes of sustainability and SDGs in the degrees related to the project; (O3) Faculty training in Education for Sustainability and SDGs; and (O4) Analyse the students' learning in Sustainability and SDGs during their training at the university. The current project began in 2019 and is scheduled to end in December 2022. This paper presents the main results achieved so far in the O1. SDGs have been included in the SCMs previously designed by the EDINSOST project. Each SCM learning outcome is related to a set of UNESCO learning objectives and UN indicators of the SDGs. As EDINSOST2-SDG results, the SCM has been simplified to make it easier for teachers. A pilot project is currently being carried out at the UPC-BarcelonaTech to analyse ten engineering degrees using this simplified SCM. The results of the pilot project will be presented in June 2022, but the preliminary results show that the reduction in the number of learning outcomes has been a key aspect to motivate those responsible for the different degrees involved in the pilot project to use the SCM as a tool to introduce sustainability in their degrees.

1 INTRODUCTION

The university has an important role to play in an eco-social transition that is essential to overcome the major challenges our society faces as part of nature [1]. As an institution dedicated to the creation and transmission of knowledge, the university may lead the way towards a culture of sustainability, through research and teaching [2] and from the experience and learning of the university community itself. To this end, the integration of Education for Sustainable Development (ESD) in Higher Education (HE) contributes to the development of sustainability-related competencies of students and university staff. Competencies such as critical and creative thinking, systems thinking, collaboration, action and problem-solving skills contribute to the training of potential eco-social change agents.

The United Nations 2030 Agenda identifies the need to integrate the Sustainable Development Goals (SDGs) into university curricula [2] as a service to society. This integration represents an opportunity for interdisciplinary and transdisciplinary collaboration in education, research, and innovation, oriented towards the 17 SDGs. The new global framework "Education for Sustainable Development: Towards achieving the SDGs" or "SDGs by 2030", adopted at the 40th session of the UNESCO General Conference [1], encourages the introduction of the SDGs in HE.

The increasing commitment to EDS of more than a thousand HE institutions is reflected in more than thirty international declarations and initiatives [3]. Yet the syllabus of the world's universities is still far from achieving a sustainability orientation. Sustainability is often present in isolated experiences and initiatives that do not reach the learning of all students [4]. Universities should strive to expand and improve teaching-learning actions beyond the usual teaching practices [5], since it is in this area where the greatest difficulties arise for both teachers and students [6]. On the other hand, some studies (in this case focused on the field of engineering) show a lack of social commitment as students' progress in their studies [7], [8], indicating that the challenge is even greater in engineering [9]. It is therefore essential to move towards curricular sustainability in the University System, allowing critical reflection, fostering interdisciplinary collaboration, and learning the necessary skills so that the university community can catalyse change towards a more sustainable society.

Different research groups have worked from many points of view and at many levels on the competencies needed to meet the challenges of sustainability and the SDGs. These works have led to the UNESCO Education Guide for Sustainable Development Goals: Learning Objectives [10], which presents eight key competencies for sustainability: Systems thinking, Anticipatory, Normative, Strategic, Collaboration, Critical thinking, Self- awareness competence, and Integrated problem solving. The Guide proposes 15 learning objectives for each of the 17 SDGs, classified according to a three-level taxonomy: Cognitive, socio-emotional and behavioural.

The Executive Committee of the Conference of Rectors of Spanish Universities (CRUE) defines in its "Guidelines for the Introduction of Sustainability in Curricula" four sustainability competences considered essential in the curricula of higher education degrees [11]:

- C1: Critical contextualization of knowledge by establishing interrelations with social, economic, environmental, local and/or global problems.
- C2: Sustainable use of resources and prevention of negative impacts on the natural and social environment.
- C3: Participation in community processes that promote sustainability.
- C4: Application of ethical principles related to the values of sustainability in personal and professional behaviour.

Different perspectives are aligned with the mentioned UNESCO and CRUE competencies for sustainability [9] in engineering. The Barcelona Declaration [12] of the International Conference on Engineering Education for Sustainable Development proposes the competencies that engineers should acquire in order to face the sustainability challenges. The accreditation agencies for engineering degrees (ABET, ENAEE, Canadian Engineering Acreditation Board) also recognise the need to incorporate these competencies and propose a series of learning objectives.

The EDINSOST projects, financed by the Spanish State Program for R&D&i, arise from the need to promote ESD in Spanish universities. In two consecutive projects, EDINSOST and EDINSOST2-SDG, more than sixty researchers have carried out a highly multidisciplinary work between twelve universities in three fields of knowledge: Engineering, Education, and Business Administration and Management. The research has been contextualised and applied in all the participating universities. Both projects are carried out with the aim of integrating sustainability into the curricula of the participating universities by designing innovative teaching-learning actions, evaluating the knowledge of the teaching staff in sustainability and designing a training strategy for them, and discovering the competency level in Sustainability of current graduates in the Spanish university system.

Based on the sustainability competencies defined by CRUE [11], the EDINSOST project [13] developed Sustainability Competencies Maps (SCM) for the three areas of the project [14] and evaluated pedagogical strategies and appropriate evaluation instruments to develop the sustainability competency. Three years later, the need to incorporate Education for the SDGs in the same three areas resulted in the approach of the EDINSOST2-SDG project. The project developed two other tools for the introduction of sustainability in the university system. The first, the "Map of sustainability presence" of a degree, shows the percentage of presence of sustainability competencies in the curricula. The second one consists of a questionnaire that, for each competency, asks about the level of ESD that students perceive they have acquired. The comparison of the result of both tools allows us to glimpse the effectiveness of the incorporation of ESD and the SDGs to a degree.

However, this effectiveness should be validated through direct assessment of student learning. At the same time, the project is working on the development of a database of open educational resources (OER) related to the SCM, on the design of a teacher training course, and on tools that allow the introduction of ESD in final degree projects.

The incorporation of ESD and the SDGs in university degrees is not trivial. Strategies must be modified to integrate courses, activities, and content in the different degrees in a systematic, interconnected, and coherent way [5]. Several of the participating universities in EDINSOST2-SDG are implementing initiatives to achieve this integration. In 2021, the Universitat Politècnica de Catalunya (UPC-BarcelonaTech) started a pilot project in ten degrees to introduce sustainability in their curricula using the EDINSOST2-SDG methodology. The pilot project represents an opportunity for sustainability competencies to be normalised as part of university engineering education [15]. Management teams and teaching staff have been involved in the implementation of the EDINSOST2-SDG tools in each degree: SCM, Map of sustainability presence, teacher training courses and OER database. During this process, a problem inherent to the SCM presented in [9] has arised: in degrees where there are no sustainability experts, teachers have been reluctant to use the SCM due to the large number of learning outcomes it contains (53). To solve this problem, the EDINSOST2-SDG team has simplified the SCM to make it easier to understand and use. This paper presents the work developed to achieve this goal.

2 METHODOLOGY

The Engineering SCM of objective 1 of the EDINSOST project was presented in [14]. The SCM is structured based on the four CRUE sustainability competencies, which are subdivided into seven competency units (CU). Each of these seven CUs is defined using the Simplified Miller Pyramid [16] as the taxonomy of learning. This is a taxonomy of three domain levels: know, know how, and demonstrate + do. For each domain level of each CU, the set of learning outcomes related to sustainability that an engineering graduate must acquire on completion of their studies are defined.

The EDINSOST project had considered multiple sources of information to create the SCM, but the SDGs were not among these sources because their publication coincided in time with the work done during the project. For this reason, in the EDINSOST2-SDG project it was decided to update the SCM to take into account the SDGs. The result, together with the validation process of the new map, can be found in [9]. In total, the new SCM has seven CUs and defines 53 learning outcomes. This is a very high number, which makes it difficult to implement the SCM in an engineering degree. For this reason, a process of simplification of the SCM was carried out, so that the number of learning outcomes was significantly reduced. This allowed obtaining a SCM of only 28 learning outcomes. Having a reduced number of learning outcomes not only simplifies their introduction in the curricula, but also makes it possible to reduce the number of questions in the surveys to build maps of the presence of sustainability in a degree (objective 2) and to analyse the perception of students about their own learning (objective 4). It also allows having to develop a database with less number of OER (objective 3).

The way to reduce the number of learning outcomes has been to combine several learning outcomes into a single one whenever possible. For this, two considerations have been taken into account. The learning outcomes to join:

- must belong to the same CU and to the same domain level
- must deal with similar aspects, so that the result of their union is natural

For example, the following learning outcomes:

- Include indicators in their projects for measuring social impact (e.g., Social Life Cycle Analysis, ISO 26000, Directive 2014/95 / EU for non-financial reporting).
- Take into account in their projects and actions safety, health and social justice criteria (e.g. ergonomics, accessibility, user experience, equity, diversity, common good, transparency, human rights, gender perspective, needs of the most vulnerable groups, discrimination, dignity, fight against corruption).

have been joined in a single learning outcome in the simplified MCS:

- Takes safety, health, and social justice criteria into account in their projects and actions and includes indicators to measure social impact.

As it can be seen, the process has also served to simplify the writing of the learning outcomes, which makes them clearer for teachers.

To relate the learning outcomes with the SDGs, the relationship matrices of the learning outcomes with the learning objectives of the SDGs defined by [10] and with the goals of the SDGs [2] have been used. These matrices had been initially developed for the MCS presented in [9] so it has been necessary to simplify them. To do this, each learning outcome of the simplified SCM has been related to the learning objectives of UNESCO [10] and to the goals of the SDGs with which all the original learning outcomes were related (from the MCS of 53 learning outcomes).

3 RESULTS

Table 1 shows the simplified MCS structure and an example for the Competency C4: Application of ethical principles related to the values of sustainability in personal and professional behaviour, with its three Learning Outcomes at different learning levels.

Table 1. Example of the simplified MCS for Competence C4.

Competency	C4. Application of ethical principles related to the values of sustainability in personal and professional behaviour.

Dimension	Holistic
Competency Unit	CU4.HO. Acts according the ethical and deontological principles related to the values of sustainability
Level 1- know	C4.HO.1.x. Knows their professional deontological code, the main ethical dilemmas and the laws and regulations related to sustainability. C4.HO.1.y. Knows the concepts of social commitment and corporate social responsibility, its possibilities and limitations.
Level 2- know how	C4.HO.2.x. Is able to identify and critically evaluate the implications of the ethical and deontological principles related to the sustainability values in their professional domain and to critically evaluate the social responsibility of companies' activities.
Level 3- demonstrate and do	C4.HO.3.x. Is capable of exercising their profession, and of actively participating in responsible action in the entities in which he/she develops their profession, taking into account ethical principles related to the values of sustainability (e.g. equality, justice, precautionary principle, prevention of damage, responsibility towards present and future generations, protection and restoration of a healthy environment, social, economic and environmental human rights).

The analysis for all 28 Learning Outcomes of the simplified SCM with the SDGs Learning Objectives and SDG indicators shows that they cover all SDGs but SDG2- Reduce Poverty. The more represented SDGs in the SCM are: SDG4 - *Quality Education,* SDG9 - *Industry, Innovation and Infrastructure* and SDG 12- *Responsible Consumption and Production*, which make sense for engineering education. Table 2 shows, as an example, the relation between the Learning Outcomes for C4 and the SDG.

Table 2. Example of the relation between learning outcomes of the SCM and SDG for Competence C4.

	C4.HO.1.x.	C4.HO.1.y.	C4.HO.2.x.	C4.HO.3.x.
SDG1			X	X
SDG2				

SDG3	X		X	X
SDG4	X	X	X	X
SDG5	X	X	X	X
SDG6	X		X	X
SDG7				
SDG8				
SDG9	X		X	X
SDG10	X	X	X	X
SDG11				X
SDG12	X		X	X
SDG13			X	
SDG14				
SDG15	X			X
SDG16		X	X	X
SDG17			X	X

The simplified SCM is currently being piloted in 10 degrees at UPC-BarcelonaTech in order to effectively introduce sustainability learning in all University degrees.

3.1 SUMMARY AND ACKNOWLEDGMENTS

In this paper some results of objective 1 of the EDINSOST2-SDG project have been presented. The reduced Engineering Sustainability Competencies Map (SCM), which contains 28 learning outcomes that all engineering students should have acquired on completion of their studies, allows curriculum designers to introduce sustainability and the SDGs, and makes it easier for teachers the design of related activities. The learning outcomes of the SCM include the UNESCO learning objectives and the goals of the SDGs related to engineering. We want to thank the work of all the members of the EDINSOST2-SDG project, and in particular the components of the engineering working group. All of them have made this work possible.

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TEACHING AI COMPETENCIES IN ENGINEERING USING PROJECTS AND OPEN EDUCATIONAL RESOURCES

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ABSTRACT

A major challenge in engineering education is to empower students to use their acquired technical skills to solve real-world problems. In particular, methods of

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Artificial Intelligence (AI) need to be studied as tools in their respective application contexts. This puts pressure on university lecturers concerning the didactical design and elaboration of a course, and requires them to move towards a practice-based learning approach. Moreover, working on real-world problems leads to uncertainties for the lecturer and their students. Before and during the course, it is not always clear which methods will be used to solve the problem, respectively which competencies the participants need to acquire.

Therefore, we propose to combine two established approaches: a project-based learning approach and the use of digital, curated learning content provided by Open Education Resources (OERs). We hypothesise that a practical study project solving a real-world problem using a combination of OERs and project-based learning is beneficial to AI education. Furthermore, we show implementations of our concept in three different courses.

The first results indicate that student-centred tasks lead to high intrinsic motivation. At the same time, lecturers have to deal with a modified and extended role: They are no longer the broadcaster of knowledge but rather a guide within the learning process. Using the combination of OERs and project-based learning, the courses are attractive and exciting for students and lecturers without becoming unmanageable.

1 INTRODUCTION

1.1 Motivation

The use of Artificial Intelligence (AI) as a tool and assistance is growing and requires engineers to enhance their digital skills including data and AI competencies. Thus, higher education institutes must complement current engineering curricula with these competencies.

Current approaches to teaching AI are mostly algorithm-oriented, meaning that the learning goal of a unit is teaching a class of algorithms in one particular context, whereas earning the competence of choosing and adapting known methods to a given real-world problem is neglected most of the time. Thus, students first get to know an approach or a methodology to solve problems in a class and the transfer to real-world problems is only a minor aspect. This is not a sufficient preparation for real-life situations, where engineers are required to handle complex situations “on the fly” [1]. In our volatile world independently acquiring context-specific knowledge on demand (often called “ad-hoc” learning) becomes a key competence. This cannot be achieved through the classical “stockpiling of knowledge” but only through learning by doing [2].

With AI as a tool, it is even more important to teach it in its applied context using real-world problems and projects [2]. However, designing a practice-based university course that is interactive and stays up to date with the latest trends remains difficult. Moreover, integrating projects in courses leads to situations where it is not always clear which methods will be used to solve the problem and which competencies the participants need to acquire for them.

In the following, we discuss how a practical study project solving a real-world problem with AI tools can be implemented using a combination of project-based learning (PBL) and Open Educational Resources (OERs). We hypothesise that the use of OERs in PBL can combat uncertainties in the process of a project for students and teachers. Moreover, we argue that the use of OERs in a PBL setting changes towards an on-demand use, which in return changes the role of the lectures. To support our hypotheses, we implement the idea in three different courses and provide the first lessons learned. We discuss our initial findings on the changing roles of lecturers and their effect on students and give an outlook on the next steps.

1.2 Project-based Learning

The idea of practice-based learning is not new and was proposed in multiple forms, one of the most prominent being project-based learning (PBL). PBL means dealing with a subject matter based on a concise, self-contained, project-based task, that is solved independently. The focus is not only on finding an original solution but also on planning and conducting the solution process itself, including compiling and acquiring the relevant information and materials.

The PBL approach is suitable wherever the application of knowledge to a practical problem is involved. Thus, it is extremely helpful when dealing with the complex methods and approaches that AI poses [3]. In comparison to traditional engineering classes, where a given problem is solved with given methods, PBL requires students and lecturers to deal with uncertainties. These are similar to the uncertainties that will occur later in real life: at the beginning, it is not entirely clear whether the project will work out as expected and which approaches will be successful.

The decisive advantage of PBL as an instructive approach lies in the direct and intuitive learning experience for students. Once learners have gone through a PBL solution and implementation process, it often does not only have a positive effect on their motivation. Knowledge acquired through PBL is usually also remembered better due to the high degree of personal involvement. The learning process is more intense and practical pitfalls that are missed in purely theoretical considerations can be (fore)seen and dealt with by employing a PBL application [4].

For lecturers, the use of PBL approaches poses multiple challenges. First, methodological and didactic planning and organisation are more complex and time-consuming as a wide range of material has to be made available to address the uncertainty of the projects and the heterogeneous learning preferences. The project outcome and possible solutions are not always clear in the beginning and lecturers have to take into account heterogeneous learning preferences and states of knowledge of their students. Second, for lecturers in the field of engineering who want to incorporate AI applications into their teaching in order to convey AI skills, there is the additional challenge of integrating knowledge from other disciplines. Third, students need support for planning projects, adjusting plans when necessary and developing solutions.

Students, as well as lecturers, have to deal with an immensely increased complexity and a general openness of the process when it comes to project-based learning. Yet the chances for fostering capacity-building outweigh these challenges. In the following, we demonstrate how the integration of OERs in teaching can support project-based learning, especially with respect to interdisciplinary AI competencies.

2 APPLICATION-ORIENTED TEACHINGWITH PROJECTS AND OERS

2.1 Integrating OERs in Teaching

OERs are learning media that are free to use. Usually, the material is digital and developed by others. OERs can be both individual materials such as texts, images, or videos on a specific topic, as well as curated content that is compiled into entire courses.[2]

For lecturers, the advantage of using such material is that they can rely on quality-assured content, which allows one to integrate content from a different discipline into one's teaching without preparing educational content like textbooks or lectures for each topic. Furthermore, it is not possible to have deep expertise in all fields that are related to one's own work. OER can help solve this problem. This is especially relevant when integrating AI competencies in domain-specific course settings. Moreover, such a dynamic and open teaching setting creates a new and uncommon situation for lecturers. Their role changes from being a knowledge broker to being a learning coach. The lecturer is no longer solely responsible for explaining the content but becomes a learning companion who guides the students through their individual learning process. Consequently, studying with OERs also empowers the self-responsibility of the students.

From a didactic perspective, integrating OERs causes a new organisation of the learning process that forms a learning pyramid, illustrated in Figure 1. Lecturers, students, and the object of learning usually form the so-called didactic triangle in which the learning process is organised [5]. When digital educational material is used additionally, the triangle forms a three-sided tetrahedron as described by Prediger et al. [5]. However, we argue that the digital lecturers who are the creators of the digital educational material also influence the learning process. Thus, the learning process forms a didactic pyramid of teaching.

Lecturers in such a setting are confronted with a multitude of challenges. At the same time, integrating OERs in teaching opens up space for more self-directed learning and for learning settings that enable a highly interdisciplinary, practical acquisition of knowledge and skills. In the following, we show how the integration of OERs differs in a project-based learning scenario.

2.2 Using OERs in Project-based Learning

There are multiple ways of integrating OERs. In a classical way, they can be used for self-study before a class. Thus, students consume and study selected material as a prerequisite before their class, and the lecture is used to deepen and apply the studied material (so-called "Flipped Classroom") [6]. In this context, a lecturer needs

[2] An example for curated AI learning opportunities is the AI campus, available at *ai-campus.org*.

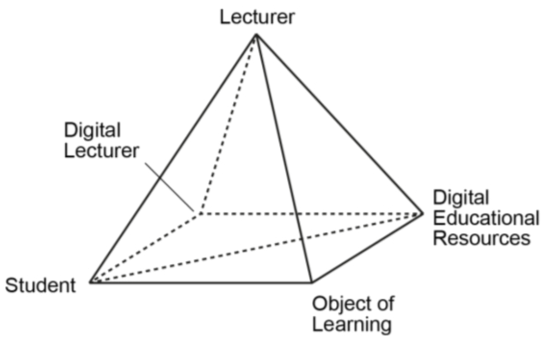

Fig. 1. Didactic pyramid of teaching that extends the didactic triangle of lecturer, student, and object of learning with an additional digital lecturer and digital learning material.

to communicate the learning goals and guiding questions clearly or curate the material for the students (see for example Fig 2-C, prep. phase).

In the project-based learning setting, the use of OERs is *on demand* throughout the project, as illustrated also in the implementations in Fig. 2. Here, students have access to a (curated) library of material and study selected material based on their individual needs. This fosters self-directed learning and allows for a more individual, practice-based learning experience in the different phases of a project. Furthermore, relying on OERs as knowledge broadcasters allows to provide a broader range of specific project topics that would be not possible to cover as an individual lecturer. At the same time, students are still accompanied by their teacher, who helps them understand the external content and answers open questions.

The use of OERs in PBL is especially useful in interdisciplinary settings like AI in engineering, where the classical domain know-how is combined with new data-driven methodologies. Furthermore, it can address heterogeneous groups of students, different levels of experience and even interdisciplinary project settings. To exemplify the use of OERs in a PBL setting, the next section discusses the implementation of *on demand* OERs in three different courses and summarises our lessons learned.

3 IMPLEMENTATION

3.1 Research Project Seminar

An implementation of the concept of a research project seminar was done in a project seminar (5 ECTS-CP) focusing on developing an algorithm that can track an arbitrary moving object over time. In the project, we incorporated collaboration and competition using teams consisting of 24 students from computer science, medical engineering, and AI. As the audience was very heterogeneous, OERs were a central theme to supplement the individual’s knowledge at the beginning of the seminar (see Fig. 2-A). In the first phase, the lecturer selected a range of OERs as a prerequisite of the course.

Throughout the course, every student had the aim to implement a tracking algorithm. In this phase, students had the opportunity to access further OERs on relevant topics around tracking algorithms. However, this was not mandatory and based on their needs. The lecturer supported finding the right material for the respective student groups by providing guidance and pointing to general and more specific OERs.

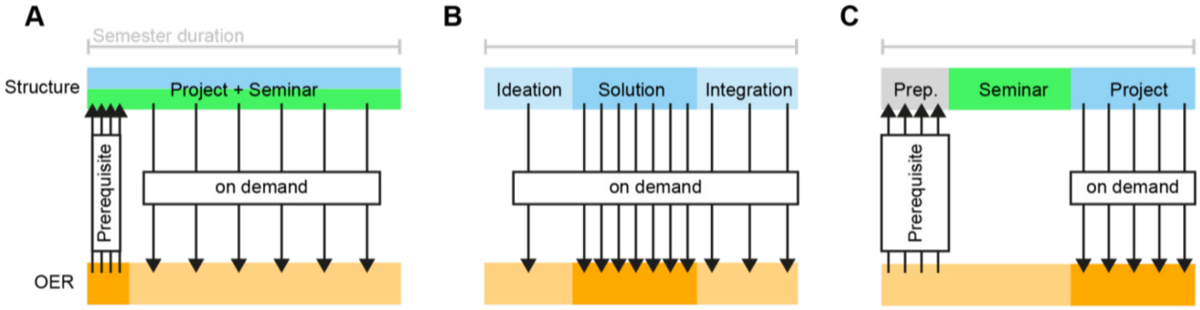

Fig. 2. Overview on discussed implementations of teaching AI competencies with OERs and projects: A) Implementation as a research project seminar, B) Implementation as product engineering project, C) Implementation as a block project seminar. Arrows indicate if students were provided with OERs as a prerequisite or used them on demand.

To succeed in the seminar, the student groups needed to collaborate within their teams to find a common team solution. At the end, each student presented a paper or created their own OER related to the project topic. The latter should foster the creation of new, specialised high-quality OERs which could be potentially used in future semesters. However, the quality of the student-created OER varies.

3.2 Product Engineering Project

The implementation was done in product engineering projects (5 ECTS-CP) for students from mechanical engineering in their 4th or 6th semester without previous knowledge of AI. Here, the concept of fully on-demand OERs was tested (refer to Fig. 2-B). The projects aimed to teach students an understanding of how smart, data-driven products work and how to include AI components in engineering products. Exemplary project topics varied from developing a machine that sorts LEGO bricks, developing an autonomous car control in a car simulator, or implementing games with AI components in online environments.

Since the overall goal in the course was teaching product development, the project started with a definition and ideation phase, where the requirements to the solution and the fulfilment criteria were specified. Next, the development followed the traditional way of product engineering by defining functions and their relations as a basis for partial solutions that shall be investigated. When using this development approach, it is not clear beforehand what part of the solution uses an AI component and how the component is integrated into the overall system. Therefore, the students accessed required material and knowledge needed to develop their solution on demand as OERs. Thus, the knowledge transfer was not provided through classical lectures with clear, defined topics but through flexible on-demand OERs.

3.3 Interdisciplinary Project Block Seminar

Another form of integration was done in the interdisciplinary seminar on the topic of AI in Neuroscience (3 ECTS-CP). The aim was to equip participants with the knowledge and ML tools to analyse electroencephalography (EEG) data. The small, heterogeneous and interdisciplinary group consisted of eleven students with backgrounds in computer science, psychology, and neuroscience as well as different semesters.

Similar to the block research project described in Fig. 2-C, the seminar had three phases: self-preparation, seminar days, and a project phase. It combined the idea of an inverse classroom concept with PBL. OERs were used in two parts. First, in a curated form as a prerequisite for the preparation of the seminar and second, on-demand as support during the implementation of the project phase. By integrating OERs in the seminar, the participants were addressed based on their background and needs. Furthermore, the seminar days could be used for group work rather than knowledge transition, focussing more on applying the knowledge.

3.4 Lessons Learned

From implementing the courses and evaluating them in open discussions with the participants, we can already derive the following lessons learned:

- Students perceived the integration of digital material as helpful, especially highlighting the flexibility of short videos and other forms of material, such as podcasts.
- Students experienced self-directed learning and autonomy as satisfying and self-affirming.
- Investing time at the beginning of the course in discussions and definitions of goals and tasks pays off in the remaining time of the course. Moreover, it also allows students to embrace the openness of the process.
- Using OERs allows lecturers to integrate AI content into the particular domain without the need of preparing their own learning content for all possible topics.
- Working on practical problems helps the students to gain a hands-on understanding of the underlying AI concepts.
- Projects help to teach AI in its relevant, domain-specific problem context and support students to understand the benefits and limitations of the technology.
- The availability of high-quality OERs for the specific project context and experience level is a limiting factor (especially in the fast-moving field of AI).

4 DISCUSSION

4.1 Changing Role of Lecturers

The integration of OERs into a course or a project causes a new situation concerning the role of the lecturers. They are no longer the only lecturer in the course, because of the digital learning content that is created and partly conducted by another digital lecturer. First, this means giving up some of the control a lecturer usually has during a course. Second, it also requires the lecturers to re-interpret their own role when it comes to dealing with external content that is neither from their own discipline nor designed in their own teaching style. Experiencing different teaching styles, different ways to present knowledge, and different levels of difficulty can be helpful for students. At the same time, it can be a challenging, new situation for the lecturers who need to become mentors, learning companions and curators rather than being the single source of knowledge. It is, therefore, important to reflect and communicate the role in the learning process.

The use of OERs and projects also bring different advantages for the lecturers. First, there is the obvious benefit of relying on curated material, which is helpful in a field that is not part of one’s own expertise. The knowledge transfer of certain topics is partly outsourced to domain experts. Second, the use of external material can save time in the course preparation and in more resource-intensive settings like project-based learning. It might even be the only way to cover the possible wealth of learning material at all. Done right, the lecturer has more time for discussing and conducting, which becomes the new key function of the lecturer.

4.2 Effect on Students

Challenges are not only imposed on the lecturer when using project-oriented approaches in class. Students also have to adapt to the new learning situation and have to leave a consumer’s role in favour of a more active self-concept as learners. Suddenly being responsible for one's own learning process, for the organisation of real-world tasks, communication, and structuring problems may be challenging, especially for students in earlier semesters.

The lecturer has to bear this in mind when planning a course. It includes providing students with material or guiding questions to enable them to master processes and tasks in a self-directed way. Some students may be able to succeed here with nearly no help. Others may need more attention or help at a certain point. Thus, the lecturer has to focus more on individual learning and adaptive learning designs, when choosing material and creating tasks for the students. Tasks have to be formulated very clearly and precisely to prevent misconceptions. Clarifying the goals and possible questions right in the beginning is very important and may well take more time than in other settings. Yet afterwards, students should be able to act more or less independently without constant input from their lecturer.

5 CONCLUSION AND OUTLOOK

In this paper, we proposed to combine OERs and PBL to teach applied competencies in an engineering context focusing on the example of AI competencies in engineering. We combined the open format of a project with a curated form of on-demand open education content. Furthermore, we presented three different ways of implementing the combination in courses across levels and disciplines focusing on integrating AI into different domains. The first results and lessons learned indicate that using OERs and PBL can be a useful way to extend existing teaching formats towards more practical and applied learning with a manageable effort. This also suggests an additional benefit of sharing high-quality open educational content.

Our findings are limited to the experience from the three implementations. Thus, further work is needed to generalise the concepts and provide more evidence on the effects on students and lecturers.

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AN INTERDISCIPLINARY COMPETENCE PROFILE FOR AI IN ENGINEERING

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ABSTRACT

The use of Artificial Intelligence (AI) in engineering is on the rise and comes with the promise of cost reductions and efficiency gains. However, classical engineers often lack the necessary skills to implement data-driven solutions. At the same time, computer scientists lack the required understanding of engineering systems. Thus, we need to extend the current set of competencies of engineers across the boundaries of disciplines to include competencies of Artificial Intelligence as well as skills necessary for interdisciplinary work. In this paper, we propose a competence profile of a so-called AI Engineer that combines the expertise of AI systems in the context of engineering. Based on perspectives from literature and interviews with experts from industry and research, we highlight the most important set of competencies across the professional, methodological, social, and self-competencies. The contributions of our paper can act as a reference point for developing and advancing future engineering curricula. Furthermore, it serves as a guide for professional self-development.

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1 INTRODUCTION

1.1 Motivation

Artificial Intelligence (AI) is a powerful tool and is seen as enabling technology in many use cases. Hence, there is a growing interest in applying AI in engineering applications such as increasing energy efficiency, optimising processes, quality management, and predictive maintenance [1]. The rise of AI and digital tools also changes the competence profiles of the next generation of engineers. The value of digital innovation and data-driven processes lies in the intersection of disciplines. Thus, more than ever, strong interdisciplinary learning is required, integrating competencies across the boundaries of disciplines [2,3].

Recent studies have investigated changing competence requirements in the engineering discipline [2,3,4,5], competence requirements for developing and working with AI [6,7,8,9], and general future skills [10]. However, there is currently no work on which competencies are required across the boundaries of disciplines to work and develop solutions at the intersection of AI and engineering. Furthermore, established engineering competence profiles, such as the CDIO syllabus [11], ABET [12], and EUR-ACE [13], do not yet address the integration of AI competencies in engineering curricula. Thus, this paper aims to answer the question *which professional, methodical, social and self-competencies are needed in these future roles of AI in engineering.* We hypothesise that the next generation of engineers does not solely focus on one domain but needs an interdisciplinary skill set that includes digital and AI competencies. We refer to this generation of future engineers as *AI Engineers*.

We address the question by developing a competence profile of an AI Engineer that is based on perspectives from literature as well as interviews with experts from industry and research. Our work aims to be a reference point for further adoption of the engineering curricula in the future and a guiding point for engineers that want to upskill themselves.

The paper is structured as follows: The next subsection clarifies the used terminology and background. Section 2 describes the methodological approach. Section 3 gives an overview of the competence profile and the supporting literature and interviews. Last, we discuss the findings and limitations and conclude with an outlook.

1.2 Terminology and Background

In this paper, we use the term *competencies* as the ability to act in and cope with context-specific demands [14]. In the context of education, we emphasise the development of competencies to act within certain professional environments. Following [14], we can roughly distinguish four categories of competencies:

- *Professional competencies* describe the specific knowledge, skills and experience to carry out the professional function.
- *Methodological competencies* represent cognitive skills that can be applied across situations and are required for mastering complex tasks and problems.
- *Social competencies* characterise knowledge, skills and abilities to accomplish goals in social interactions.

- *Self-competencies* describe skills and behaviours that relate to the self-awareness and behaviour of a person and influence their working practice.

In the context of AI, different roles can be defined, for example, AI developer, AI user and AI observer [7]. Accordingly, when selecting relevant competencies, it is also necessary to define the applicable role. In the following, the focus lies in finding the relevant competencies for the developer role. Another important factor to keep in mind is that roles depend on multiple factors, for example, the industry and the size of a company lead to a focus and also a more broad or specialised profile.

2 METHODOLOGY

The research question was answered using a qualitative content analysis based on semi-structured expert interviews and an explorative literature review. To understand the developing occupational field of AI engineers, the aim was to combine scientific perspectives from literature with practical insights from the industry. In this context, recent literature studies and the reported experience of associations provide an overview of required competencies, whereas the experience of the experts supports and supplements these with practical insights.

For the expert interviews, we selected industry partners who work on the intersection of AI and engineering and come from different industries. These include manufacturers of logistic systems, engineering service providers in mechanical engineering and IT, pharma companies, automotive manufacturers, applied science, and IT consultancies. Next to the different industries, we considered that the interviewees come from small, medium and large companies and performed functions in a variety of areas (data science, strategic business development, IT strategy, software development, collaborative factory, business process management, consulting). More than two-thirds of the interviewees were in a leadership position. A total of eleven guided online interviews were conducted by one of the authors. The interview questions focused on the general understanding of AI, current and future use cases in the respective companies, challenges in the use of AI, and the question of professional and interdisciplinary competencies required in the field of AI. The interviews were recorded and transcribed for further analysis.

The literature was selected using various search terms such as "competence", "competency", "skill", "engineering", "artificial intelligence" and "machine learning". Scientific studies, as well as reports of associations, were considered and results from German-speaking as well as English-speaking countries were used. In total, nine different sources [2,3,4,5,6,7,8,9,10] were examined, which are also mostly based on literature surveys and qualitative interviews themselves.

Both the expert interviews and the sources from the literature were evaluated using qualitative content analysis. The competencies were filtered out and assigned to the competency areas of professional competencies, methodological competencies, social competencies and self-competencies. Last, subcategories were formed and the most mentioned competencies were selected and described as part of the competence profile.

3 COMPETENCE PROFILE OF AN AI ENGINEER

In the following section, we give an overview of the competencies and the supporting literature and interview extracts. Fig. 1 summarises the competencies across the different categories and gives a more detailed description of the individual competencies.

Fig. 1. List of competencies with their description in the four categories of professional, methodological, social and self-competencies.

Competency	Description
Professional Competencies	
Data and AI Knowledge	Handling and understanding of the fundamentals of data and AI technologies, as well as the ability to employ tools and models to analyse them.
IT Competencies	Designing, building and programming applications (with intelligent functionalities) and the ability to deal with respective frameworks and platforms.
Interdisciplinary Domain Know-How	Understanding of the technical foundations, physical components, and technical and business processes in the application domain.
Methodological Competencies	
Process- and System Thinking	Structuring, analysing, describing, modelling and optimising (AI) processes and systems.
(AI) Problem Solving	Recognizing and dealing with complex problems and situations and having solution strategies for them (that can involve AI).
AI Reflection	Reflecting the impact of AI technologies, for example with respect to ethics, legal, safety and social aspects and understanding one's own role in it.
Social Competencies	
Interdisciplinary Communication and Cooperation	Communicating and cooperating in an interdisciplinary team setting, or with people of different cultures and experience levels. Ability to adapt the communication and working style to the respective environment and team.
Change Management	Managing and shaping change processes, supported by the ability to communicate value, listen, inspire, and resolve fears.
Leadership and Decision Making	Ability to organise, coordinate and manage teams, and the ability to make decisions within the boundaries of the current responsibilities.
Self-Competencies	
Learning and Curiosity	Ability to individually acquire contextual knowledge from different sources and the interest, curiosity and openness to learn new topics.
Creativity	Developing novel, innovative solutions and questioning the "status quo" of processes and ideas.

3.1 Professional Competencies

Data and AI Knowledge - As a central point, various authors highlight the handling and analysis of data, such as Data Analytics and Data Science [2,3,4,6,7,8,10]. Furthermore, some authors explicitly state the understanding of AI technologies, in particular Machine Learning (ML) [2,6,7,8]. In this context, it is important to understand the mathematical foundations, such as statistical knowledge, as well as the benefits and limitations of models [2,8]. Furthermore, understanding and using the currently available tools and libraries is mentioned [8].

Six of eleven interviewees mention the handling and understanding of data. Particularly, they refer to pre-processing, structuring and uniting data from different systems, as well as an assessment of data quality. On the topic of ML and AI, the interviewees point out the ability to build and deploy models. This includes understanding different types of models with their benefits and limitations. Moreover, few interviewees state the value of having a “building kit” of tools for various use cases and data types. Furthermore, the interviewees value an understanding of the mathematical foundations of ML and the model parameters.

IT Competencies - In the context of Information Technology (IT) competencies, an understanding of digital tools and technologies as well as computer science basics is found important [2,3,4,5,7]. More specifically, multiple papers point at the fluency of programming languages, design patterns, platforms, frameworks and libraries, next to an understanding of software engineering [2,5,6,8,10].

The IT competencies are supported through the expert interviews. Around two-thirds of the interviewees put forward the importance of an understanding of software engineering, the application development of intelligent functionalities, and how AI as a building block engages with other code elements. Furthermore, some interviewees state user-centric (application) development and agile software development.

Interdisciplinary Domain Know-How - One common theme in the literature is the integration of interdisciplinary skills and knowledge [3,4,5,8]. Accordingly, multiple authors put the focus on having a foundation in one core engineering discipline, especially when AI is integrated with a physical interface or hardware such as a robot [2,5,6,7].

The interviews are aligned with the importance of understanding the domain, especially the underlying business and technical processes, and the engineering basics. One interviewer refers to it as the most important skill, as the value of AI comes only from the combination of Data Science and domain know-how.

3.2 Methodological Competencies

Process- and System Thinking - Another group of competencies highlighted by literature are process- and system competencies, especially for processes controlled or enhanced by AI [5,6]. More generally, two papers mention system thinking [2,3] and Huang et al. [9] add logical and abstract thinking as high-level competencies.

The interviews emphasise the importance of understanding and contextualising business and technical processes. An example is the ability to analyse, structure and break down processes and systems. Moreover, around half of the interviewees mention system and process thinking. This goes along the lines of understanding the boundary conditions in the domain, the drivers of the process and what data could be used to optimise it.

(AI) Problem Solving - Multiple studies mention problem solving competencies [3,5,6,8,10]. More generally in this category, Huang et al. [9] endorse observation skills and analysis skills, whereas Gottburgsen et al. [3] highlight the ability to deal with complexity.

The answers from the interview can be clustered around problem understanding and problem-solving with AI. Next to the importance of understanding and working from a real defined problem within a business context, it is important to have an idea of the boundary conditions, tools, and data available to decide if an added value can be derived from using AI.

AI Reflection - From the engineering perspective, the literature highlights the importance of assessing technology and its social, legal, and ethical impact on the development [3,6,7], capacity for judgement [10] as well as responsible action and the ability to reflect the effect of one's own actions [3,6,7]. Accordingly, the ability to judge, reason, analyse and draw conclusions is mentioned [9]. AI reflection is supported through knowledge of (digital) ethics and an understanding of the legal basis and norms, such as data protection [3,7,10].

One key cluster in the interviews is the understanding of the impact of using AI in the application context and the assessment of the usefulness of AI in this context. Moreover, two interviewees explicitly state the ability to develop explainable AI models to allow the translation of the AI models into understandable user language and gain trust in the model’s decisions.

3.3 Social Competencies

Interdisciplinary Communication and Cooperation - The literature mentions the ability to communicate, cooperate and work in teams with people from different disciplines, cultures and levels of experience [2,3,5,6,7,8,10]. Next to communication and cooperation between different stakeholders, two papers also highlight the importance of explaining AI behaviour to various user groups [5,7]. Moreover, competencies for dialogue, conflict management, and digital collaboration fall under this category [10]. The foundation of interdisciplinary communication and cooperation can be described in the ability to adapt communication and working styles [2,6,10].

These competencies are also supported by more than two-thirds of the interviews. Here, the interviewees emphasise adaptive communication and cooperation with different target groups, as working on AI systems is usually at the intersection of multiple divisions. Moreover, the communication aspect is seen as very important to gain acceptance with the final user and to understand the requirements of different stakeholders.

Change Management - Kirchherr et al. [10] state the development of strategies to execute transformation, especially with respect to group dynamics, group cultures, networks and systems. Similarly, André & Bauer [6] mention the communication of potentials and limits of AI, and supporting the change process by removing fears and coordinating the expectations of various stakeholders.

More than half of the interviews support this competency and see it as one key competency. It is mentioned in various forms such as to inspire people, present added value, formulate success stories, address concerns, listen to people, manage expectations of different stakeholders, resolve resistance, convince and sell. The underlying message is that integrating AI in systems and processes requires a transformation of the existing processes (and sometimes even culture) which makes it necessary to also manage the change process next to the technological process.

Leadership and Decision Making - The literature mentions the ability to organise, coordinate and manage teams, and the ability to make decisions within the boundaries of the current responsibilities [5,6,8].

This group of competencies was not directly stated in the interviews.

3.4 Self-Competencies

Learning and Curiosity - The literature highlights the ability to learn and independently acquire contextual knowledge [2,3,5,9]. Furthermore, André & Bauer [6] emphasise the curiosity and willingness to learn how to work with ML and AI systems. In this context, two studies stress the need for openness to new experiences and technologies in the changing world [2,7]. Moreover, Kirchherr et al. [10] encourage digital learning such as processing digital information from different sources and using learning management systems.

Three interviewees stress the importance of self-learning and lifelong learning, especially in the context of the fast-moving field of AI. From their perspective, it is a key competency to know where and with what methods one can find help and stay on top of current technological developments. Moreover, the fascination and curiosity to discover new insights were brought up.

Creativity and Innovation - Multiple studies express the importance of creativity and innovation competencies, such as developing novel ideas and improvements through questioning the “status quo” and critical thinking [2,5,9,10]. From a company perspective, this also requires a failure culture [7].

This is also supported in a few interviews, mentioning the eagerness to systematically experiment, the resilience to failure, patience and drive in finding solutions to complex problems as well as thinking out of the box. Moreover, questioning existing processes is stated. One interviewee explicitly states the difficulty for engineers to think out of existing control loops.

4 DISCUSSION

The presented competence profile confirms the initial hypothesis that an interdisciplinary set of competencies is needed to integrate AI systems in engineering and highlights the most relevant competencies for the role of an *AI Engineer*. First, the professional competencies show that to develop AI systems for the engineering domain, a combination of Data and AI knowledge, IT competencies, and interdisciplinary domain know-how is needed. Second, the methodological competencies indicate the importance of process and system thinking, problem solving as well as the ability to reflect on the implications of using AI. In the category of social competencies, interdisciplinary communication and cooperation gain more importance with more cross-disciplinary working teams. Furthermore, managing and leading people through accelerated change and transformations is essential. Last, self-competencies in themselves gain importance through the accelerated change among industries, above all the ability to learn and independently acquire knowledge. Some of the mentioned competencies are also of increasing importance in other subject areas and are already included in the scope of previous education of engineers or computer scientists. However, they need to be brought together into one novel profile of an *AI Engineer* that combines the expertise of AI systems in the context of engineering.

The trend towards interdisciplinary profiles and competencies also needs to be reflected in engineering education. This can be, for example, achieved through interdisciplinary and cross-disciplinary projects or the integration of topics from different industries in the engineering curricula. Furthermore, the importance of methodological, social and self-competencies needs to be further strengthened and incorporated into the technical subjects.

The significance of our findings is limited by two factors. First, *AI Engineer* is not yet an established role and can be found in different forms across company sizes and in literature. Depending on the envisioned role, different competencies might get assigned different importance. We try to overcome the limitation by selecting interview partners and literature from different perspectives, for example, literature on competencies for engineering in Industry 4.0 and AI literacy competencies. Second, our interview sample is relatively small and currently represents only German companies. Thus, there is a need for more investigation to what extent the proposed profile can be generalised.

5 CONCLUSION AND OUTLOOK

In this paper, we proposed a new interdisciplinary competence profile for AI in engineering, based on findings from the literature and interviews with industry experts. The competencies support the hypothesis that AI in engineering needs interdisciplinary access. Next to solid professional competencies in AI and the domain, our findings show a high relevance for interdisciplinary communication skills and strong methodological competencies, such as system- and process thinking.

Based on the initial competencies, further work involves a definition of required levels for different job profiles. Moreover, the competence profile can serve as a reference for competence-oriented study development and in designing a curriculum for people learning these competencies from scratch or people who want to upskill themselves. This can also include more research around the question of well-suited competence-oriented teaching methods in the engineering and AI field.

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Introduction of process in embedded programming supporting students’ self-efficacy - case study

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ABSTRACT

This work is directed towards the improvement of programming skills for students on the 2nd semester of Electrical Engineering (EE) BEng signed up for the “Digital Electronics and Programming” (DEP) course. The goal is to support students who tend to drop out in the first half of the semester or give up and not show up at oral exams. In our research hypothesis we state: Decreasing and eliminating negative emotional experiences will increase student’s self-efficacy thereby lowering dropout. We experiment with a programming process guide in text and video to gain students' capability in solving programming problems and increase metacognitive awareness. Additionally, we measure students' emotional experience of programming by using a special self-assessment vignette inquiry. For comparison purposes we introduced the same measurement methodology in 2021 on the courses where there is no focus on the process guideline. The results show a positive effect on lowering the negative emotional impact when students use a programming process guide. The article describes the theoretical background based on literature studies for both the process and the students’ self-assessment, and discusses results achieved in relation to the findings in the literature. The preliminary results are described in [8] and in paper here we present recent outcomes for the autumn 2021 and spring 2022 semester over 9 weeks.

1. INTRODUCTION

1.1. Observation and theorical foundation

Several papers [1][2][3], show that strong students' self-efficacy has an influence on their ability to learn programming and tackle many kinds of problems which arise (compiler message, logical faults, etc.). Students with a lower self-efficacy have a higher negative self-assessment. During the last 7 years when the DEP course has been offered, we have observed that 10 - 20% of the students give up or do not

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show up at the exam. The literature describes several criteria by which students evaluate their programming abilities. For example, prior experiences, speed of solving assignments, grades, social comparisons, and whether their program works, expectations in fluency [2] [3]. Furthermore, students’ performance compared to other students, where students construct their perceptions of ability compared with other students, for example in group/teamwork. These factors may have an impact on how strong the negative or positive self-assessment is and thereby influent students’ self-efficacy. Self-efficacy is part of the Bandura’s [4] social cognitive theory and described as: “to believe in one’s capabilities to organise and execute courses in action required to produce given attainments”. Gorson. J et.al.[1] studied why students think they are bad at programming by using self-assessment by using 13 moments of programming. The study was carried out in computer science courses for novice programmers at. 3 universities. They concluded: “We also found that the frequency with which students negatively self-assessment correlates with their overall self-efficacy in their programming courses.” Studies about self-assessment and self-awareness in computer science courses inspired us to do the project within Scholarship of Teaching and Learning (SoTL).In SoTL work we try to find answer to the research question: “Can metacognitive processes help students to gain more self-confidence and thus continue to be active during the course?” and one of the hypotheses leads to the statement: “Lowering negative emotional experiences increase self-efficacy.” For helping students in programming assignments, problem solving and for seeing if it could lower the students drop-out during the semester we introduce a process in programming hands-on assignments to show and guide how to solve programming problems inspired by Loksa [7]. The process is based upon literature study [5],[6] discussing learning processes when dealing with programming problems, self-efficacy, and self-confidence when programming. Next, we measure students' self-emotional experiences using a self-assessment tool inspired by Gorson ‘s et.al [1] work for measuring the emotional impact when programming. We customized this framework for measuring quantitatively of what degree students emotional impact changes due to receiving help from our guideline to be more self-confident and get less negative influence. At the same time be motivated to follow the course and go to the exam. The self-assessment is done by using 13 moments of programming which a professional would come through. Therefore, it is relevant to use at our bachelor (Diploma-engineering 3½ year program) studies in Electrical Engineering and IT (Information Technology) and Electronic Engineering studies. Gorson et. al [4] also posed 4 general questions in a survey for qualitatively testing self-efficacy. Due to limited time and constraints, we do not focus on this in our studies. Neither we do not measure self-efficacy in programming as Steinhost et al. [5] In contradiction to Gorson, we use the vignette questionnaire survey 3 times during the semester for testing if the introduction of a process in programming helps students to have fewer negative feelings when dealing with programming and thereby, we assume that the less negative impact has a positive impact on the self-efficacy. It is not in the scope to measure the self-efficacy by tools as suggested and used in [5]. We did start the experiment in the autumn 2021. In O. Schultz et. al [8] we show results by using process guidelines instead of using the Moments of Programming Vignette survey.

Conclusion was that using the process guideline lowers the negative self-assessment.

1.2 Programming processes

Learning how to program involves more than just syntax, control, and data structures. It also involves mental scaffolding around the learner where the learner can place knowledge and become metacognitive aware [7]. That means the student understands where one is in the problem-solving process. Several studies describe and discuss problem solving stages when dealing with programming. Loksa. D et al and Prather et. al [6][7] investigated metacognitive awareness for novice programmers and they identified 6 specific stages in learning to solve programming problems. The stages are: (1) reinterpret the prompt, (2) search for analogous problems, (3) search for a solution, (4) evaluate a potential solution, (5) implement a solution, (6) evaluate the implemented solution. That study and other studies [3][6] lead to our process being introduced for 2nd semester students in the first week and used repeatedly when solving the assignments. The programming guideline process introduced to students on 2nd semester EE from first class-lecture is adjusted according to the DEP course content and hands-on exercises to be carried out by students. The process used is presented below:

1. Read the whole assignment. Does the assignment make sense?

2. What could a solution to the task /subtasks look like? Outline the solution with pseudocode and / or a flow-chart.

3. Imagine a simulated execution of your hypothetical program / parts of the program. Use your pseudocode and flowchart. Simulate running the hypothesis program. Does the expected happen?

4. What can the C-code for the sub-task / task solution look like?

5. Open Microchip studio, start a new project, select GCC C executable, give the project a suitable name and place the project somewhere where you can find it again. Press ok. Choose to use an ATmega2560. Program the solution you have found for each sub-task found under 2.

6. Does the program perform the hypothetical run-through performed in 3?

The subsequent process steps help students to focus on problem refinement and narrow to the solution which unloads unnecessary confusion and thoughts about overall assignment.

1.3 Didactics used in the Digital Electronics and Programming (DEP) course

The experiments are done in DEP course. The content consists of a digital electronics programme supported with practical programming tasks with focus on microcontroller interfacing peripheral devices. Observations and surveys from students are collected and shown in section 3. The students must understand how to read a complex datasheet and use the information to set up microcontroller-registers by C-programming language for the distinct kinds of interfaces. Compared to standard C-programming courses it requires also comprehensive understanding of electronic device manufacturer documentation and the way of essential information transformation from datasheet to a program. The teaching method used in this course is blended learning. Before each lecture, the students are asked to watch a video about the topic for the coming class and take a quiz about the content in the video and the related chapter in the course-book. Students work on 5 different assignments for 13 weeks, and 4 of the assignments are for hand-in in pair groups. For each assignment they hand-in a report documenting various aspects of the programming work. The requirements for taking the exam are all submitted reports approved as well as the answered quizzes taken during classes. The exam is oral where students randomly choose one question out of six from the digital electronic field and they present orally the answers to the question. Furthermore, the examiner asks questions related to C-programming part in the last assignment

2. Data collection

2.1 Characteristics of the classes in subsequent years from 2017 to 2021

Gradings of the classes since 2017 up to 2022 have been analysed for finding the exact numbers of students dropping out at the examination. The data is listed in the Table 1 and described below

year	stud. spring	not met	median	average	std. Div.	stud. autumn.	not met	median	average	std. div.
2017	64	6	7	7.25	3.96	29	6	7	6.86	3.95
2018	64	7	7	7.50	3.46	25	3	10	7.86	3.82
2019	49	15	10	8.23	2.92	33	14	10	8.78	3.55
2020	52	10	7	7.40	3.00	25	4	7	7.80	3.29
2021	59	10	7	7.38	3.64	34	9	10	8.84	2.93

Table 1. Students' enrolment statistics in particular year.

The course is taught twice a year, Spring and Autumn. The column “stud. spring" and “stud. autumn" shows the number of students enrolled to the exam. Next is shown number of students who do not show up. The grading scale is pass: 02, 4,7,10,12 (excellent) and not pass: -03 and 00. The median grade-values are shown together with the average grade and the standard deviation. Table 1. shows the grades are higher in the smaller classes but the standard deviation is greater. The number of students who do not show up is little greater in the autumn. The students in the autumn semester are more diverse in background as some have been working fulltime before studying. That could explain the larger drop out. Overall, if the process introduction can bring some of these students to the exam, then it could mean less students drop the exam, due to stronger self-confidence. Process introduction in autumn does not show any changes as 26% did not enrol to the exam. Even in 2020 15% did not enrol to the exam.

2.2 Measuring emotional impact

Purpose in this work is to measure if the process guideline helps students lowering the negative self-assessment and thereby continuing the course and participate in the examination.

The 13 moments of programming with the vignettes in [1] is translated into Danish. We have made a pre-test on students before using the 13 moments of programming vignettes. Based upon that we adjusted the vignette belonging to each moment of programming, we substituted the names with 1st and 2nd person singular subject pronouns. Due to the time, we had for the experiment we use Google form to collect results and thereby the scale from 1 to 6. Where 1 means less negative impact and 6 is most negative impact. In the Gorson study they used a scale of strongly agree for the most negative impact and most positive impact as total disagree. We do not directly use the positive impact. We assume less negative (1) is reflected as positive and gains more self-efficacy. The survey is carried out in the 1st lesson and 7th in autumn and 8th lesson in spring and the 3rd one is done in the last week 13th (last lecture). The full text for the 13 moments of programming with vignette statements is presented in [9].

3. Results

3.1 Answers to the self-assessments

The population in the autumn was 27 students in the 1st survey and second survey 22 students. In the spring 46 students participated in the 1st survey and the 2nd survey 33 students answered. The 1st survey is done during the lesson 10 minutes after start. The survey is performed without influence from the teachers. The 2nd survey was carried out in the middle of the semester during the lesson after the first break. The participants are also asked about their programming experiences and what programming language they know. They have an opportunity as well to comment upon the vignette survey. These extra answers show the appr. 50% are novices and 50% had been programming before enrolling on the education from 1 to 8 years more and less. The moments of programming shown below are indicated by letters from A to M:

A. A Simple Error.
B. Start over.
C. Do not understand the error message.
D. Stop programming to plan.
E. Get help from others.
F. Spending time looking up syntax.
G. Spending time planning in the beginning.
H. Spends a lot of time solving a problem.
I. Do not know how to get started.
J. Spends a long time finding a simple mistake.
K. Struggling to find the error.
L. Unable to complete within expected time.
M. Do not understand the problem of the task.

In most of the moments except B, I and M, the self-assessment is measured on the general programming work, where the compiler and IDE is used. And the process guideline does not address that. Whereas during the semester students should be more used to the IDE and the compiler, therefore lowering the negative-self-assessment. For each moment from A to M there is a vignette. An example of vignette related to M is: “You solve your programming task. You do not understand what the task asks you to do. You feel sad and frustrated because you cannot even understand the question. How much does it affect you?". The vignette for each moment of programming can be seen in [9]. In this paper we present the self-assessment data of moments of programming shown in table 2 where we found the greatest changes and scores in the autumn 2021and compared with the data from spring 2022. In Table 2 data is compared for self-assessment on five moments of programming, and the data is compared to data in Goron’s [1] study ([10] show results for all 13 moments of programming). Data shown in Table 2 is created by choosing to use scores of 4 and up to 6 interpreted as negative which may have the most impact on the self-efficacy. We present only moments with highest scores. In general, the Table 2 data have the same orders of magnitude as Gorson’s study [1]. The moment: C.” Do not understand the error message” are also having a negative emotional effect together with moment I. “Do not know how to get started,” moment L. “Not being able to finish in time” and moment M. “Do not understand the problem of the task.” The moment C has decreased by 10% lower for the spring class which may be because students get used to the IDE and the compiler messages. But it is not happening in the Autumn semester. For the moment L “Unable to finish in time.” the score is lowered in Autumn but increased in spring semester, which may be in a relation to workload from the other courses. The process introduced should lower the negative self-assessment for moment I where the figures show for the autumn class, but not for the Spring class. Also, for moment M self-assessment score should be lowered due to the process introduction as seen decreased by 6% for Spring and 36% for the Autumn The moment K Struggling finding the error assessed less negative score as expected during the semester, as students get used to the compiler messages

Moments of programming	Week 1 F21	Week 7 F21	Week 1 S22	Week 8 s22	Gorson [1]
C. Do not understand error message:	44%	55%	72%	61%	62%
I. Do not know how to get started:	70%	59%	67%	66%	84%
K. Struggling to find the error:	56%	14%	35%	30%	59%
L. Unable to complete within expected time:	48%	32%	46%	57%	50%
M. Do not understand the problem of the task:	77%	41%	72%	66%	79%

Table 2. Negative self-assessment in % of total participant.

The data has also been analysed regarding the students’ background in programming before the study start. The results are shown in Table 3 and 4. The data is split into students who have no programming experiences before the study start and students who have experience in programming before study start. Data shows here that the novices have a higher median value, and the 75% quartile is higher compared to students who had been doing programming before the study. It shows over time when you get more experienced you also act more professionally, and the negative self-assessment is lower. Regarding moments I to M the novices also self-assess more negatively than the experienced students. And novice students in spring does self-assess more negatively for moments I and M, compared to Autumn semester students. Moment M "Do not understand the problem of the task may also address capability of student's understanding of the assignment text. That shows teachers need to be very aware of formulation of assignment

Experiences - not novice				no experiences - novice		
vignette	25%	50%	75%	25%	50%	75%
C	2.00	3.0	5.00	4	5	5
I	2.75	4.5	6.00	5	6	6
L	1.00	3.0	5.00	3	4	6
M	2.00	4.0	5.00	4	5	5

Table 3. Quartiles for the Spring semester class data split in novice and not novice.

Experiences - not novice				no experiences - novice		
vignette	25%	50%	75%	25%	50%	75%
C	1.0	2	3.0	2.0	3	4.0
I	2.0	4	4.5	2.5	4	5.0
L	2.0	2	3.5	2.0	3	4.0
M	2.0	3	4.5	2.5	4	5.5

Table 4. Quartiles for the Autumn semester class split in novice and not novice.

3.2 Survey about the process

In the 10th week of the semester, we asked students about the uses of the process. We asked these questions in a written survey: **a.** How much does the process help you understand what the program / sub-program should perform, **b.** How much confidence the process gives when you need to program, **c**. Was it clear from the start of the course what the process was to be used for? On a scale from 0 to 6. And in spring 2022 we added two questions more **d**. Does the process guide increase your problem-solving skills in programming? **e**.: will you faster solve programming problem without process guide?" The Table 5 shows that 47% to 55% of students find the process useful when using scores 4 up to 6.

Year	N. stud.	a >=4	b>=4	c>=4	d>=4	e>=4
Autumn 21	19	9 (47%)	10 (52%)	12 (63%)		
Spring 22	31	17 (55%)	11 (35%)	8 (26%)	18 (58%)	3 (10%)

Table 5. Evaluation of the process Spring 2022 and autumn 2021.

The question b. about confidence shows a different picture. The class in autumn finds it raises the confidence, but only 35% in the Spring 22. The answers to the question c if it was clear what the process should be used for, indicates that even the process actively was used from 2nd week in the Spring semester only 26% understand it. Better in the Autumn by 63%. Therefore, we need in the future to explain better why it is important for students to use process and how to work with it. The question d. is only asked in the spring for getting more understanding about how much support the process gives students. 58% of the students find it helpful in problem solving. Only 10% find it as a waste of time by answering question e.

4. Conclusions

We find the changes in scores analysed in the autumn indicate lowering scores for the moments of programming during the semester, by introducing the process guide in the course (DEP) and students' self-assessment using the 13 moments of programming with vignettes [9], We can conclude the process could have an impact on students lowering negative self-assessment for the moment M and I as the self-assessment is lower at the end of the semester. But the formulation of assignment text may also have an impact. It can be concluded students with experiences before the study have less negative score in self-assessment. Which confirms that the moments of programming are defined from the way a professional works and therefore students with a previous background are more used to tackling the moments of programming. From the Table 5 we see that students find the process useful approximately 50% and 35% to 52% of students find the process gives more confidence. From Table 1 the students not participating in the exam do not show any changes in the Autumn, therefore lowering the score of negative self-assessment by using a process guide is not proved. But running process guide in more semesters could change the picture. The “moments of programming” self-assessments tool is useful for evaluating how the students are confident with the general programming, IDE and compiler progress during the semester. Further work must be carried out in the coming semesters to really observe the effect of the process guideline.

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ENGIMATH ONLINE COURSE. EFFECTIVE FEEDBACK FROM UPC MATHEMATICS TEACHERS (CONCEPT)

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ABSTRACT

EngiMath is a 3 ECTS online course in engineering mathematics, in seven different languages, and it is the main and practical output of the ERASMUS+ project entitled "Mathematics online learning model in engineering education" in which the authors were participating. The course is integrated with Learning Management Systems such as Moodle and it is compatible with other platforms using Learning Tools Interoperability.

Once the project is finished, authors undertake, with the support of the Institute of Education Sciences at the Universitat Politècnica de Catalunya-BarcelonaTECH (UPC), an innovation project, **EngiMath@UPC**, with three practical objectives: a) to incorporate EngiMath into the teaching activity of the widest as possible range of students at UPC, b) to gather students and faculty feedback regarding the tracking of materials and their performance in the student training process, and c) to statistically

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analyze the data collected in order to validate and adjust the follow-up of the materials. In connection with the above mentioned objective b) a training course addressed to the math professors has been prepared at UPC.

The paper introduces, on the one hand, the EngiMath course as an online open educational resource for the academic community benefit, and on the other hand, analyzes the valuable feedback given by the training activity participants. Details on the online course implementation as well as main conclusions will be presented and discussed throughout the document.

1 THE ENGIMATH ERASMUS+ PROJECT

EngiMath, *Mathematics online learning model in engineering education*, is an ERASMUS+ innovation project granted in the 2018 call Cooperation for Innovation and the Exchange of Good Practices KA203 - Strategic Partnerships for higher education. The project (run from November 1st, 2018 to August 31st, 2021) aimed to create and develop shared medium for materials suitable for web-based assessment of mathematics for various types of engineering education curricula.

The EngiMath consortium was integrated by the following Higher Education institutions: Tallinna Tehnikakorgkool (TTK UAS, Estonia, coordinator), Instituto Politecnico do Porto (IPP, Portugal), Universidad del País Vasco (UPV/EHU, Spain), Universitat Politècnica de Catalunya (UPC, Spain), Letterkenny Institute of Technology (LYIT, Ireland), Politechnika Koszalinska (PK TUK, Poland) and Universitatea Tehnica Cluj-Napoca (UTC, Romania). Complete information on objectives, intellectual outputs, dissemination activities and contact can be found at https://sites.google.com/tktk.ee/engimath.

Contributions of the EngiMath project included a) a comprehensive report on pedagogical analysis for online assessment of mathematics for partner countries and needs of engineering mathematics, b) a 3 ECTS online course in engineering mathematics in seven different languages (English, Spanish, Portuguese, Catalan, Polish, Romanian and Estonian) and c) a mathematics online assessment model in order to engage the student voice more in the learning process [1-2].

2 THE ONLINE ENGIMATH COURSE

2.1 Introduction

The aim of this course is to promote the development of basic and structured knowledge and practical skills in the mathematical area of Linear Algebra, specifically in the sub-areas of Matrices and Matrix Calculus, Determinants and Linear Equations Systems related to Engineering. The direct target groups of the Project include students in engineering mathematics programs at higher educational institutions, academic staff teaching engineering mathematics in tertiary programs and research academics in the areas of technology-enhanced learning and online learning.

Stronger student engagement or improved student engagement are common instructional objectives expressed by Higher Educational Institutions. They aim, in particular, at reducing the early dropouts of Science, Technology, Engineering, and Mathematics (STEM) studies and to involve students in their own learning process.

Finally, the EngiMath online course, implemented in Moodle and fully open, consists of a basic course on Linear Algebra composed by three topics: Matrices, Determinants and Linear Equations Systems. Firstly, an initial Introduction to Engineering Applications serves as a motivation. Secondly, each topic contains learning materials (26 Lessons), practice tests (2 Quizzes per Lesson) and at the end of each topic there is an Assessment Test. The final grade is the average of the three topic-specific assessments. At the end of the course the student is kindly requested to give his/her feedback for further development and improvement of the course. Fig. 1 allows to identificate the components and the sequence of the course.

Fig. 1. Course sequence

2.2 Engineering Applications

In order to motivate and encourage students towards independent learning in mathematical topics at the beginning of the course there are some examples of Engineering Applications (in Civil, Electronic and Mechanical fields). On the one hand, they connect basic concepts of mathematics with relevant topics of Engineering. On the other hand, they propose and state contextualised problems which are solved stepwise using EngiMath tools and procedures.

2.3 Lessons

EngiMath course has adapted the PAR (Present, Apply, Review) model for online learning [3]. PAR structures the lesson by presenting new material, allowing the student to apply the learning followed by a review of the learning. This structure may be utilized several times within a lesson to maximize the learning potential. Persistence and attrition factors were also taken into account when designing the course [4]. The course adequately combines formative and summative aims in the e-assessment strategy [5].

The course is composed by 26 Lessons and is divided into three Blocks:

- Block I: Lessons 1–14. Matrices and Matrix Calculus
- Block II: Lessons 15–22. Determinants
- Block III: Lessons 23–26. Linear Equations Systems

All the theoretical concepts are presented in a very simple and comprehensive manner. Many examples are used to support the theoretical material. In total, there are more than 400 slides with over 3900 animations. Details in Fig. 2 and Fig. 3.

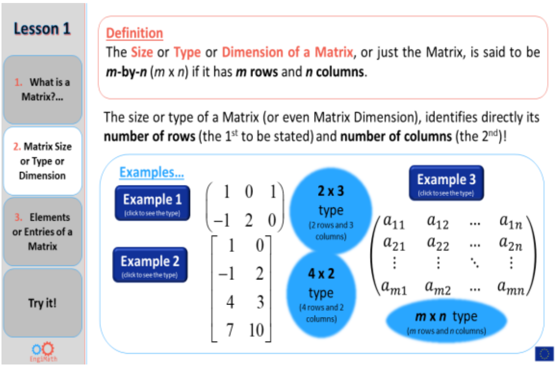

Fig. 2. Slide of Lesson 1

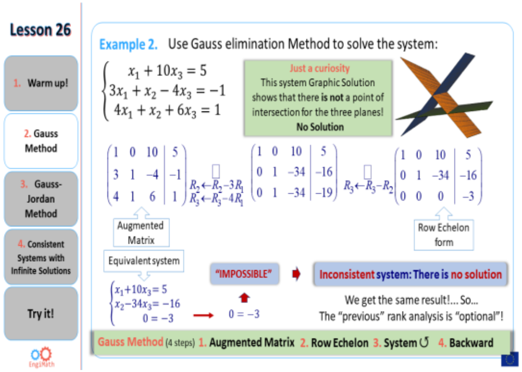

Fig. 3. Slide of Lesson 26

Furthermore, in each Lesson the student has the opportunity to check his/her skills using the “Try it” quizzes. These quizzes are composed of over 120 questions of different types: True or False, Multiple Choice, Matching, Correspondence, etc). Each question provides a step by step solution in order to help the student to arrive at the right answer. Fig. 4 and Fig. 5 show an example of a quiz and a quiz feedback.

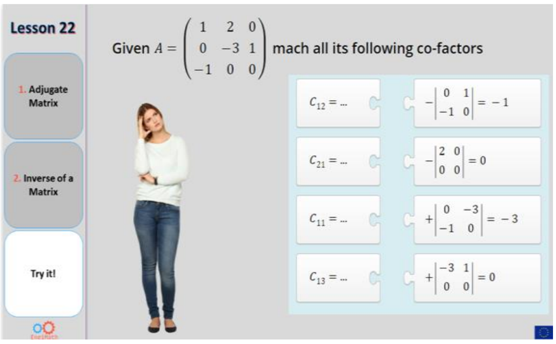

Fig. 4. “Try it” quiz

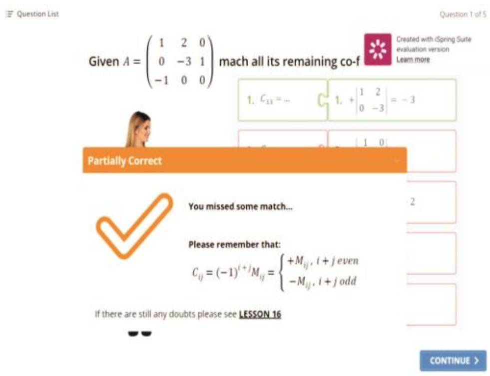

Fig. 5. Example of quiz feedback

By using iSpring, the 26 powerpoint Lessons were transformed into e-courses, producing 26 SCORM packages that were uploaded into the Moodle platform.

2.4 Practices Materials

Regarding the practical materials, with the background experience applied to the frame of Erasmus+ project EngiMath, a huge question bank has been developed for the online engineering mathematics course.

Special attention was paid to the development of STACK (System for Teaching and Assessment using a Computer Algebra Kernel) questions and step-by-step teaching tasks that give students a certain logical sequence of mental actions that must be performed to solve the problem. Based on the objectives of the practical quizzes for each lesson, a testing model was compiled: a technological matrix containing competencies selected for practice and testing. For each competency, questions were created. Regarding the variability, in order to ensure the development of different practice experiences and tests, and also to allow randomness in the definition of the practical quizzes, each of these questions has, in average, 10 versions.

The question bank consists of more than 4500 questions, 2148 for practice in lessons and 2382 for assessment. There are close-ended type questions and open-ended type questions. Exhaustive feedback has been provided for each question (Fig. 6).

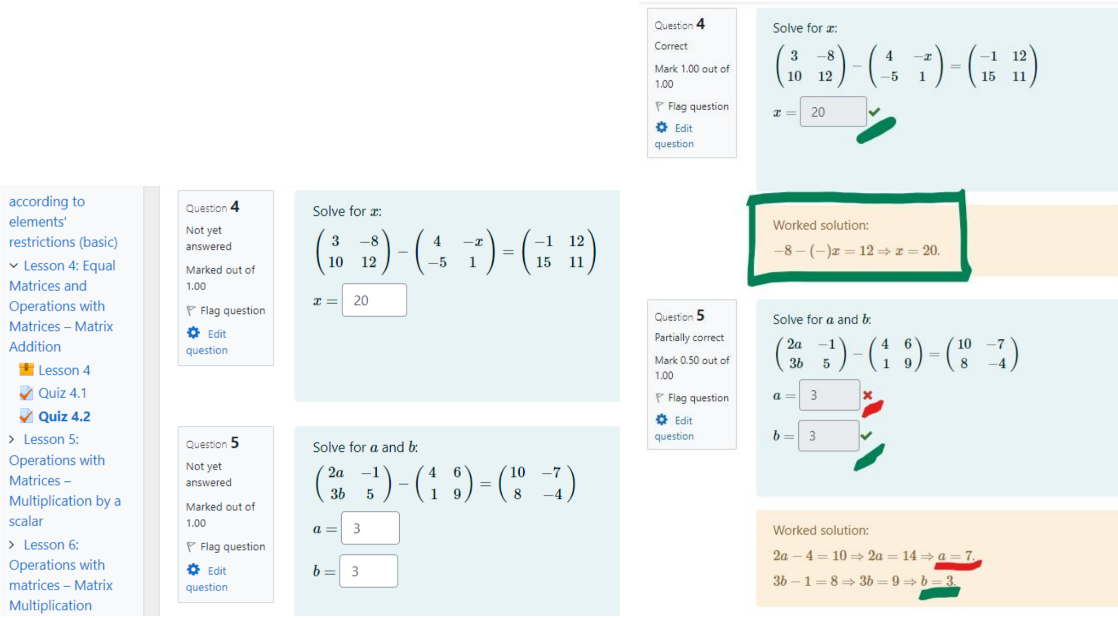

Fig. 6. Quiz 4.2 and feedback

2.5 Assessment Tests

At the end of each Block student is invited to take a 90-minute Assessment Test in order to obtain the qualification of the corresponding topic. The grade of the Block is the maximum of those obtained in the three attempts allowed in the assessment test.

Assessment materials are a consequence and interconnected to the previous activities. As one important role of online technology is to facilitate teaching and promote learning and in the context of the EngiMath online course (or any other online assessment task) only the student/user can know if the learning requirements are being fulfilled. In this sense it is necessary to ensure a form of summative assessment (as well as already pointed out for the case of training in the previous section) that validates the work developed without too much entropy caused by external to the covered contents issues.

2.6 Course Feedback

Through a Google Form students are invited to give their feedback about different aspects of the course:

- general impression of the quality of theoretical, practice and assessment materials,
- the quality of graphics, the structure of the course and the presentation method of concepts,
- the level of difficulty of the presented materials and
- the interaction with the teacher.

Open questions on the three issues of the course they liked the most and the three issues that could be improved are also included.

3 TRAINING COURSE

3.1 Workshop Structure

According to the aims of the EngiMath@UPC project, in order to disseminate among the mathematics community at UPC, either the project or the online course, a training activity was organized, targeted to the math teachers (specially to Linear Algebra ones). The title of the activity was “EngiMath. A European project for UPC students” and it was planned as a 6-hour online workshop.

The schedule of the workshop was as follows:

a) an inicial 2-hour session for the introduction of the EngiMath project and the online course,
b) an estimated 2-hour homework on working in detail (from a math teacher perspective) one or two lessons of the course, and
c) a final 2-hour session for the joint discussion on the perceptions and comments (pros and cons) about the worked materials.

First session was mainly informative and descriptive of the project and the course as a main output. For the homework, participants had two days in order to deal with a preassigned lesson and provide the corresponding feedback. In the second session, the instructor described the results of the feedback and promoted an active and general discussion on the design and structure of the course, contents presentation, procedures, questions database and assessment strategy, in order to derive the main conclusions on validation and update of the materials. Last session also allowed to invite participants to be active part in the EngiMath@UPC project during the second semester of the 2021-22 academic year.

Teachers accessed the online course, available in Catalan, Spanish and English, via an External Tool implemented in the Moodle virtual campus allowing them to directly link the materials locate at the TTK University of Applied Sciences’ server in Tallinn (Estonia).

3.2 Participants

The workshop proposal received a total of 27 registrations and 22 professors attended the sessions. Among the 22 attendees, 19 (86.4%) fruitfully contributed with their homework, feedback (similar to the one described in the subsection 2.6) and active discussion. Figures are based on the feedback provided by them.

Participants' profile: a) affiliation: 17 (89.5%) Dept. of Math, 2 (10.5%) others, b) online course language: 16 (84.2%) Catalan, 3 (15.8%) Spanish, c) age rang: 5 (26.3%) in [40, 49], 12 (63.2%) in [50, 60] and 2 (10.5%) above 60.

3.3 Results on Quality Issues

Fig. 7 and Fig. 8 display bar charts from the collected responses on quality for the EngiMath materials and resources. It can be seen, when grouping the two higher categories (4 and 5 in the Likert scale, colored green and purple, respectively) that the scores are really satisfactory in each item:

- Materials: Theoretical: 94.7%, Practice (84.2%) and Assessment (84.2%)
- Resources: Graphics: 78.9%, Structure (100%) and Presentation method (100%)

This findings state the good performance of the output and validates a high-quality standard of the EngiMath online course.

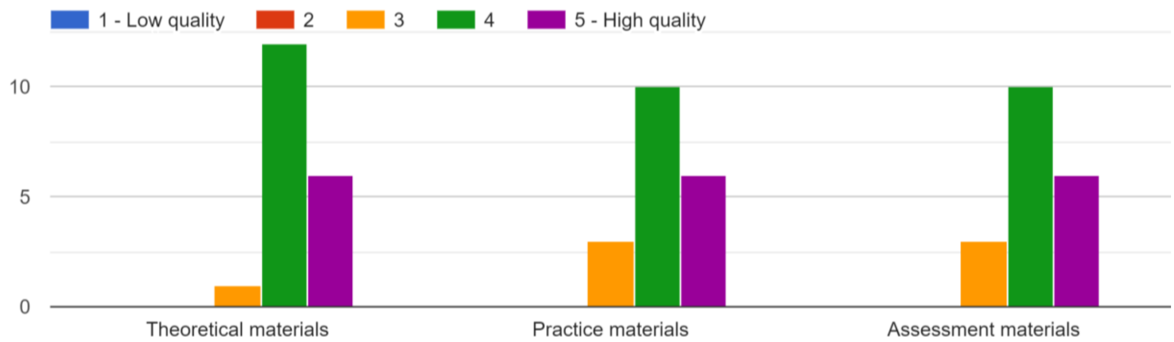

Fig. 7. Bar chart of the materials' quality feedback

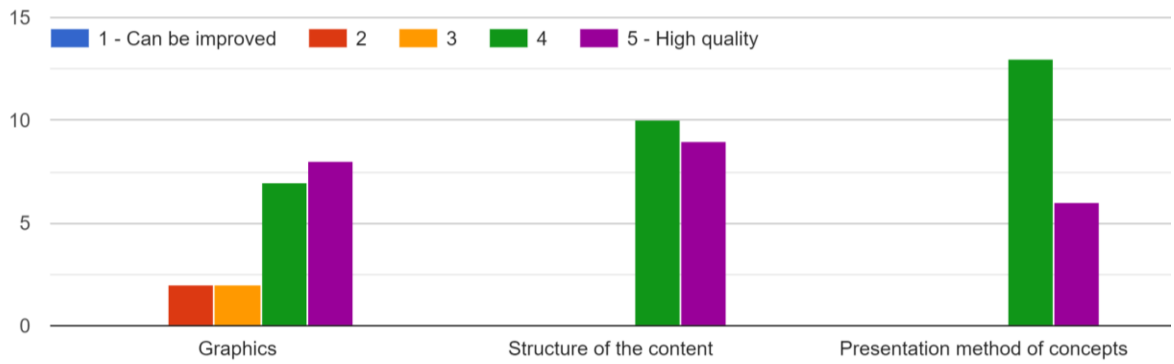

Fig. 8. Bar chart of the feedback about the designing resources' quality

4 FINAL CONCLUSIONS

Concerning the participants' positive experience, the answers focus on the following aspects (sorted from more to less frequency of responses)

a) Clarity, conciseness, progression and summaries in explanations.
b) Volume per lesson. Brief, which prevents giving up in the middle of the lesson.
c) Illustrative exemples. Helpful to understand the theory.
d) Fully coverage of the subject and different levels of difficulty.
e) Project and platform by themselves.

When proposing issues to be taking into account for improving the current version, proposals include (sorted from more to less frequency of responses)

a) Correct errors in the answers or feedback in the tests. In particular in the assessment tests.
b) Reduce overly calculative exercises (or too many boxes to fill) and add reasoning questions.
c) Avoid repetitive exercises.
d) Allow to follow the program in a non-sequential way.
e) Incorporate some additional software like Mathematica, Matlab, Maple, SAGE, Geogebra, etc

ACKNOWLEDGMENTS

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EXPERIENCES OF MINING ENGINEERING STUDENTS IN COOPERATION FOR DEVELOPMENT

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ABSTRACT

Future engineers, in addition to technical knowledge, should incorporate in their academic curricula aspects that contribute to make mining a sustainable activity. This will contribute to changing the concept that society has about mining and to be a socially accepted activity. In the mining engineering studies at the Universitat Politècnica de Catalunya (UPC), students have the opportunity to develop cooperation projects together with professors and other staff members. They all collaborate with artisanal miners from different underdeveloped countries, mainly from Latin America, and contribute to making mining more environmentally friendly. Moreover, they have the opportunity to acquire a social sensitivity that can be of great importance during the development of their professional career. This study presents some experiences of undergraduate, master, and doctoral students in cooperation activities in mining. The projects were developed as a collaboration between UPC and universities or NOGs in Latin America. The activities have been carried out in underdeveloped areas where mining is practiced with a high environmental impact and poor use of resources. A survey among the participants in the projects shows the students' favourable perception of this activity.

1 INTRODUCTION

The supply of mineral raw materials is essential for the well-being and growth of the economy and society. Thus, today's high technological development is accompanied by an increasing need for, and dependence on, a large number of metals. Currently, 30% of the metals that we use are recycled; the other 70% must come from mines. So, it is clear that we have to mine, but we have to do it sustainably.

In mining schools, there is an emerging awareness of the responsibility to train engineers with values that ensure that sustainability is always present in their activities. Future mining engineers must reconcile the requirements of the economy, the environment, and society. Therefore, the inclusion of sustainability in education represents a great opportunity to train engineers with a sense of responsibility for the future. In order to obtain raw materials in an optimal way and with a minimum impact on the environment and in a safety work conditions, the different activities involved must be carried out based on in-depth scientific and technological knowledge.

At the Universitat Politècnica de Catalunya (UPC) students are trained to be future professionals in mining engineering. In this case, in addition to acquiring scientific and technological knowledge, the training also includes the acquisition of social values, which will be of great importance in the future development of their profession. To this end, every year we carry out cooperation projects in mining areas from developing regions, where mining is still a long way from being sustainable. The Centre de Cooperació per al Desenvolupament (CCD) is a UPC body that every year launches calls for cooperation projects in which students, lecturers, and staff of the university can participate and carry out work to cooperate with institutions in developing countries and thus contribute to their development. It is based on the premise that the University has the responsibility to be actively involved in the promotion of solidarity and equity among people and the promotion of better human and sustainable development in the world, supported on its activities of teaching, research, and the transfer of knowledge and technology. In this regard, the UPC incorporated sustainability skills into the curricula [1].

This work presents the cooperation projects carried out through the Mining Engineering section of the UPC between 2012 and 2021. In this period 20 projects were developed in the Mining Engineering section and about 40 students were involved in these cooperation activities. They moved to the study areas where they carried out the planned cooperation activities. Projects aimed at improving tin mining in Bolivia and gold mining in Peru and Bolivia are presented as case studies.

The projects involve participants from Spain and the beneficiary countries. Part of the development of the projects is carried out in the mining areas of the developing countries, where the students, together with their professors, carry out the assessment of the mining activities and a sampling for the development of the research. In addition, here they have the opportunity to work alongside with miners, local university professors and the population of these communities. Once back in Catalonia, the research associated with the project is carried out at the university. Often, this research is part of the degree, master's or doctoral thesis of the students participating in the projects.

2 BACKGROUND

A sustainable mining operation must be safe, economically profitable, efficient in the use of mineral resources, and environmentally clean [2]. To achieve these targets, it must combine the extensive scientific and technological knowledge with care for the environment and the health of workers. In contrast, artisanal mining is carried out by cooperatives, and even by the individuals, with limited scientific and technological knowledge, which does not allow it to be done efficiently [3]. The exploitation of resources under these conditions entails physical, biological, social, and economic issues. Examples in Peru and Bolivia highlight the generation of acid drainage, mercury pollution, high levels of occupational hazards, and low recovery during the processing of the ores. Rational and optimised exploitation of deposit is only possible if their geology, mineralogy, and type of deposit are known. On the other hand, ore chemistry and liberation characteristics allow the selection of the most effective processing methods to maximise the recovery efficiency and prevent environmental pollution.

Artisanal mining significantly contributes to the economy of developing countries and provides work for many of its inhabitants, creating employment opportunities and reducing poverty [4,5]. There is, therefore, a need to improve the conditions under which artisanal mining takes place. For artisanal mining to be sustainable, miners need to be empowered through carefully designed training programs [6,4] and to share with them the most appropriate processing techniques and how to carry them out. However, it is also necessary to know the detailed mineralogy of the ores and gangue at the mining sites.

On the other hand, one aspect that should never be overlooked is the pollution caused by mining activity. Several institutions and non-governmental associations explain to miners how the pollution produced during their mining activity affects to the environment and to the human health. However, this information does not encourage them to make changes in their methods. Miners will consider changing their practices if they perceive that this will increase their economic benefits [6].

3 METHODOLOGY

In order to assess the impact of the cooperation projects on the students, a survey among some of the participants was carried out. It is also relevant to present their views in a time perspective, allowing them to better assess the influence of these experiences on their subsequent activities. Seven survey questions are presented here:

1. Do you think that Development Cooperation projects are a good and enriching professional complement for students?

2. Do you think that Development Cooperation projects are a good complement on a personal level?

3. Do you think that the projects in which you participated provided solutions (total or partial) to the problems they addressed?

4 Do you think that the experience in Development Cooperation projects will influence possible future career decisions?

5 Would you like to repeat the experience of Development Cooperation projects?

6 How many of the 17 SDGs (2020-2030) have been positively influenced by the Development cooperation projects you have participated in?

7 Summary in a few words the experience of the Development Cooperation projects

4 RESULTS

4.1 Case studies

4.1.1 Gold mineralisation and processing in Bolivia and Peru

The collaboration with artisanal mining was carried out in the Arequipa department of Peru and in the La Paz department of Bolivia. Local mining is mainly underground, done through galleries excavation, except in the Mapiri area, from Bolivia, which is of alluvial type. In both cases, miners use mercury as gold recovery method. The studies were focused to determine the main characteristics of the deposits, as the tectonic structures, mapping of the orebodies, gold grade and mineralogy and chemistry of gold and associated minerals, in order to propose the most appropriate processing technique. Studies were also carried out on mining safety and environmental pollution. The influence on the health of the miners and their families was assessed by analysing the mercury content in their hair. These results have been presented to the miners along with proposals to reduce the use of mercury in the short and long term. They were very concerned about the results presented and, at least in some cases, some measures to reduce mercury exposure were implemented.

4.1.2 Tin and indium mineralisation

Tin production is the main economic input of Bolivia. Collaboration with several cooperatives was carried out for the study of the geology of the deposits, the detailed mineralogy to increase efficiency in the processing plants, and the environmental pollution produced by the mining activities. As a result, the miners were provided with a detailed knowledge of the geology and mineralogy of several mines. This made it possible to establish the metals of interest in each case and their characteristics for recovery. Thus, for example, it was shown that tin is found in some mines in significant quantities in the form of the stannite mineral. However, in the Bolivian processing plants usually, only cassiterite is recovered, and stannite is removed into the tailings. Another important result was the determination of significant amounts of indium and rare earths, which are critical metals, in many of the deposits. The importance of this finding is strategic, not only for Bolivia but also worldwide.

4.2 Students valorisation of the projects

The responses of the seven questions are presented in Figures 1 and 2. The first five questions were set as double choice answers. All the students agree that Development Cooperation projects are a good and enriching professional complement for students and that participation in projects of Cooperation for Development is a good complement on a personal level. Most of the respondents (90%) agree that the projects in which they participated provided total or partial solutions to the problems they addressed (Figure 1). All of them agree that their experience in Development Cooperation projects will influence possible future career decisions. The total of respondents would repeat the experience of Development Cooperation projects.

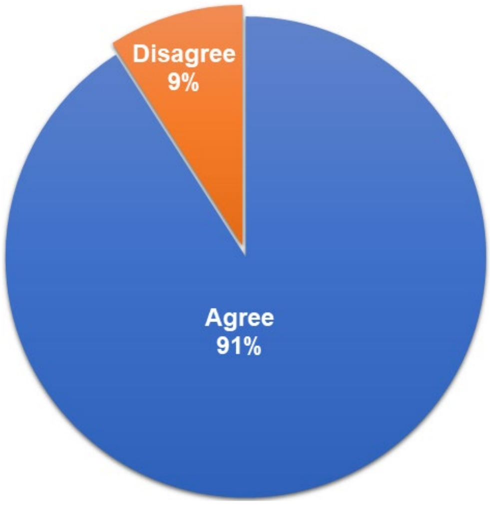

Fig. 1. Responses to the question of the projects of Cooperation for Development are a good complement on a personal level.

Question 6 aims to observe how the participants perceive the influence of the cooperation projects they have carried out on the achievement of the 2030 Sustainable Development Goals (SDG). All respondents consider that the projects they have been involved in have contributed to achieving some of the SDGs 2020-2030. Mainly SDG 8 "Decent work and economic growth", but also SDGs 3 "Good health and well-being", 6 "Clean water and sanitation " and 13 "Climate action" (Figure 2).

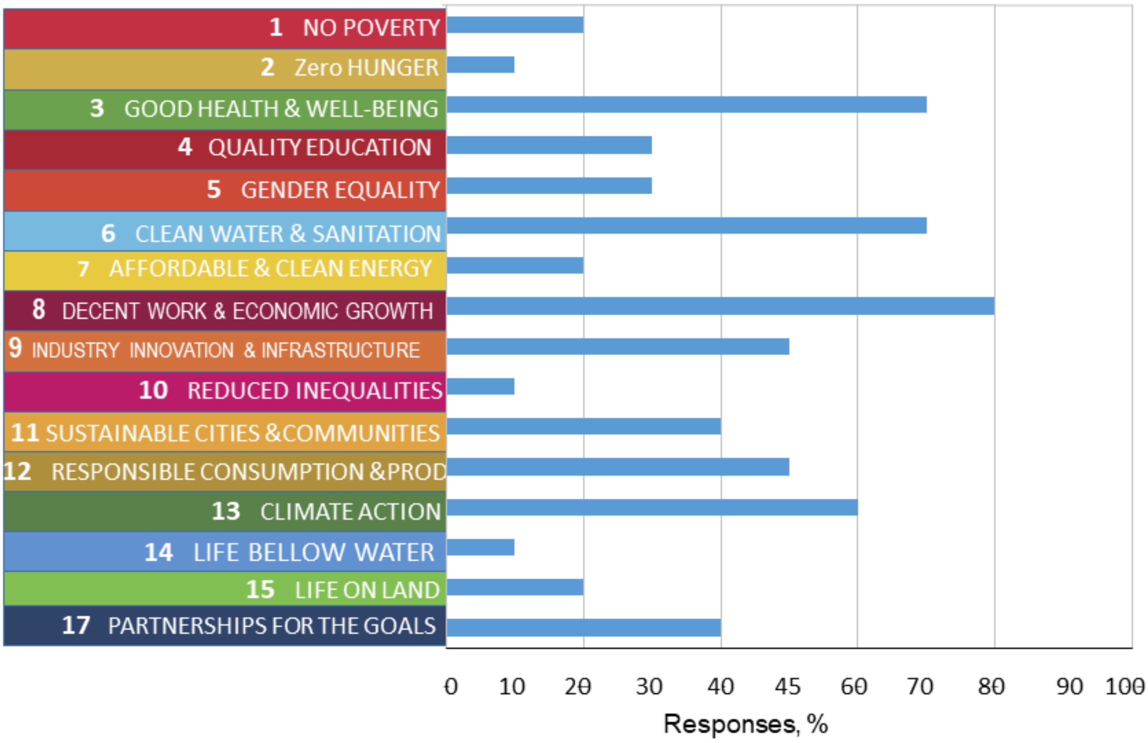

Fig. 2. Impact on the SDGs 2030 of the cooperation projects carried out according to the participants surveyed.

In reference to the experience of Development Cooperation projects students emphasised that the projects gave them considerable experience, both on a personal level as well as professional. In addition, they expressed that the first hand contact made them empathise with the communities in developing countries.

Respondents believe that it was a really good experience to have the opportunity to apply the concepts learned in classroom to real cases. They point out that having the opportunity to share knowledge with colleagues and experience the limitations of some projects and see how to deal with them made development cooperation projects an amazing experience. Therefore, they consider that it was an experience that helped them to improve as professionals. All the respondents agreed that it was an unforgettable, enriching experience that they would like to repeat.

4.3 Overall assessment of projects

The implementation of the cooperation projects has had a positive impact on both the students and the beneficiaries of the cooperation. On the one hand, the surveys show that the students have acquired a high degree of social sensitivity, an aspect which will be fundamental in the development of their profession. In this context, sustainability criteria are increasingly being applied.

On the other hand, the research carried out has given the miners a better understanding of the characteristics of their mining activities and how they can improve them in order to achieve better yields and less environmental and occupational health and safety impacts.

Local researchers have also been trained, so that universities in developing countries have the skills to conduct research that directly affects the people around them.

5 SUMMARY AND ACKNOWLEDGMENTS

Development cooperation projects have been mainly undertaken in Peru and Bolivia. These projects have made students more aware of the problems caused by mining around the world. It is well known that mining actions interact directly with the environment by extracting non-renewable resources. Therefore, future mining professionals must be aware of the importance of building environmentally friendly mining activities. To conclude, it is believed that sustainable mining activities can lead to the development of more sustainable and fair communities.

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UTILIZING ZOOM-STAMPS IN SYNCHRONOUS ONLINE WORKSHOP IMPLEMENTATIONS

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ABSTRACT

In engineering education, and in work life in general, the past two years have been struggling with Covid-19 pandemic. When considering studying, learning, and working, the teachers and other facilitators have been forced to create innovative methods for online working, aiming to good work efficiency, student engagement, and learning results. Along the development of various online working possibilities, it has been noticed that especially interaction among participants in synchronous online sessions is a challenge. Even if some participants are actively discussing and working in online sessions, some participants remain very silent and indistinguishable. Furthermore, even though the technical tools for online working and learning have developed rapidly during the recent years, technical problems still exist quite often.

There are numerous ways for increasing interaction in online sessions, including, for example, asking questions, using camera, utilizing chat or third-party applications like Padlet, and small group discussions in breakout rooms. In this paper, we will present how we utilized Zoom-stamps in two types of workshops. The basic idea in utilizing Zoom-stamps was to increase interaction and communication among participants and help them to further develop ideas created and discussed in the workshop. The lessons learnt from the first type implementations were considered when planning the second type implementations. We will describe the pros and cons of the Zoom-stamp utilization in synchronous online working as well as share our future development ideas.

1 INTRODUCTION

The covid-19 pandemic forced about all educators in all education levels to transform their teaching online. The switch from classroom teaching to remote teaching took place almost overnight. The covid-19 situation has been ongoing now over two years, and during this period, the educators have rapidly and intensively developed online teaching and studying methods.

The tools and practices for online teaching has been enormously developing all the time during the past two years, both for synchronous and asynchronous learning events and assignments. It has been noticed that one challenge in synchronous online teaching is the lack or difficulty of interaction and communication during the classes [1, 2]. In traditional face-to-face learning events interaction is easier and comes more naturally. The rapport building is easier in face-to-face than in synchronous online learning sessions [3]. It is effortless to join a discussion when you see other people around you, and you can also see their body language. For an individual student it is quite easy to stay silent and indistinguishable in synchronous online classes, especially because due to our regulations we cannot require videos to be turned on during the learning events, thus many times you cannot see the other participants at all, and their facial expressions and body language remain unseen, hence easy ways for increasing interaction and communication among participants are really needed.

Numerous ways for increasing interaction in synchronous online sessions have been developed and tried in practice, including, for example, asking questions, using polls, using camera, utilizing reaction features, utilizing chat or third-party applications like Padlet, and small group discussions in breakout rooms. These all have benefits and disadvantages, and they all suit very well to some purposes. For example, reaction features are a good way to give instant feedback to the issue on hand, and many students find writing on chat as a very easy way to express themselves during an online session. In this study we will tell our experiences about using Zoom-stamps in synchronous online workshops to boost interaction among participants and to help them to further develop the ideas created during the workshops.

2 ONLINE SYNCHRONOUS MEETING TOOLS

There are multiple options for videoconferencing, teaching and researching online, such as Zoom, RemotePC Meeting, GoToMeeting, ClickMeeting, Microsoft Teams, Cisco WebEx, Blackboard Learn Ultra, Skype, and Google Meet [4, 5, 6, 7]. The videoconferencing systems have many similar properties, but there are some differences also, and these platforms are developing all the time.

Many researchers have found Zoom to be a very good videoconferencing system, for example, Fatani piloted two platforms (Blackboard ultra and Zoom) and chose Zoom, because “easier navigation and fewer interruptions, connection dropouts, and audio-visual problems” [4]. The participants in Archibald et al’s study preferred Zoom to other videoconferencing platforms [5]. Furthermore, the reported benefits include ease of use, cost-effectiveness, accessibility, timesaving, security options [3, 5], and flexibility [8].

Zoom offers an easy-to-use online platform for interactive and synchronous teaching [4] and research [3, 5]. It allows different innovative features, such as annotation tools, polls, and breakout rooms [9]. Furthermore, it provides video and screensharing [4], chat and whiteboard. These multiple features can help interaction in synchronous online teaching. Even though Zoom is a very liked video meeting platform, also negative experiences and thoughts exist. Serhan has found that students sometimes find that Zoom makes learning experience and learning motivation worse [8]. For more information on Zoom and its features, see https://zoom.us/.

Zoom and Teams are available in our university, and therefore they are the most familiar videoconferencing systems for us. Both work well in synchronous online teaching, but some properties that exist only in Zoom make it our choice, especially for large student groups. The favoured properties that lack from e.g., Teams and Google Meet are versatile annotation tools that can be used as well with whiteboard as with screen sharing. The Zoom’s annotation tools include a stamp-tool. There are some annotation tools in e.g., Teams and Google Meet, but not very many, and they can be used only with whiteboard, not with screen sharing. Furthermore, we have noticed in practice, that if the synchronous online session participant number is big, approximately over 50, the Teams is continuously having network connection problems when used from a home network. Zoom can handle a larger number of participants without network problems. Of course, this depends on the network, and this problem does not exist in all cases.

3 UTILIZING ZOOM-STAMPS

During Covid-19 pandemic we organized workshops and discussion groups using Zoom. We used Zoom-stamps for voting in the workshops and discussion groups. We could not use the Zoom's poll tool to cast votes, because the ideas to be voted on were created during the workshop sessions. In addition, so many ideas were produced in the workshops that it would have been too time-consuming to create the poll in the middle of the session.

Already in traditional inclass sessions, as well as in online sessions, many kinds of student response systems have been used to activate students, to get their opinion on the issue, or to test their knowledge about the subject on hand. However, these systems need teacher's preparation of the questions before the session. Hence, they are not suitable to situations, where the subject is developing in the session and there is no time to create polls during the session.

The stamps are in Zoom's annotation tool. They are only available in Zoom's desktop application. If participants are attending a Zoom session via mobile phone or an internet browser, the annotation tool is not available. This caused some technical problems during the workshops and discussion groups.

3.1 Study setting 1: Workshops

We organized five workshops in Zoom where the main purpose was to create new ideas on the topic in hand, and to discuss and further develop these ideas. The participant number in these workshops varied between 5 to 15, and in addition five to six organizers participated in the workshops.

The workshop flow was the same in all the workshops:

1. Silent thinking and writing on a shared whiteboard related to the question presented.
2. Free discussion about the ideas that the participants had created. At the same time, one organizer grouped the ideas on the screen.
3. The participants were asked to give different shaped Zoom-stamps to the idea that was the most pleasant (heart shaped stamp), the most innovative (star shaped stamp), and the most challenging (question mark shaped stamp).
4. Discussion on the stamps: Why the participants gave the stamps to the specific ideas.

Participants were asked to vote for the most pleasant, innovative, and challenging idea by placing a proper stamp next to the written idea on whiteboard. Many of the participants clearly enjoyed giving stamps to the ideas, and in this way their individual voices were heard. Giving stamps also boosted the conversation, it was easy to talk about the thoughts behind the stamps. In Figure 1 is an example of how the screen could look like after workshop phase 1, when the ideas are written on the screen. In the Figure 2 is an example screen with stamps, this could be the case after workshop phae 3. In both the Figures 1 and 2 you can see also Zoom's annotation tool. The real situation on the screen was often not as clear as the examples in Figures 1 and 2, mainly because the participants did not use the colours in any planned way, and in addition many times there was really a lot of ideas, subideas, etc. on the screen. So, the screen was sometimes quite full.

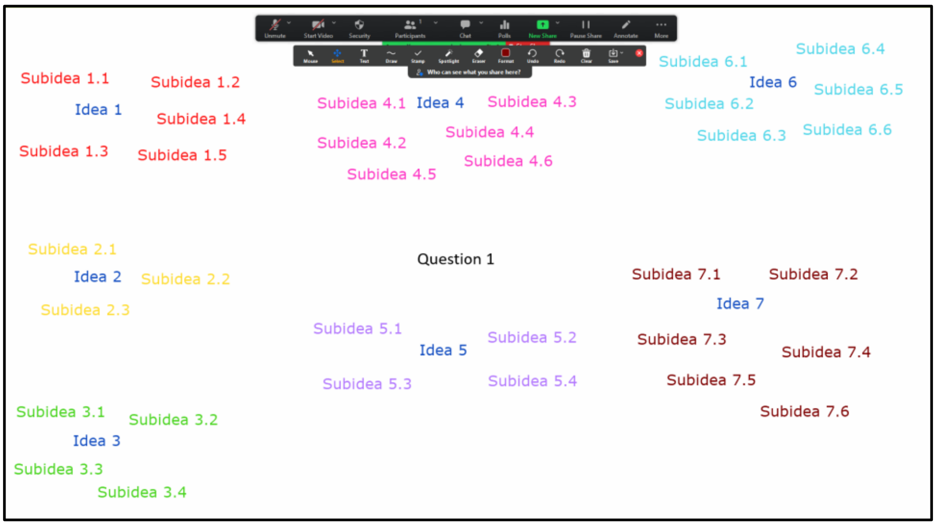

Figure 1. Example of the screen with ideas.

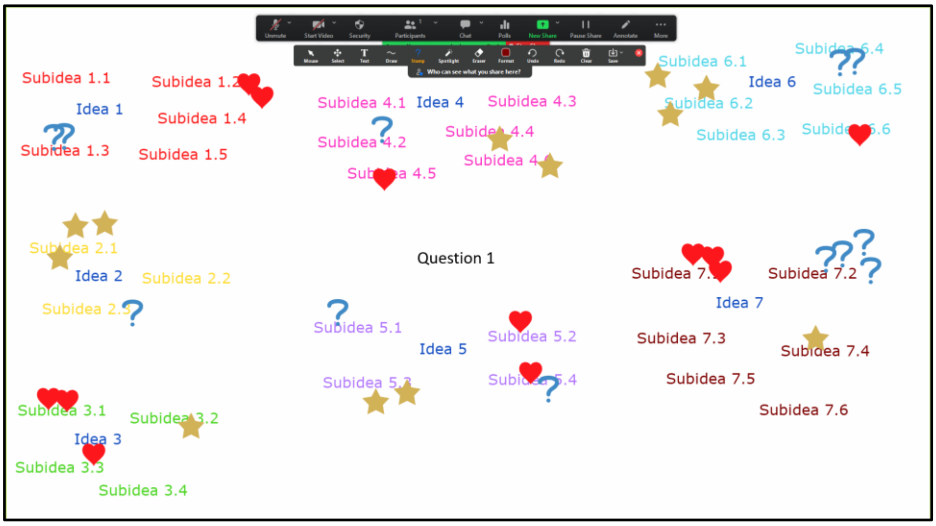

Figure 2. Example of the screen with ideas and stamps.

Even though the Zoom-stamps were found good in increasing interaction and boosting the conversation, some problems occurred. The participants that were not using a Zoom desktop application did not have the annotation tool, where the stamps are. The problem was solved by asking these participants to write in the chat to which idea they want to give their stamps, and then one organizer sat the stamps to the right place on the whiteboard. Furthermore, another difficulty was that it was sometimes hard to place the stamp to the right idea on the screen, because in some cases the whiteboard was so tightly filled with the ideas, that the stamp hit many of them at the same time. Many times, there were lots of stamps simultaneously on the screen, and they got mixed and buried under each other. This was because every participant gave three stamps altogether, and in workshops with a larger number of participants this resulted in a stamp-mess. Thus, it was difficult to distinguish which idea each stamp was aimed at.

We found that thorough informing and clear guidelines are important to smooth flow of the workshop. In this first implementation round we had instructions, but even more would have been needed. Overall, the Zoom-stamps showed their potential in synchronous online sessions. The process needs some development to avoid the problems that existed in this first implementation round. Hence, we decided to use stamps again in discussion groups.

3.2 Study setting 2: Discussion groups

Two focus group discussions were organized for 12 participants to create, evaluate, and develop ideas for prototype development. This focus group study was organized according to the methodology suggested by Hamilton including the sections of "create", "evaluate" and "develop". We will report the "evaluate" section that utilizes the usage of stamps for voting in detail [10].

With experience from the Workshop setting 1, we decided to pilot the study and test the technical procedures. Casting fewer votes was considered more efficient and resulted in less confusion among the participants. As a result, we decided to have the participants to vote for two ideas that they felt were appropriate for further development.

After the "creating" -section, participants were asked to look at an extensive list of options they had created before the workshop and during it. They were then asked to vote on the two they felt were most suitable to develop further. Unlike in the first workshops, the Zoom-stamps were now asked to be placed on top of the written option to make it easier to identify which word the stamp was targeted to. Despite careful preparations, technical problems occurred in voting and a few participants (using mobile devices) could not use the tool. They were asked to vocalize their opinion; one organizer added their votes to the list. An option of using the chat was also provided, but none of the participants used it for voting. In each focus group, three of the most voted ideas were selected to further exploration. The voting was considered successful for the purposes of the study. However, it was noted that those who had problems with placing the stamps may have felt rushed to do so as solving the technological problems took a lot of time resulting in less time to evaluate the options. After the study, we asked the participants to fill in a university's subscription to Office 365, Microsoft Forms, to elicit further ideas and to give feedback in general. While two participants commented on the technical challenges, most participants felt that technical problems are somewhat inevitable and did not interrupt the flow of the discussions greatly.

4 SUMMARY AND ACKNOWLEDGMENTS

In this study we found that using stamps is an excellent way to reach independent votes during teaching or for research purposes. Zoom-stamps increase engagement and provide a tool, in which the participants' individual voices can be heard. Zoom-stamps also help in building rapport among participants and teachers. Careful preparation and prior testing are needed to achieve a smooth synchronous online session flow. It is recommended to use Zoom desktop application instead of web browser or mobile devices to diminish the occurrence of technical problems in synchronous online learning events. It is necessary to give the participants information at the beginning of a session that technical issues may occur, especially when using mobile devices (such as smartphones and iPads). In such cases it is important to have a plan to overcome the issues, such as an assistant present to help. If participants cannot use Zoom's annotation tool, the participants may vocalize their opinions or use chat option. When an independent vote is needed, as sometimes is in research, providing a phone number or e-mail to cast a vote (to maintain anonymity) is advised. Furthermore, it is important to give the participants enough time, so that there is some time considered also for covering the possible technical problems.

Even though information is in general a good thing, based on our experience, we do not recommend providing excessive information on how to use the stamps before the session, as it may confuse some participants. However, we found that it is extremely important to give clear and comprehensive guidelines for the session, e.g., it is important to tell, how the Zoom-stamps should be placed on the screen to gain the wanted result. Furthermore, we found that Zoom-stamps are quite difficult to target to a particular word if the whiteboard is full of text. Hence, using stamps for voting is easier when there is enough space between the words written on the whiteboard, and when the number of stamps altogether is not huge on the whiteboard.

Overall, even though the Zoom-stamps are only one of Zoom's annotation tools, we found them very efficient in interaction and communication boosting in synchronous online sessions. They are easy and simple to use, and the participants clearly liked them.

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ONLINE CO-DESIGN OF A UNIVERSITY WORK-BASED LEARNING DEGREE PROGRAMME: LESSONS LEARNED FROM COMPARING CASES IN UNITED KINGDOM AND ESWATINI

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ABSTRACT

Greater collaboration is required between universities, industry and society to provide the engineering education that will tackle society's challenges. Work-based learning (WBL) programmes offer an industry-aligned, academically-informed education to support such socio-economic development. Co-design of such programmes is vital with responses to the COVID-19 pandemic innovating alternative ways to design programmes. Knowles et al (2021) [1] outlined an approach to online programme co-design in the UK university context, framed using Signature Pedagogy and through online conferencing and Miro (online whiteboard). Subsequently, the approach has been utilised to co-design a WBL degree programme in Electrical Engineering in Eswatini, supported by Knowles and other UK and Eswatini colleagues.

This paper compares and contrasts cases from UK and Eswatini, and from this address the research question, "What considerations are required to support an effective online process to co-design a work-based learning programme in Engineering?" A collaborative autoethnographic methodology based around field notes, observations and reflections is used to allow exploration across pedagogy, technology, work practices, expectations and challenges.

Many aspects of the approach worked well in both cases (for example, effectiveness of Signature Pedagogy, Miro as shared space), whereas differences arose related to limitations in the synchronous use of technologies, and readiness to adopt an

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outcome-focused approach. Addressing these differences, along with balancing progress against full participation and having clear expectations of participants, are key considerations in online co-design of WBL programmes. Moreover, the approach of Knowles (ibid) has shown to be adaptable with potential for broader adoption.

1 INTRODUCTION

Engineering must be at the heart of providing solutions to the societal challenges of the next decade and beyond, and to do so then engineering education has to adapt [2]. This change must happen across the spectrum of delivery modes to meet the needs of individuals, organisations, the economy and society – from full-time to lifelong learning. Additionally, engineering educational approaches must now support the development of a more holistic engineer and engineering graduate, and that authentic learning experiences offer clear potential to achieve this goal. Moreover, greater collaboration between academia and society is required, whether to provide challenges, to develop required transversal skills, to support ongoing employability or to learn how to work with and address complex, 'wicked' problems.

In terms of current engineering curricula and outcomes, there exists a long history of employers' dissatisfaction with the capabilities of graduate engineers, and by implication the academic system which produces them [3]. Moreover, newly qualified graduates often feel 'incompetent' [4], and experience difficulty in transitioning into the workplace as graduate engineers [5] [6]. This is perhaps unsurprising, given that that there is little, if any, correlation between academic performance and success in the workplace [7]. It should, perhaps, be noted that the call for graduates who can 'hit the ground running' with appropriate skills is contested; indeed, previous studies suggest that education is about 'higher skills' which equips students to be leaders in their chosen professions [7] [8]. On the other hand, there is some argument that the development of workplace skills is better done in the workplace [9].

Work-based learning (WBL) is a form of partnership between academia, students and organisations (typically industry) that is and will be an important mode of engineering education to meet the above challenges. WBL embraces different forms of engagement, from placements and internships to a fully co-designed (and co-delivered) programme – a challenge in itself [10]. In terms of co-creation in higher education research has typically considered the dyadic partnership between students and learners and the various levels of engagement [11], whereas in WBL there is a need to engage all stakeholders throughout the design and delivery. In terms of co-creation of WBL programmes, then there are some general guidelines [12], but a gap in terms of models of programme co-design, specifically around work-based learning. Co-creation of programmes is challenging as it involves working across boundaries (whether these are organisational, language or epistemic) and to reap the full benefits of collaboration requires an approach that will facilitate genuine dialogue and consensus building between the partners. Additionally, programme design is complex, as is underpinned by a mixture of wider educational theory including Outcome-Based Learning [13], Concept Mapping [14], and discipline-specific theoretical approaches which have emerged out of Engineering Education Research (for example [15]). Disappointingly in Engineering, course design is often criticised as being too content focused and a sum of its modules (inputs) [16], rather than a coherent and authentic learning experience [9].

To address the potential deficiencies in collaborative programme design, Signature Pedagogies [17] represents an important epistemological standpoint as it encapsulates an applied pedagogy in which the *habits of 'head', 'hand' and 'heart'* are central drivers in how the curriculum is designed and delivered [18]. These are derived from the things that professional engineers do ('hand'), what they believe and their worldview ('heart') and how they think and engage with knowledge and practice ('head').

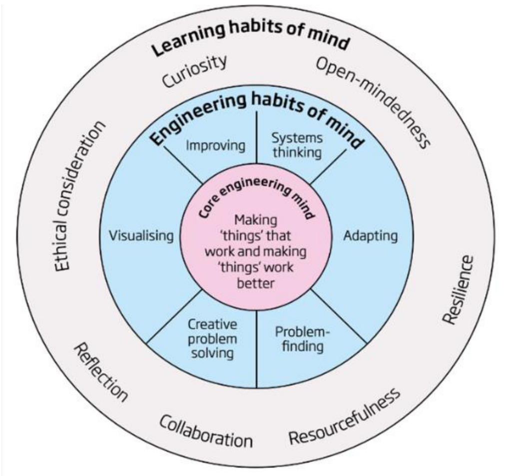

Figure 1. Engineering Habits of Mind Lucas and Hanson [19]

Taking this notion one step further and grounded in the Engineering Habits of Mind concept (Figure 1) [19], the approach developed in The University of Warwick represents a holistic model of student development. The focus is on the graduate characteristics in three distinct yet interlinked pillars of curriculum design, representing the affective, cognitive and functional aspects of education that are given equal consideration in developing a more connected and 'holistic' curriculum [20]. This approach has particular applicability in co-design spaces as industrial partners are uniquely well-placed to contribute to the understanding of graduate characteristics in the three areas which are relevant to their context.

Despite Signature Pedagogies having been around for a significant amount of time [17], there has been little evidence of attempts to significantly operationalise the concept beyond it 'informing' course design in largely unspecified ways. This means that the approach taken in this paper relates to a fuller operationalisation of the concept than has hitherto not been the case in the Engineering. The initial implementation of Signature Pedagogy to co-design of an Engineering WBL programme (in the form of Degree Apprenticeships) in the UK has been previously introduced [1]. The onset of COVID-19, when one Degree Apprenticeship was going through significant redesign and another about to enter the design phase, meant that a previously face-to-face approach of workshops, allowing for team building and constant adjustment of artefacts such as flip charts, post-it notes and diagrams to reflect the progress of the thinking needed to be re-imagined. The first challenge was to find an online collaborative environment which allowed for the easy and intuitive creation, combination and re-combination of artefacts representing ideas, concepts, and processes. Upon investigation several design platforms were identified as viable options with Miro being selected as it was simple, intuitive, had good tutorial support to help staff get up to speed, and was free for academic use.

The second challenge was to adapt the process to an online environment. The principal adaptations were made as follows:

1. ***Using the online space:*** recognition that tolerance for working online is lower than in face-to-face situations. More but shorter group sessions were organised to avoid fatigue.
2. ***Supporting active engagement:*** The team was trained in the use of Miro and the sessions carefully facilitated to ensure that everyone was able to use the tool efficiently, and that everyone was contributing
3. ***Rebalancing the workload:*** elements of the work which had previously done in-workshop were set as homework with detailed guidelines and clear deadlines to allow the next workshop to continue. Staff facilitating this co-design approached, monitored and summarised the work done prior to the next session.

The online co-design methodology is shown below:

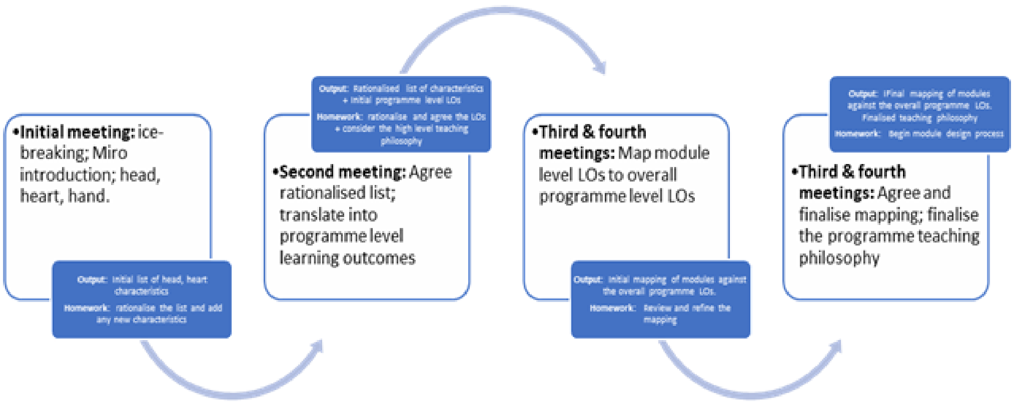

Figure 2. Standard online co-design process

In terms of institutions, then The University of Warwick is a member of the Russell Group of research intensive Universities in the UK. Situated in the middle of the UK and has almost 30,000 students registered, it is highly ranked in international league tables, including in employer reputation and targeted by UK employers. The specific unit within The University of Warwick has had a strong focus on academic-industry links, with co-creation being central to its accredited programmes with international employers.

University of Eswatini is located in a small country based in Southern Africa, classified by the World Bank as a lower-middle income country having a young-aged population. However, the distribution of wealth is highly skewed with nearly 60% of the population, predominately from rural areas, living below the poverty line **(**living on less than US$1.9 a day**)** with 20% being considered extremely poor. University of Eswatini has three campuses with 7000 enrolled students across 40 Bachelor's and Masters' degree programmes, as well as two PhD programmes. Its programmes are typically four years in duration (with Engineering being five years), being mainly traditional academic programmes – either delivered on campus or through distance learning. In the context of this paper, then University of Eswatini has limited experience in the creation of co-designed WBL programme in Engineering, but through a Royal Academy of Engineering funded project that began in 2019, it has committed itself strategically to develop a range of WBL programmes, starting with Electrical and Electronic Engineering. It is in this context, that the methodology previously applied at The University of Warwick was selected to support the co-design during COVID-19 at University of Eswatini, thereby offering an opportunity to compare and contrast the implementations between the UK and Eswatini contexts.

Consequently, this paper aims to answer the question “What considerations are required to support an effective online process to co-design a work-based learning programme in Engineering?” Next, the methodology will be outlined before the initial findings from this research will be detailed, with conclusions and next steps being outlined finally.

2 METHODOLOGY

A qualitative methodology was chosen to answer the above research question, by seeking to capture the experiences and insights from those leading the co-design process. In this research, the authors are both researchers and active participants in the process, so collaborative autoethnography has been chosen as it allows reflective and reflexive consideration and shared sense-making of lived experiences. Autoethnography is a qualitative research methodology that has emerged from the authentic exploration of under-represented voices, but it is increasingly being used in areas of professional practice. The research involves the self, a process and culture, and offers an approach that goes beyond autobiographical (personal ‘stories’), as auto-ethnography is about interpreting those stories/experiences – the interplay between the individual and others. As co-design involves different stakeholders, then the interaction between individuals and their context is an important dimension of success. Collaborative auto-ethnography emphasises more clearly the collaborative aspect – where participants seek to explore, outline (and potentially make sense) of shared experiences [21].

Throughout the co-design processes, the co-researchers have made notes about the process, their reflections and experiences – along with what worked well and what worked less well. The co-researchers then have used these notes to write an individual reflection around the experiences that sought to capture views from before the co-design process started (previous approaches to programme design) to their experiences of the online co-design process in Eswatini. These individual reflections were then shared with each other, reviewed separately by each co-researcher, commented on and then individual observations were discussed together in online discussions to extract the main considerations (differences and similarities) between the two implementations. These shared perspectives and insights around key considerations are shared in the findings section.

3 FINDINGS

The discussions around the individual reflections highlighted several shared perspectives that are relevant to the research questions, namely the considerations that influence the on-line co-design of a WBL programme, these being 1) Organisational environment; 2) People and culture; 3) the co-design methodology and 4) Technology and its use in the co-design process. In terms of sharing the findings, we identified that in the case of Eswatini that the knowledge transfer around the co-design methodology and designing the programme happened contemporaneously, so our findings provide insight into both the methodology, and around factors that influence its adoption.

Firstly, any programme development takes place within an organisational context that includes the systems, policies and processes, administrative structures, relationships and roles and responsibilities. It was common in reflections to acknowledge that the existing university programme development processes were often seen as bureaucratic and overly content focused. Additionally, that these processes relied on a small group of academics, with varying levels of engagement with industry and other stakeholders, so any new programme (re)developments were often iterative rather than a stepped change. In essence, don't rock the boat. In contrast, co-design resulted in positive examples of co-operative development that created a shared vision and collective accountability - a positive aspect for the ongoing health of the programme. We recognised that policies and procedures and their embodiment in practice are important, as this can provide a shared language and set of expectations, e.g., around outcome-based design. Without that collective understanding, then collaborative design is more challenging, so establishing common ground between participants is key.

Where commonality is not present then recognising that there is an ongoing change process was viewed as another key consideration. For example, the engaged form of shared development mentioned above required a change – in outlook, and in methodology – and often having the right people in place. Management of change requires sustained levels of senior management support, leadership, time and resources, and accompanying training. The readiness to change is also important. In the case of Eswatini, then having an externally funded project was supportive to such an endeavour, whereas in the UK new standards and a clear institutional vision for a new model brought about a shift in mindset and approach in the team (industry and academia).

Additionally, in co-design, there are not just intra-organisational dynamics but also inter-organisational relationships. In the context of change, then the reflections and discussions highlighted positive and trusting relationships as crucial: between colleagues, across internal organisational boundaries and between organisations. For example, in the case of Eswatini, then key relationships amongst industry and academic colleagues was vital, particularly when there were frustrations (e.g., around pace and progress, as well as understanding their role within the process); they were the lynchpins. The co-design methodology did provide opportunities for sharing and building confidence in each other, but as trust was growing through this process, then we felt that levels of engagement in workshop activities were influenced accordingly.

Encompassing this last point, around relationships and trust, then the second area was around people and culture. Specifically, the importance of having the right people in place, with the required vision, knowledge and relational skills was identified. Whilst leadership - "*champions*" (C2) - was known to be important traditionally, the broader set of skills for co-design amongst academic programme development leaders was expressed by several of co-researchers. As mentioned above, colleagues in Eswatini were learning about the process at the same time as using it. However, core members at University of Eswatini had gained a deeper understanding of WBL through a placement in the UK and ongoing knowledge exchange, and this knowledge around the vision for WBL and the co-design process was key for maintaining progress and answering questions from their academic and industry colleagues. Additionally, these change champions were vital to bridge the differences between industry and academic colleagues, and to highlighting uncertainties and how best to adapt the methodology. In the UK, having both champions in industry and academia was found to benefit the process. Furthermore, the influence of different working cultures on how participants engaged with the development process was evident – with greater asynchronous discussions in Eswatini, as compared to the directness in the UK case in synchronous activities "*I have time in my diary so let's get this done now*" (C6).

The third area was around the co-design methodology. The underpinning concept – Signature Pedagogies – was found to be applicable in both cases. It encouraged greater collaboration and engagement between academia and industry with a focus on the outcome of the programmes, and not on content. Differences between the two implementations emerged around the balance between synchronous workshop activities and asynchronous/offline development – with the UK activities being more focused around synchronous workshop activities with less done off-line, and in Eswatini considerable progress on 'homework' between workshops was achieved (facilitated by change champions mentioned above). As discussed below, some of these differences in implementation may be due to technology limitations, but may also reflect that colleagues were learning about the methodology and applying it concurrently, so the inter-workshop meetings provided a space to reflect and take forward the activities. The time for this new approach was identified as unexpected (due to the need for greater collaboration) with a lesson being that reminding colleagues about the overall vision, process and benefits needed to be repeated several times. Related to this, the division of labour (between industry and academia) represented a change in previous working, with differences between the two cases evident (UK were more comfortable being involved with details of programme design, whereas in Eswatini after agreeing overall programme outcomes, the expectation was for academics to develop the detailed programme for review by industry). Such differences potentially reflect that various levels of engagement are possible in co-creation [11], and that engagement throughout the process appears to be dynamic. Such variation in engagement (and therefore perceived progress) needs to be managed well.

Finally, as this process was conducted online using online tools, then there were technology-related issues. Miro did provide a shared working space in both cases, but was used differently – in UK case for both synchronous and asynchronous work, whereas for Eswatini was a tool for synchronous workshops and a record of consensus building. Additionally, in Eswatini there were technical issue accessing Miro – initially related to firewall configuration – but consistently related to bandwidth constraints. Moreover, for new users of Miro, it takes time to learn how to navigate and use tools, so greater attention needs to be paid to introducing the tool and how to use it before it is used as part of the co-design methodology process. Other online tools (e.g., Padlet) were found to work better for some later activities in the process, so careful consideration to the mix of online tools in each case is another key consideration for future application. Finally, we felt that the online tools failed to develop the same level of relationships, which as identified above is important for the success of this approach.

4 SUMMARY AND ACKNOWLEDGMENTS

In response to the research question, "What considerations are required to support an effective online process to co-design a work-based learning programme in Engineering?" then, through a collaborative auto-ethnographic methodology, we have identified four main considerations: 1) ensuring the correct organisational environments (industry and academia) for a co-design approach to succeed; 2) the importance of having appropriate people with the necessary knowledge and skills to lead that process (in both academia and industry); 3) that the Signature Pedagogy approach worked well to facilitate agreement on desired outcomes, but that the detailed aspects of the co-design methodology needed to be adapted to the working cultures and expectations. Moreover, the importance of reminding co-participants around the vision and benefits of this approach, was seen as vital; 4) that different technology tools can facilitate the online collaboration necessary for co-design, but being clear about how tools will be used, and aligning to bandwidths as well as proficiency in these tools is important for their successful use. These findings indicate that this co-design methodology is applicable in a significantly different context with the above identified adjustments.

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Collaborative, multidisciplinary, international, and societal relevant: A framework combining challenge-based learning and thesis writing across European universities

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ABSTRACT

ECIU University is an EU-funded European University initiated by a network consisting of 13 universities across Europe. At its core is collaborative learning and research on a European level in close connection with various stakeholders to tackle societal challenges. Learners are engaged in joint project work based on the approach of challenge-based learning (CBL). Here, learners are actively involved in a real and relevant setting. Teams are composed of learners coming from different cultural backgrounds, disciplines, and levels of progress in their individual studies. A challenge within the ECIU framework starts with a “Big Idea” in the area of the UN Sustainable Development Goal 11 “Sustainable cities and communities” that has potential for societal impact. ECIU University offers four types of challenges that differ in length and depth. Within this paper, the first run of an ECIU Strategic

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Challenge, the most complex challenge type, is introduced. The Strategic Challenge is a six-month format that combines individual working phases while writing on one's master's thesis with collaborative working phases while cooperating closely in the team challenge. Hence, it offers a framework in which the progress of challenge and master's theses are expected to go hand in hand. The concept of how students collaborate in the Strategic Challenge builds up upon the Erasmus+ projects COLIBRI (Collaboration and Innovation for better, personalized, and IT-supported Teaching) and its follow up EPIC (Improving Employability through Internationalisation and Collaboration).

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1 INTRODUCTION

The ECIU[2] University is an Erasmus+ funded alliance that brings together 13 European universities[3] and one associated member to address societal challenges faced by European countries. Students and university teachers from all ECIU partners, stakeholders from business and public organizations, as well as citizens come together to engage, investigate and act to find innovative solutions for real life challenges with real societal impact. The educational framework of the ECIU University offers a creative, inspiring, and meaningful learning environment in engineering education. It is based on the pedagogical approach of challenge-based learning (CBL). Within the framework, four types of challenges are offered: Nano Challenges, Mini Challenges, Standard Challenges, and Strategic Challenges [1]. The challenge types differ in their length resp. workload (30 hours to 360 hours) and depth (level of CBL phases). This paper introduces the first run of an ECIU Strategic Challenge. The pilot of the Strategic Challenge is a six-month format that combines participating in a challenge with the writing of individual master's thesis. The format has started in February 2022.

2 FRAMEWORK

2.1 Challenge-based learning in the ECIU context

Challenge-based learning provides an efficient and effective educational framework for learning to solve real-life challenges. The framework aims at the acquisition of disciplinary knowledge while developing transferable skills. Learners are engaged in team projects while being actively involved in a real and relevant setting [2]. The teams are composed of learners coming from different cultural backgrounds, disciplines, and levels of progress in their studies. With different stakeholders involved, CBL aims to find collaboratively developed solutions that are

[2] ECIU is the European Consortium of Innovative Universities.
[3] University of Twente, Aalborg University, Dublin University, Hamburg University of Technology, Kaunas University of Technology, Linköping University, Tampere University, University of Barcelona, University of Aveiro, University of Stavanger, University of Trento, Institut National des Sciences Appliquees, Lodz University, and TEC de Monterrey as associated institution.

environmentally, socially and economically sustainable [3]. Hence, the learning experience is international and intercultural, multidisciplinary, and collaborative. Within the learners-driven approach, students are enabled to take complete ownership of their self-defined challenge, cooperating closely with the teachers and (external) partners in a co-learning environment.

A challenge within the ECIU framework starts with a “Big Idea” in the area of the UN Sustainable Development Goal 11 “Sustainable cities and communities” that has potential for societal impact. The approach is made up of three phases: Engage, Investigate, and Act (Fig. 1). Constant documentation, reflection, and sharing is an elementary part of the entire process [1].

Fig. 1. CBL circle [4]

The engage phase is initiated by sharing the Big Idea, which is usually provided by (external) partners. Based on the Big Idea, the learners themselves define essential questions tackling related aspects according to their interest, or which skills and competencies they want to further develop.This leads to the creation of their individual actionable challenge, which is at the same time the result of the first phase. In the second phase of the CBL cycle, the learners formulate the basis of sustainable solutions to their individual challenges by conducting the actual research and analysis according to their skills and expertise. The investigate phase results in learning outcomes like reports and presentations demonstrating individual conclusions. Within the act phase, the learners implement and evaluate their solutions ideally with an authentic audience highlighting their societal impact [1].

The teacher in the overall framework guides the learners during the whole process. While promoting team culture, being challenging to the participants, and supporting learners to create actual impact, the teacher takes the role of a facilitator.

2.2 Idea of the concept

Combining the approach of challenge-based learning and writing a master's thesis shapes a novel and innovative pedagogical format. It combines working on a challenge in an international, multidisciplinary team with individual working phases when writing one's master's thesis according to home university guidelines. The concept of how students collaborate in the Strategic Challenge is based on the former Erasmus+ projects COLIBRI (Collaboration and Innovation for better, personalized, and IT-supported Teaching) and its follow up EPIC (Improving Employability through Internationalisation and Collaboration). EPIC aims to increase employability through closer collaboration between students, academia, and industry. It provides a framework for international student projects in close collaboration with companies [5]. The joint student projects in the EPIC framework deal with similar issues: different start and end times at participating institutions, different requirements from different institutions, assessment and documentation varies between institutions. To face these aspects, different models of collaboration were developed within the EPIC project that combine joint work and thesis writing [6]. These models serve as a basis for developing the Strategic Challenge collaboration framework.

3 PROJECT DESCRIPTION

3.1 Strategic Challenge as a unique master's thesis opportunity

The Strategic Challenge offers an exceptional opportunity for advanced master students to collaboratively work on a societal challenge in an international and multidisciplinary team while also individually writing a master's thesis that is linked to the topic of the challenge. Within the framework, the progress of challenge and master's theses are expected to go hand in hand and ensuring to benefit from one another.

As all ECIU challenges, the Strategic Challenge starts with a “Big Idea” in the area of the UN Sustainable Development Goal 11 “Sustainable cities and communities” and has potential for societal impact. The Big Idea in the case at hand is to develop a climate neutral campus in Europe with innovative ideas and bold solutions and thereby, advance climate protection and reduce CO_2 emission. Students are asked to develop concepts that enable their home university or any other university to reach a climate neutral campus in the future.

In the first realization of the described concept, each ECIU partner institution is asked to find one academic advisor and one master student to participate in the challenge. Participants are selected with respect to their readiness to begin their thesis and with respect to multidisciplinary. For the first run of the ECIU Strategic Challenge nine eligible students from seven ECIU institutions have been selected. Before the challenge officially starts the academic advisors are invited to a Supervisors Kick Off to learn more about the main challenge. As a result they are asked to inform their respective master student in order to get prepared for the challenge start: this means, to collect first ideas on a climate neutral campus in

Europe, however, not to elaborate on a concrete master's thesis topic yet. The actual topics are expected to be developed alongside the actionable ECIU challenge so that the master students are still flexible.

3.2 Phases and milestones of the Strategic Challenge

According to ECIU University's challenge-based learning framework, the Strategic Challenge includes three phases:

1. Phase of engagement: Students from ECIU partners enter the challenge team, narrow down the topic, develop essential questions, and define their actionable challenge.
2. Phase of investigation: With different stakeholders involved, students research and engage in activities to define a solution to the challenge. While collaboratively working in the challenge team students also work towards their respective master's thesis that are content wise linked to the challenge.
3. Phase of action: Solutions are prepared and master's theses are written. The challenge team opens the findings to society. This includes either the implementation of the outcome or delivering a product.

Fig. 2 illustrates the framework of the Strategic Challenge and shows how the three phases of CBL are combined with individual thesis writing.

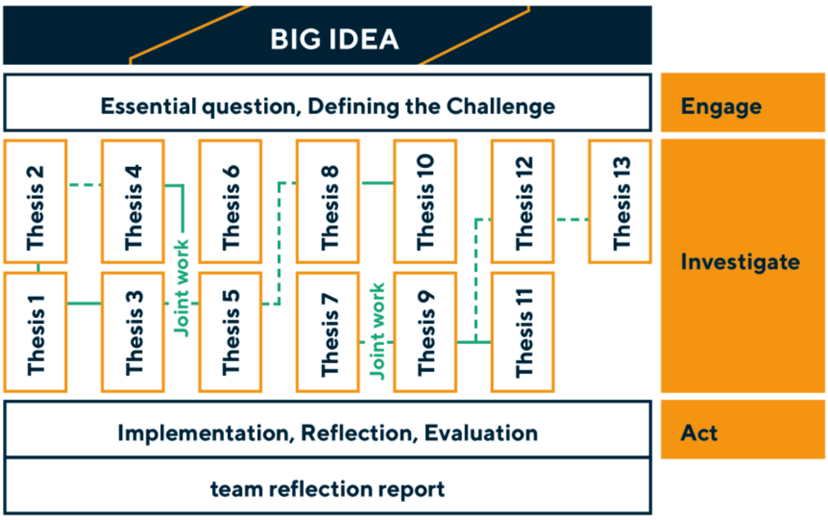

Fig. 2. Strategic Challenge framework [7]

The Strategic Challenge officially starts with a Kick Off event for the students. The online Kick Off marks the beginning of the engagement phase. Apart from getting to know one another and learning about the steps of CBL the Kick Off primarily aims at finding subgroups to form teams according to the students' interests and ideas for their master's theses. This is to facilitate that the student teams can develop an actionable challenge that can be linked to their individual theses respectively.

In the first ECIU Strategic Challenge, nine students from seven ECIU institutions work in three teams of three students each on in total three self-developed challenges based on the Big Idea of "Climate neutral Campus in Europe" (Fig. 3). The academic advisors are invited to join the sessions of the Kick Off to provide feedback to ideas. Also, they participate in a discussion on the supervisor's role in the overall Strategic Challenge.

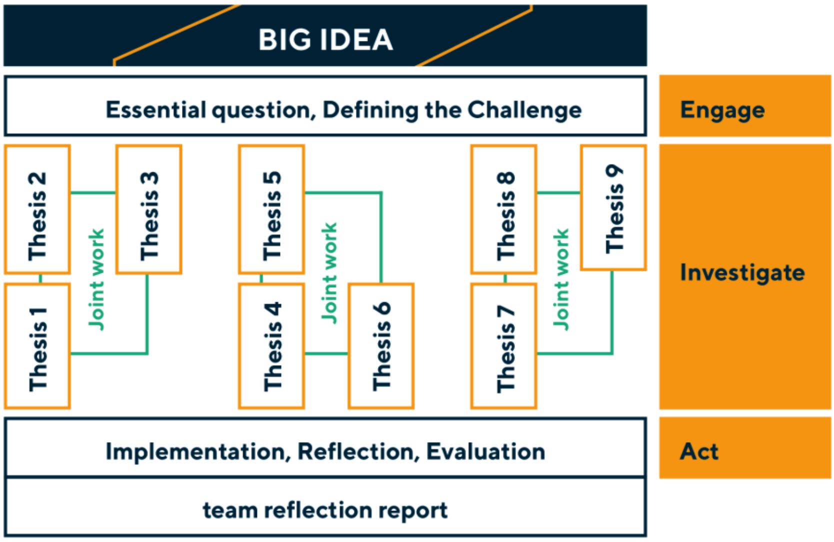

Fig. 3. Strategic Challenge 2022 [8]

The Strategic Challenge is structured by four milestone meetings for the whole group of students (one as a face-to-face meeting). Those allow the student teams to work self-determined on their individual challenge. However, during the engange phase weekly support is offered to the subteams to ensure that all teams get on the right path and manage to develop their actionable challenge. In the phases of investigation and action, biweekly support is offered to the teams to reflect e.g. on their team progress, stakeholder management, struggles, and final outcome. Also, various workshops related to team work and project work are offered throughtout the challenge to promote skills and competences required to successfully complete the project.

Continual reflection and documentation accompany all three phases. The students are asked to keep a team learning diary and submit a team reflection report at the end of the challenge. Also, opportunities to share (interim) results with the wider community are created.

3.3 Challenges of the design

The first run of the Strategic Challenge faced a few challenges that were at least attributed to the internationality of the participants. Due to different timelines and regulations of their home universities (different start points, different total duration, different submission dates) the students turned out to be less flexible concerning their thesis writing than expected. Hence, some students had already defined their thesis topic when entering the engagement phase as illustrated by figure 4. This challenges the approach of CBL that typically allows learners to individually move from a “Big Idea” to a concrete and actionable challenge. Hence, the engagement phase in the Strategic Challenge was limited since also the already approved topics had to be taken into consideration when developing a concrete challenge.

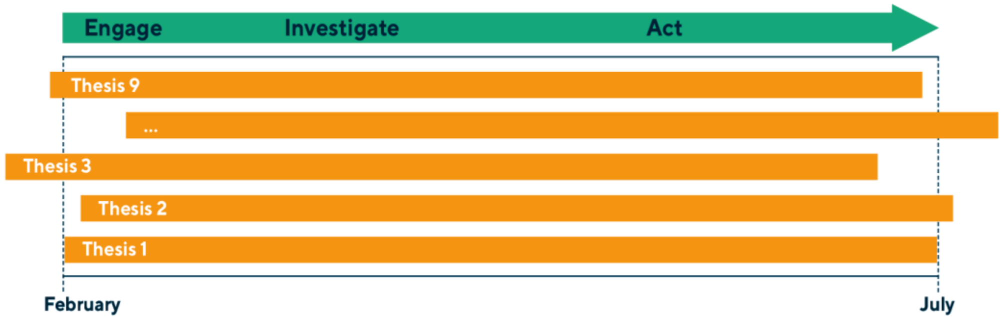

Fig. 4. Illustration of different timelines [9]

Different submission dates might have also affected the work process. While some students had to submit their thesis before the end of the challenge, others still have weeks beyond the closing event to finish their thesis. This might have had an impact on the groups’ progress and outcome.

In the learner-centered approach of challenge-based learning, the teacher usually acts as a facilitator. In the Strategic Challenge, the constellation is more complex as each student is additionally supervised in his or her master’s thesis by a local academic advisor. The supervisor’s role is primarily to supervise the thesis. Therefore, active communication and a clear allocation of roles are essential to enable a productive learning environment and to avoid potential conflicts.

4 CONCLUSION

The first run of the Strategic Challenge has been promising so far. The students worked in three subgroups on a challenge they had developed themselves from the Big Idea of "Climate neutral Campus in Europe". Although the engagement phase had to be adapted to the circumstances (some prior to the start of the Strategic Challenge approved master's theses topics) the students went through all further steps of CBL to the (planned) implementation or (initial) development of a product/prototype. The students’ commitment and the contribution they made to the project were great. Moreover, they further developed future skills like international team communication, project management, and co-operation with stakeholders. The exchange of ideas and experiences on a European level seemed to be inspiring for everyone involved. Hence, the first Strategic Challenge offered students not only a novel opportunity for writing a master’s thesis but also a unique learning experience. The main working phase is finished by now, however, the evaluation of the project is still running. First verbal feedback that we received in several settings was in general positive but also drew attention to challenging aspects of the format. Overall, the feedback indicates that the format of the ECIU Strategic Challenge is perceived as rewarding by the majority of the participants. Apart from a final online evaluation that is now in progress to find out how students and academic advisors value their participation, the group reflection reports will be evaluated to critically reflect on the concept and to derive potential improvements. In addition, interviews will be conducted with some of the partcipants to get a deeper understanding of what experiences they have made.

Based on these results, the concept of the Strategic Challenge will be optimized. The improvements will be implemented in future ECIU Strategic Challenges.

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WHY CHANGE ENGINEERING EDUCATION?: PRAGMATIC PERSPECTIVES FROM THE HUMANITIES AND SOCIAL SCIENCES

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ABSTRACT

Engineering education in the early 21st century is being transformed in many ways to meet the technological challenges of the future. In particular, the role of the humanities and social science in engineering coursework is under new scrutiny, as educators attempt to strengthen students' proficiencies in aspects of the profession including interpersonal and intercultural skills, assessment of broader impacts of technical work, and especially ethics. These developments are often framed as responses to the demands of employers and institutions, who view these 'soft' skills as increasingly relevant to the work life of technical professionals. In this concept paper, we wish to pursue a somewhat different line of thought: We will examine arguments from the philosophy of science and technology, and from the social sciences, about the value of teaching engineers (as well as other technical professionals) to think through humanistic, social, and cultural lenses. We will review a range of perspectives supporting educational reform along these lines, with a particular focus on work in the recent pragmatic tradition (including Sellars, Mitcham, and others). Having established a range of theoretical defenses for educational reform along these lines in engineering fields, we will then consider the distinctions among them and how these insights might be applied most effectively in engineering curricula. We will conclude by reviewing available evidence for the practical utility of such interventions. We hope, by situating current reforms more firmly within a principled framework of ideas, to provide deeper support for positive change in the education of future engineers.

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1 INTRODUCTION

Why change engineering education? Our title question is meant to be somewhat provocative for a number of reasons. Foremost, we observe that engineering education might be expected to change continuously in response to new developments in technical knowledge and associated technological systems. Furthermore, continuous improvement is part of the accepted ideology of both engineering fields and contemporary institutions of higher education, making change an expected default condition for curricula in general. In these senses, the answer is obvious. However, here we are concerned not with this kind of process of spontaneous pedagogical adaptation, but rather with an intentional guided shift that has been conspicuous in engineering curricula for more than 30 years – particularly in the United States – toward greater inclusion of humanistic, social, and cultural subject matter in undergraduate engineering courses, or in elective coursework associated with engineering degree programs.

In that context, our question remains challenging to longstanding assumptions about the specialized nature of engineering knowledge, as a fundamental technical skill set. In addition, it calls for consideration of what the fundamental objectives of engineering education, and higher education more broadly, are and ought to be in the 21st century. It might also provoke responses from some quarters about how to assess the merits of engineering curricula (or, again, university curricula in general) and the outcomes that they produce. As such, an examination of recent trends toward broadening engineering curricula opens up a potentially productive discussion about both educational practices and the principles they represent.

Our primary interest here is in the relationship between engineering education on the one hand, as a specific form of institutionalized technical preparation, and general education on the other, as a process of providing individuals leverage to participate fully in a contemporary society permeated by technologies and engineered systems. Recent shifts – either proposed or actually adopted – in engineering education have conspicuously focused on strengthening the capacity of students in technical programs of study to include a greater depth of humanistic and social skills. These include developing capacities in such areas as communication, team dynamics, human-centered design, ethical reasoning, cross-cultural understanding, and analysis of social impacts. All of these can be (and are usually) justified by the demands of engineers' professional role in a highly technological society: The technical preparation of 21st century engineers is understood to entail working within distinctive social and institutional contexts that require skills that are oriented more toward interaction with other people than with the technological objects that engineers devise, produce, and maintain.

2 DISCUSSION

2.1 Demands for Design Knowledge

We begin this discussion by noting that curriculum changes such as those just described have been institutionally mandated by professional accreditation boards on the basis of feedback from professional societies and consulting bodies, industrial employers, and other stakeholders. In this sense, broadening the engineering skill set is straightforwardly a matter of demand, which has been solidified by evidence for the efficacy of such changes. To remain an accredited engineering program, ABET requires specific student outcomes related to social responsibility, including "an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability", pg.1 [1].

While there is an obvious logic to this line of thought, we want also to examine some more foundational arguments for strengthening the intersection between engineering education and general education. To begin, we note some observations about the limitations of putting social awareness into practice in an engineering context. Students may absorb and retain a consciousness of such considerations while still failing to develop effective ways of incorporating them into engineering work. Within design tasks, for example, students have difficulty in connecting social consciousness with user needs. Often, when students are responsible for identifying customer needs, their efforts are limited to the results of surveys and focus groups, in which relevant data is collected early in the design process often without subsequent iterations. Students typically treat the customer as a list of requirements that serve as an input to the design process. Within this context, interventions are needed to help students better think through details beyond survey results while striving towards socially conscious levels of understanding. Designers need both domain-specific knowledge and situation-relevant strategies to design effectively [2].

It is apparent that students need to know how customer or client information influences the design of products and systems even when the human-centered details are not explicit. This thinking can be enabled through an increased level of social consciousness, or an awareness of the impact that design decisions could have on the cultural, social, and emotional aspects of the end-users. In situations where the designers lack exposure to end-users, the mapping between user needs and product attributes is non-trivial and challenging for students. Thus, while adopting this approach may provide an added level of understanding about constitutive human factors, obstacles still emerge from the diversity of users and contexts that may be relevant from one situation to the next.

2.2 Fostering the Individual Engineer

Another perspective on broadening engineering design education, less focused on the needs and wants of users, might emphasize instead the personal development of the individual engineer themselves as the primary benefit. Societies more than ever are more knowledge-based with a drive for development of new competencies effective for rapidly changing global world. In a such global society, where everyone deserves the opportunity to be educated, the philosophers Rousseau and Dewey's educational models both emphase the learner's own motivation. As discussed by Noddings, Rousseau's open education model recommends building education on the interests of students, enriched with hands on experience, and learning by doing, feeling, observing and deemphasized formal lessons [3]. Dewey is also known for his work on the role of experience and its function in education. "Experience" in the context of education, for Dewey, is personal meaning and social interaction. Dewey wanted students to experience a personally unified curriculum – one that makes sense to them in terms of human experience and particularly, in terms of their own experience [3]. This train of thought recommends a broad and flexible curriculum primarily by virtue of the beneficial outcomes expected to accrue to the engineering student. In effect, both Rousseau and Dewey are arguing for engineering education to be construed as a process of *Bildung*, in which both technical and social skills are fundamental to the engineer's personal development.

However, this perspective still leaves a significant role for social interactions and experiences in driving the process. Design is an extremely social form of inquiry. Design is defined as a reflective practice as described by Donald A. Schon [4]. Major concepts of this model are surprise and reflection. A designer or student has a canonical way of doing and something unusual happens when these practices confront a new social situation that causes the student to reflect on the situation. Surprises come from the unpredictability of design situations and a designer engages in a reflective conversation with the context and materials, a process that may aid in developing a deeper understanding of the design problem [5]. The early stage in design and the iterirative nature of design in general, resembles educational model explained by Dewey and his emphasis on immersion and experience in education. It is also highly congruent with the spiral curriculum approaches often taken by educators to guide students through a developmental process within general education. Viewed from this perspective, engaged personal development is facilitated by repeated exposure to new contexts and interactions. Engagement and development over time mitigates some of the concerns noted earlier about engineering students' initially "transactional" approach to user-centered design.

Whether motivated primarily by questions of social consciousness or personal development, advocacy for broadening engineering education ultimately entails a renewed emphasis on the professional and ethical responsibility associated with the engineering profession. In an educational environment that strongly distinguishes technical knowledge from social or human knowledge, attending to both can easily appear to be a challenging task, especially if construed as the sole responsibility of the educated professional engineer. Consider: In learning the engineering profession today, students are encouraged and expected to consider the effects of their actions (and non-actions) including the economic, environmental, political, societal, health and safety consequences of their work, while also keeping in mind the manufacturability and sustainability of their structures and products. As Robin Tatu notes in discussing the book of Douglas, Papadopoulos, and Boutelle "Citizen Engineer": "A successful 21st century engineer must become "part environmentalist, part intellectual property attorney, part MBA, and part diplomat – not to mention an expert in an engineering discipline, a great teammate, and a skilled communicator" [6] (Prism, pg.52). Similarly, the National Academy of Engineering suggested in *Educating the Engineer of 2020* [7] that:

> Within the context of the changing national and global landscape, The USA National Academy of Engineers enunciated a set of aspirations for engineers in 2020. The future engineers have to be technically proficient engineers who are broadly educated, see themselves as global citizens, can be leaders in business and public service, and who are *ethically grounded*. The committee set targeting attributes needed for the graduates of 2020. These include such traits as strong analytical skills, creativity, ingenuity, professionalism, and leadership.

Presented with calls such as these for engineering education to instill such comprehensive and multivalent competence, both educators and students have struggled to fulfill the brief. This has led to extended controversies over specifics of curriculum design (spiral or across-curriculum models, standalone courses, discipline-specific requirements or interdisciplinary elective structures, etc.) each of which offers its own benefits and limitations for content, learning, and engagement. From the perspective of student engagement in particular, it is difficult to motivate students to take ethics education seriously as ethics is usually included in the engineering curriculum as an elective.

Further, the cases use as models in teaching engineering ethics are intended to reflect ethical problems that arise frequently in engineering under rather ordinary circumstances, but undergraduate students found these dilemmas too complext. However, real-life is complex, dynamic and embigous and it is important that students understand the differences between models and real life, and the importance of selecting the model which is appropriate for the situation. One way to overcome this tension is if case studies are limited and the main focus is on cases inspired by real interviews and guest speakers from professional engineers. This partial circumscription of the framework for ethical education facilitates disciplinary engagement (per the previous paragraph) but also provides an opportunity to rehearse different perspectives as models for real human-social situations.

2.3 Building Scientific Culture

In addition, the notion of engaging with complexity through models leads back to a perspective articulated by the pragmatic philosopher Wilfrid Sellars in his 1962 “Philosophy and the Scientific Image of Man” [8]. In that essay, Sellars addresses a fundamental issue regarding the epistemological divide between scientific knowledge (collectively designated the “scientific image”) and human-social knowledge (which he refers to as the “manifest image”) – interpreting each as models of the real world to be reconciled with one another in human experience. While Sellars was concerned primarily about how philosophy might function to mediate between the (apparently distinct) scientific and manifest images of the world, his analysis also offers a new perspective on how technical knowledge and humanistic knowledge might best be synthesized – an obvious concern in contemporary debates about broadening the engineering mindset in practice.

In brief, Sellars argues that the elements of the manifest image, which include such things as intentions and communality and which represent the intrinsically social-human side of reality, must be considered as subjects for inquiry through both scientific and humanistic lenses. The central position of ethics (principles of proper action) to these concerns should be obvious. Thus, the simple moral of Sellars' argument is that principles of good judgment and knowledge of how to act are at stake in our development of knowledge about persons. The shared concerns of humanity – both in our contemporary situation and perennially – encompass multiple sociotechnical dimensions. Sellars pushes us to recognize that addressing these considerations effectively must be a holistic enterprise. On his view, it is the purpose of philosophy, as a human endeavor to produce a synoptic view of these various dimensions of reality as a precondition for fundamental understanding of the world. Philosophy not to be thought of as an intellectual activity in isolation, but rather philosophical perspective serves as a mark of both personal education and cultural development. The emphasis is less on individual *Bildung* than on social progress through collectively shared knowledge. This is not an argument against disciplines *per se*, but a recognition of the value in bringing disciplinary perspectives into conversation with one another more effectively. This requires some level of shared education at the individual level, as well as coordination of communities of knowledge.

Bringing this train of thought back into contact with our concerns about engineering education, Sellars' viewpoint attempts to break down the division between technical and non-technical knowledge that looms so large in debates about how to broaden the engineering mindset to include human and social factors. In his own words,

> [T]he conceptual framework of persons is not something that needs to be *reconciled with* the scientific image, but rather something to *be joined* to it. Thus, to complete the scientific image we need to enrich it *not* with more ways of saying what is the case, but **with the language of community and individual intentions**, so that by construing the actions we intend to do and the circumstances in which we intend to do them in scientific terms, **we *directly* relate the world as conceived by scientific theory to our purposes, and make it *our* world** and no longer an alien appendage to the world in which we do our living [8].

Thus, in our context, the fundamental pragmatic argument that Sellars is making can be summed up as follows:

1) The historical development of science and technology has led to an apparent – but ultimately false - dichotomy between two worldviews: One founded in reason ('scientific image') and the other in human intentions ('manifest image').
2) Among the consequences of this false dichotomy is an externalization of ethics from technical work. This is a problem for engineering education.
3) Human-centered development of science and technology requires greater attention to the individual and collective phenomena of human experience.
4) New knowledge from the social sciences can serve as the fulcrum point for this reconciliation.

Ultimately, then, Sellars' perspective suggests that the key to developing the kinds of engineers being sought by advocates of change today is to embrace an interdisciplinary vision of knowledge that focuses in particular on sciences of humanity in all their apparent complexity. From a practical viewpoint, this would entail a greater pedagogical emphasis on boundary crossing and developing capacities to take multiple perspectives on real world issues, especially beyond a narrow conception of scientific knowledge, as well as a shift in priorities for associated research programs across the modern university. In other words, Sellars encourages us to think about issues in 21st century engineering education from the standpoint of comprehensive institutional change, not merely curriculum change.

This vision is strongly echoed in a variety of recent sources in the social sciences and humanities. For example, one recent review of the social sciences in the United States notes a number of characteristic conceptual foci guiding contemporary work, including 'comparative historical sociology', 'social causal mechanisms', 'new institutionalism' and the 'cultural turn'. Taken together, these emphases reflect several foundational principles: that social – and by extension sociotechnical – outcomes are best viewed as deeply and causally contingent on circumstances requiring case-by-case study within a context of social entities and institutions by means of a heterogeneous interdisciplinary array of methods. One of the key challenges involved in sustaining such inquiry is to coordinate and communicate among the various contributing fields. Another key point of reference is the National Science Foundation's recent survey, Rebuilding the Mosaic [9]. This synthetic treatment of prospects for productive investment in the social, behavioral, and economic [SBE] sciences notes an emerging focus on work with systematic, synthetic, problem-oriented, and data-intensive dimensions. It documents interdisciplinary transformations encompassing not only greater collaboration within and among SBE fields, but also stronger bonds with STEM and humanities fields as well. The four central thematic areas identified in the Mosaic study highlight issues of population, resource access, communication, and technology, and emphasize the challenges of tracking the social environmental mechanisms involved in the disparate paths of different cultures to material and intellectual stimuli; fostering interaction among technical communities and interested publics; and negotiating global versus local interests, values, and cultures. This cross-section of global ethics concerns represents an important connecting thread between inquiry in a wide variety of critical and interpretive disciplines. The same concerns are also articulated in Frodeman and Mitcham's recent call for a 'broad, deep and critical' interdisciplinarity spanning – and transcending – academic boundaries as a means of integrating contemporary knowledge for the formulation of better STEM policy [10].

3 SUMMARY

While this brief survey can only indicate some of the factors that motivate contemporary change in engineering education, we hope that we have at least indicated a few significant distinctions apparent in calls to broaden technical curricula to incorporate specific humanistic and social skills that are more traditionally associated with general education. These different – and potentially mutually reinforcing – motivations reflect an intersection of priorities from professional, pedagogical, and philosophical perspectives. At one level, attention to human-centered design practices has stimulated greater recognition of the value of social knowledge within the engineering workplace. At another, studies of educational engagement suggest that broadening curricula will foster a more satisfied individual engineer, thus making the profession more attractive to a greater spectrum of students. Further, philosophers of science have observed that the demands of modern technological society require new kinds of practical knowledge that are based in human and social factors. While oriented toward different positive outcomes, all of these stimuli point toward a congruent strategy for improvement in the education of engineers, with the common thread being that an ability to contend comprehensively with issues of values – at the level of the individual, the profession, and society at large – is increasingly required in today's world.

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Restoring the prestige of the engineering education through a fourth engineering wave in the development of the fundamental scientific knowledge of economy

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ABSTRACT

There is no doubt that in the EU and the USA, engineering education has completely lost its previous prestige. The finest youths have shifted away from aspiring to become engineers towards aspiring to become professional economists and businessmen. It has been forgotten that the enterprises for machines, which are best understood by engineers, are the backbone of every national economy. Furthermore, the lack of human capital capable of managing their economy efficiently, as well as supporting their internal activities, will lead not only to us observing a shift of the finest youths steering away from engineering but also a shift away from a sustainable economic future.

This paper presents a new approach that will bring back the previous and well-deserved prestige of the all-important engineering education, a prestige connected to the names of Henry Towne, Frederick Taylor, William Deming, and all the engineers responsible for the three engineering waves in the development of the fundamental scientific knowledge of economy. However, we find ourselves on the brink of a fourth engineering wave in the development of the fundamental scientific knowledge of economy. A wave connected to the Bulgarian-based Institute for Systemic Economic Engineering, which has successfully developed a systemic universal model of the enterprise for machines, a model widely thought to be impossible to develop, but if developed successfully, would bring economic changes equal to the combined magnitude of the economic changes brought by all the previous engineering waves and would form a new type of professional defined by the term “systemic economic engineers”.

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1 INTRODUCTION

For us, engineers, it is a well-known fact that the world we live in would not be as we know it today without the enormous advances of the industry for machines[2,3]. It is perfectly clear that today, the industry for machines represents the basis for the operation and development of all other industries. If some unknown force suddenly wiped out all machines in our contemporary world, this would lead to a devastating calamity comparable to a nuclear war.

The fact is that the modern world owes its level of development precisely to the industry for machines. But it would be impossible to establish, maintain, or develop the industry for machines without the existence of a huge multitude of engineers. This status of the industry for machines as leading in the development of all other industries means that engineering positions must be of the highest level of importance and be desired by the most qualified young people in the modern world.

And while this was the case for the majority of the 20th century, in the 21st century this significance and hence prestige have been questioned. The technical universities in the Western world find it increasingly difficult to fill their student quotas, while the industry has been experiencing "acute hunger" for engineering personnel. At the same time, we observe huge growth in all kinds of socio-scientific professionals and, above all, professional economists.

With this concept paper, we will briefly outline the causes of the shocking loss of prestige of the engineering education, but most importantly, we will present a concept for a Fourth engineering wave in the development of the fundamental scientific knowledge of economy, which aims to reorient the population back towards the engineering profession.

2 METHODOLOGY

The methodology for developing the current *concept paper* is as follows:

The method of sourcing *"secondary data"* is used multiple times – this is done to obtain data on the state of the engineering education "past and present".

The methods *"library research"* and afterward *"in-depth analysis"* of selected parts of their content are dominant in the current *concept paper*. Using these methods, we will prove to the scientific community that there is a great necessity for the creation, development, and mass dissemination of a new quality of fundamental scientific knowledge of economy through a Fourth engineering wave in the development of this knowledge. A wave that is of key importance in the restoration of the prestige of the engineering profession, but also for securing the future development of our world.

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[2] **Machine** - In the context of the term industry for machines, "machine" is the umbrella term that covers all of the various kinds of machines, which include: mechanical, electrical, computer, automotive, aerospace, hydraulic, etc.

[3] **Industry for machines** - the multitude of enterprises providing machines and spare parts to all industries as well as the multitude of enterprises providing services for those machines.

3 BACKGROUND

3.1 The state of the engineering education at the beginning of the 20th century and the three engineering waves in the development of the fundamental scientific knowledge of economy

By 1903 the United States of America and Europe were producing thousands of engineers per year, compared to the insignificant number of business personnel (about 30 people). [1] [2] The engineering profession was particularly celebrated during that period due to the fact that most Western countries were in the process of industrialization, with the U.S.A. at the forefront of this process. Many famous engineers stood behind the industrialization of that time. But optimizing the management of all these enterprises for machines required the development of a new type of knowledge to complement the technical skills of engineers. A necessity emerged for knowledge of the principle set up and way of functioning of the enterprise for machines, which would derive universal approaches to management. Such knowledge — towards the end of the 19th century — was absent. The realization of the absence of such understanding gave rise to the *First engineering wave* in the development of the fundamental scientific knowledge of economy[4].

This wave is associated with the names of the engineers Henry Towne and Frederick Taylor, two prominent members of the American Society of Mechanical Engineers (ASME). Henry Towne reached the conclusion and declared in his work “The Engineer as Economist” (1886) that *“(Shop management) should come from those whose training and experience has given them an understanding of both sides (viz.: the mechanical and the clerical)...* ***for the reasons above indicated, particularly from mechanical engineers.****”* [3] The First engineering wave creates, develops, and disseminates knowledge of operational modeling of the production processes in an enterprise.

The First engineering wave is followed by another two. The Second engineering wave of development of the fundamental scientific knowledge of economy covers the 1930s, 40s, and 50s. It involves the creation, development, and dissemination of knowledge of production management focused on quality. It is associated with the names of the US engineers Walter Shewhart, William Deming, and Joseph Juran.

By 1950, the number of engineering graduates compared to business and economy graduates was almost equal, but still in favor of the engineers. Dozens of people were fighting for a single place in the technical universities, and the West held a “comfortable” leadership position in a geopolitical plan.

The Third engineering wave covers the 1970s, 80s, and 90s. It involves the generation, development, and dissemination of knowledge of computer-integrated modeling of the sales processes, manufacturing processes, and manufacturing supply processes.

The key concepts for this knowledge are MRP I (Material Requirements Planning) and MRP II (Manufacturing Resource Planning). MRP I refers to knowledge of computer-integrated modeling of the sales processes, manufacturing processes, and manufactur-

[4] The knowledge about management of the enterprise processes is fundamental for the knowledge about management of the enterprise economy.

ing supply processes without taking into account the production capacity of the enterprise. MRP II refers to the same type of knowledge; however, it also takes into consideration the production capacity. The Third engineering wave of development of the fundamental scientific knowledge of economy stems from the work of two IBM engineers – Joseph Orlicky and Oliver Wight.

The purpose of all three engineering waves was to address the deficit of knowledge of the management of the economy of the enterprise for machines. Even though they provided extremely useful practical solutions, they had not reached a holistic knowledge of management; holistic knowledge, which consisted of unified theory and terminology about the principle set up and way of functioning of the enterprise for machines. It is not clear why American engineers abandoned that goal. The emergence of ERP, the successor of MRP, should have been a step in this direction, but by that time the positions of "ideologues" who affected the direction of development had become the representatives of the different economic schools. They integrate various "business" modules to the classic MRP system. However, this approach leads to the significant departure of the functional constructs of all modern ERP systems from the cognitive universalism, which is inherent in the functional construct of every pure, application-free MRP system.

Nevertheless, it is precisely the three engineering waves and the serious achievements of engineers that gave rise to the United States as a world economic power, as well as the "economic miracle" of Japan after World War II.

3.2 The state of the engineering education today

In recent years, we have observed a huge "outflow" of students from technical universities in the West. An outflow, that is paradoxical, as it is the engineering profession that allowed the Western world to become a world leader. For technical universities, it has become increasingly difficult to fill their quotas of engineering majors due to a lack of candidates. According to data for 2020 at the Technical University of Sofia, the enrolled number of students is only 50 % of the university's total capacity, even though the entry requirements are as low as possible (admission in the program is dependent upon a matriculation exam in the Bulgarian language). [4] This is not an isolated case and unfortunately, it is not only happening in Bulgaria. It is a fact throughout the Western world. Even technical universities in countries with rich manufacturing history, such as Austria and Germany, cannot fill their universities' capacities. Why do we say the Western world? Because in the East - China, Japan, and South Korea - the situation is rather different, as shown in Figure 1. Meanwhile, the Western industry is experiencing an "acute hunger" for engineers and technical specialists. Therefore, we need to ask the question *"Which majors related to the management*

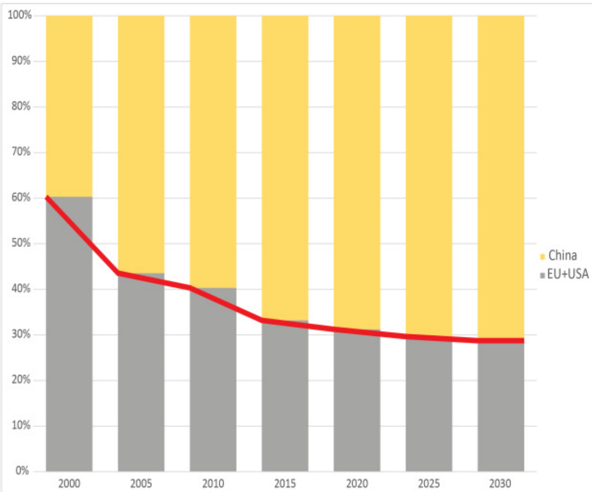

Figure 1. The trend of development of engineering personnel in the Western world and China.

of the real industry do students pursue?" The answer is the disciplines related to economic science - *Economics, Business and Management, Entrepreneurship,* etc.

In the United States during the 2018-2019 academic year, 426,000 undergraduates graduated with a Business and Economics major, and only 190,000 undergraduates graduated with an Engineering major. In the EU, the situation is no different: 459,000 graduates with a Business and Economics major and 280,000 with an Engineering major.[5] [6] The quality of incoming students in the engineering majors is also questionable. In 2004, for every 100 applicants, only 20 were admitted to the TU-Sofia, while in 2021, there was no competition whatsoever. [7] And as we know, quality is found in the competition. As of today, in the Western world, the number of undergraduates in business and economics disciplines has increased by a factor of 10 since 1950 and engineering only by a factor of 3. Perhaps the Western world's loss of leadership in the global economy to the advantage of China is not accidental either.

3.3 Causes of the loss of prestige in the engineering education

The reasons for the loss of interest in the engineering field to the benefit of the economic field are numerous. The very word "Management" in the Business Management degrees gives the impression that it provides students with high-quality management skills and abilities. Indeed, it is a fact that an economics degree is required to undertake a managerial position. Another reason is the fact that an engineering degree is much more difficult to complete than an economics degree since economic science lacks uniform theory, terminology, and systematic upgrade of knowledge.

However, there are also more global reasons, such as the political ideology of the *knowledge economy* adopted by the West between 2000-2010. According to the Lisbon Strategy, the countries in the West should *"get rid of the outdated manufacturing and to focus on innovation,"* and above all, focus on the services sector – financial services, legal services, and consulting services for "effective management of the economy". Thus, candidates began to shift from engineering professions to a range of social science professions, especially professional economics, and we can observe this decline as shown in Figure 1.

This is all the more unwise because by giving up the industry for machines and the development of numerous and capable engineering professionals, Europe and the United States are voluntarily giving up their geopolitical leadership position. Furthermore, it is becoming more and more evident how they are losing their advantage in innovation and even worse - becoming extremely dependent on China's industry for machines. A fact that was made clear during the "COVID 19" crisis. What does the future hold? The cultivation of countless social scientists and, above all, professional economists at the expense of engineering specialists will lead the Western world to the inability to maintain and develop its current industry for machines, which would eventually lead to industrial collapse. But why can't we rely on modern economists to create, develop, and disseminate practically effective scientific knowledge for the management of the existing industry for machines?

Our in-depth studies of the numerous parts of the modern fundamental scientific knowledge of economy show that the most significant ones (from a practical point of view) are: knowledge of accounting, knowledge of productivity and quality management, and knowledge of production planning and control by utilizing the MRP algorithm. The first was the work of a monk, and the other three were the work of American engineers. Among these, and all other parts of the fundamental scientific knowledge of economy, there is a lack of unified theory and terminology that would allow graduates of this field to speak a common managerial language. For comparison, the state of medical science was similar before the introduction of the systemic anatomical and physiological model of the human body. This means that in the age of digital information technology, the fundamental scientific knowledge of economy is still at a scholastic level of development, compared to the level of development of the fundamental scientific knowledge of medicine. A fact that is reflected in numerous quotations from the great engineers before us:

Henry Towne, 1886: *"(Management of works as a science) is unorganized, is almost without literature, has no organ or medium for the interchange of experience, and is without association or organization of any kind.";* [3]

Oliver White, 1981: *"…but where in our manufacturing economy is a school on how to run a manufacturing business in all of its facets? What about the subject of manufacturing itself? … There is not even a well-defined body of practical knowledge on the subject. There are virtually no college textbooks that address the subject from a practical viewpoint."* [8]

What about today? Our survey of economics students from the leading business universities in Bulgaria has shown that economics students, even when allowed to use specialized literature, are incapable of providing a uniform explanation of the objective meaning of terms such as *economy* and *economic science*, *goods* and *service*, or explain the principle set up and way of functioning of an enterprise for machines. One disregarded reason for youth unemployment lies precisely in the fact that our educational system produces graduates who are incapable of meeting the demands of the labor market, both in terms of professional orientation and in terms of the quality of their preparation.

Today we are witnessing how after enrolling in economics and business majors, Europe's youth with the greatest potential do not receive practically useful knowledge for managing the real industry. It turns out that the European educational system has been turned into a machine for intellectual and professional distortion of its most valuable human resources. It sounds absurd, but this is a fact. A fact, which presents a grave issue for the future of the European world.

3.4 A concept for a Fourth engineering wave in the development of fundamental scientific knowledge of economy

Today we live in the age of the so-called '"Industry 4.0". An age when many new technologies are expected to emerge and be produced in "smart factories". This poses a serious problem for the entire Western world, namely that modern economics education does not provide practically useful knowledge for re-engineering already existing enterprises, or for creating entirely new ones. At the same time, a huge number of young people are directed precisely towards an education in economics in search of this kind of knowledge. Unfortunately, it is not possible to rely on the elder generation that created the vast industry for machines of the West, as these people are either retired or no longer among the living. The currently existing huge shortage of engineers and technical specialists is of no help either. Thus, the Western world is faced with the task of creating an industry for machines of a higher quality without the know-how for this process and without sufficient engineering personnel to fulfill it. This is a prerequisite for a huge division between the West and countries like China – where the specific knowledge is also missing, but their enormous engineering armies and models derived from practice, which they duplicate with phenomenal speed have already earned them the title of “new technological leader”.

This means that we, the engineers, especially those at the head of the engineering organizations of our Western World, need to take cardinal measures responsibly and quickly in order to return the interest, and hence the prestige, in the engineering education and to direct more and more young people back towards it. This can be realized through a Fourth engineering wave in the development of fundamental scientific knowledge of economy. A wave that would complete the work of all the great engineers before us and would consist of the creation, development, and above all, dissemination of a new class of digital technologies for managerial modeling of the economy of the enterprise for machines. Technologies whose functional construction includes knowledge of a universal model of the economy of these enterprises, which describes their basic structure and way of functioning as a systemic object and subject.

4 RESULTS:

4.1 Is it possible to create a universal model of the economy of the enterprise for machines?

Perhaps we also would not have arrived at the concept of a Fourth engineering wave if we were not convinced that such a model really exists. One such model, the only one we are aware of, is the result of more than 20 years of efforts by the Bulgarian Institute for Systemic Economic Engineering (ISEE). During all those years, the main goal of ISEE was to prove to the world that a new generation of holistic ERP systems can be created. ERP systems that are currently available on the market (without exception) are built on the basis of a fragmented (scholastic) fundamental scientific knowledge of economy – knowledge that we have repeatedly found to have large functional gaps.

In this regard, the new ERP systems are completely different. Their engineering design is based upon a holistic fundamental scientific knowledge of economy, which provides a clear understanding of the principle set up and way of functioning of each enterprise for machines as a systemic object and subject. This knowledge is available in the form of hundreds of pages of theory and terminology. This difference opens up the possibility for the new ERP systems to entirely outperform the systems that are currently available on the market. This superiority is clearly observed through a direct comparison between the current prototype of the new holistic ERP system created by ISEE and all currently-available ERP systems. All developments made by ISEE were subjected to practical testing in functioning enterprises for machines.

A number of scientific discoveries were made as a result of the testing activity, two of which have the most significance. Both are defined as "cognitive engineering platforms" for understanding of the enterprise of machines as a systemic object and a systemic subject simultaneously. The first cognitive platform provides knowledge for the understanding of an enterprise for machines in its capacity as a systemic object, which exists as a result of the synergy of five functional systems. The visual representation of the cognitive platform created by ISEE for the understanding of an enterprise for machines as a systemic object has the form of a cross and is called the "Industrial Cross" (Figure 2). The second cognitive platform provides knowledge for the understanding of an enterprise for machines in its capacity as a systemic subject. Within the second cognitive platform, the enterprise for machines is considered as a complete subject, characterized by an inherent, hierarchical system of five types of knowledge, including a system of responsibilities for continuing its own existence. The visual representation of the cognitive platform created by ISEE for the understanding of an enterprise for machines as a systemic subject has the form of a tree and is called "The Tree of Industrial Cognition". The knowledge of the universal model of the economy of an enterprise for machines is extremely extensive and is not within the scope of the current paper. It is presented in the book "Business Model Ontology: The Basis for Digital Reform of Economic Science".

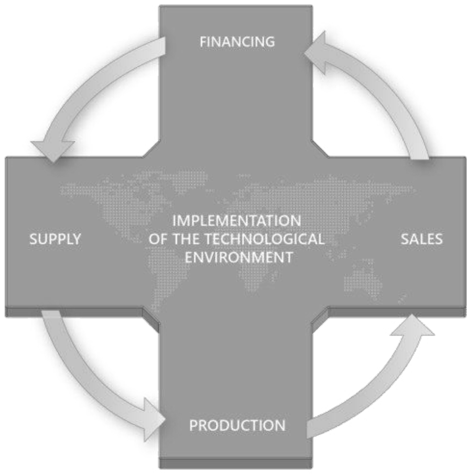

Figure 2. The Industrial Cross

4.2 Results of the implementation of the holistic ERP system, bearer of a universal engineering model, within enterprises for machines.

The developed knowledge of the universal engineering model and the holistic ERP system built on its basis have been applied and experimented within mid- and large sized enterprises for machines in Bulgaria and Russia. Once the engineering staff mastered the knowledge and application of the ERP system, they were able to carry out activities within their enterprises at a significantly lower cost of resources and within a shorter period of time than the much more experienced international consultants. Some of the experiments included:

- Large-scale re-engineering of an enterprise for hydraulic cylinders, consisting of more than 500 workers. During the re-engineering process, more than 70% of all workplaces were restructured and relocated. Notably, this process was completed without any suspension or even delay of the production processes.

- Assimilation and modernization of the constructive and technological documentation of axial piston hydraulic pumps and motors and their subsequent implementation in production, technology which had previously never been produced in the Balkan Peninsula. The results of this experiment are spectacular: five young machine engineers, who did not have any prior experience in plant design but were very well versed in the ISEE ERP system, managed to design, build, and ensure the operation of the extensions of the technological environment of two plants. They accomplished all this for the same amount of time and money that foreign consulting companies required to simply update the product documentation.

These, as well as other such results, have proven that after only several months of study of the universal model of the enterprise for machines, engineers with no substantial experience in managing enterprises can achieve practical results that even the most renowned professional economists cannot accomplish[5].

4.3 Potential outcomes of the Fourth engineering wave in the development of fundamental scientific knowledge of economy.

We will try to briefly present the potential effect of the theoretical and practical study of knowledge of the functional construct of the holistic ERP systems by students studying engineering majors.

The people who should consider this knowledge to be of the highest priority and should study this knowledge are engineers, and more precisely machine engineers[6], as the real professionals who create, develop, and manage the industry for machines. This view is in complete agreement with the concept of "The Engineer as Economist" – an idea born in the late 19th century that led to the three engineering waves in the development of the fundamental scientific knowledge of economy, but which has remained incomplete to this day.

The only viable chance for a dignified and equitable development of the Western world by reducing the technological lag in comparison to China is through the realization of a Fourth engineering wave in the development of the fundamental scientific knowledge of economy. This wave will lead to the finalization of the work of the American engineers, Henry Towne and Frederick Taylor. A finalization, crowned by the emergence of a new generation of machine engineers, which we define as "*systemic economic engineers*".

A *systemic economic engineer* is any professional machine engineer who, as a result of purposeful education, has acquired fundamental and specialized engineering knowledge in a certain field of the industry for machines, and has also acquired theoretical and practical knowledge of the new class of holistic ERP systems. The *systemic economic engineer* - as a result of several months of theoretical and practical study of the functional construct of the holistic ERP system - forms a cognitive potential for managerial modeling of the economy of the enterprises for machines, which is far superior to the one possessed by even the most renowned professional industrial economists. A superiority, which is expressed in the conscious understanding and application of:

(1) knowledge of the principle set up and way of functioning of the enterprise for machines as a systemic object and subject;

[5] The experiments and some of the results are presented at https://isee.bg/en/.

[6] **Machine Engineer** – a practitioner of machine engineering. Machine engineering is the branch of engineering that involves the design, production, and exploitation of all types of machines. "Machine engineer" is the umbrella term that unites all those engineers dealing with machines, which include: mechanical, electrical, computer, automotive, aerospace, hydraulic, etc., engineers.

(2) practical knowledge for development of highly effective strategies for future economic development of the enterprise for machines with a focus on anticipating the development of its innovation potential;
(3) practical knowledge for the development of highly effective programs for training, retraining, and motivation of the staff of an enterprise for machines – programs that aim toward the realization of the strategies for future economic development of the enterprise for machines;
(4) practical knowledge for auditing enterprises for machines in order to assess the current and future development of their economy and to generate ideas to increase the effectiveness of this development;
(5) conceptual knowledge for the creation and development of a truly effective accounting model of the economy of the enterprises for machines;
(6) knowledge for the management of the cost and quality of a product and the ability to conduct a technological analysis of the process of creating the goods and services sold, while offering different options for implementing this process;
(7) practical knowledge for the development and management of projects for implementation of systems for lean manufacturing (Single-Minute Exchange of Die – SMED) of goods and services sold by the enterprises for machines;
(8) practical knowledge for the planning and management of the execution of engineering and reengineering of enterprises for machines or large parts of them.

5 THE CONCLUSION

The Fourth engineering wave in the development of the fundamental scientific knowledge of economy will lead to the finalization of the work of all engineers who have dedicated their lives to the previous three waves in the development of this knowledge. A finalization, crowned with the emergence of a new generation of machine engineers – *systemic economic engineers.*

It is the managerial advantages of the new knowledge of a universal engineering model of the economy of the enterprise for machines that will bestow huge prestige to the engineering profession, which will naturally attract the young people who want to engage in industrial management. The emergence of *systemic economic engineers* and the shift of the human capital of the Western world back to engineering, the natural environment for cultivating quality executives for the industry for machines, will bring our Western world back to its morally responsible, creative foundations of the early and mid-20th century. The same foundations that made the Western world the technological and economical leader of the whole world.

All this must happen through the mass dissemination of the new quality knowledge for managerial modeling of the economy of the enterprise for machines. This dissemination should first be extended to all technical universities, and subsequently, the knowledge of a universal model should become a standard for enterprise management. A standard controlled by the best technical universities of our world.

The responsibility to make all this happen rests upon us, the engineers, and the engineering organizations concerned about both the future of our profession, as well as the future of our world.

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TEACH AS YOU PREACH – ACTIVATING PEDAGFOGICAL TRAINING FOR UNIVERSITY TEACHERS IN LAPPEENRANTA-LAHTI UNIVERSITY OF TECHNOLOGY

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ABSTRACT

Lappeenranta-Lahti University of Technology (LUT) offers its teaching staff various pedagogical training courses. This paper describes the first module, “University Pedagogy, Basic Module (10 ECTS), and its feedback and results. The module itself was compiled in collaboration between two universities: the ordering university LUT and the delivering university Tampere University of Applied Sciences (TAMK). In pedagogical training it is important to teach as you preach. The participants should be able to experience themselves all the methods, principles, and skills they are supposed to acquire during the training. It is difficult to learn to activate students or to become student-centred only by listening to lectures. Therefore, the teaching methods should be in line with the learning goals and the participants should be active doers and learn hands-on rather than be passive listeners. The Basic Module

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contents focused on two main aspects: general activating pedagogical skills and teacher's digital tools and their use from pedagogical point of view. First, the basic elements of the pedagogical module are presented together with its structure. Second, the results of participants' experienced learning gains in different categories of the contents are presented together with their perception of the importance of different parts of the content.

1 INTRODUCTION

1.1 Pedagogical training in LUT University

At LUT University teaching staff is not required to have pedagogical training - having a PhD in teacher's own field of research is the only strict requirement. However, pedagicial skills are valued and seen important by the university and therefore LUT offers the teaching staff the opportunity to take pedagogical training courses. The studies consist of one 10 ects basic module followed by optional optional orher courses, e.g. "*Supervising Doctoral Studies*", "*Interaction and teaching presence*" and various other courses in co-operation with other Finnish universities. Teachers will receive a certificate of their teaching skills, and they can use that in their performance discussions within the department or use it otherwise in their life-long learning plan. The goal of the training is to develop and support LUT teaching and research staff's pedagogical and teaching skills, enhance interaction skills and strengthen teacher identity. The 10-credit basic module is bought from other organization (TAMK) and the optional courses are provided by LUT University.

1.2 Activating methods in teaching

Active learning covers a variety of instructional methods which engage students as active participants instead of (passive) listeners of lecturing. Active learning is usually defined as any instructional method that engages students in the learning process. Thus, engaging and activating students during their learning process are the core principles of active learning [1]. In science, technology, engineering and mathematics (abbreviation STEM), examples of active learning methods are i.e. simulations, demonstration, laboratory work calculating, group discussion, peer instruction, taking online exercises, self-assessment, quizzes, using clickers and polling to collect individual and group opinions and explanations and so on. Such instructional methods promote students' own activity and taking responsibility of their own learning process. Instead of passively listening to a lecturing, students actively do learning activities and process information in various ways. They also need to present their ideas and conceptions to their peers in discussions. Different studies have highlighted benefits of active-engagement learning methods. Prince [1] has found support for all forms of active learning examined in his studies. Freeman et al. [2] carried out a meta-analysis of 225 studies that had reported course scores and passing rates in STEM courses, and they compared results of studies between traditional lecturing method and active learning methods. Their analysis indicated that using active learning methods can increase passing rates and course scores. Deslauriers et al. [3] has shown improved learning outcomes in a large-enrolment physics class when using pre-class reading assignments, pre-class reading quizzes, in-class clicker questions with student-student discussion, small-group active learning tasks and targeted in-class instructor feedback. Especially, they found that active learning methods have great benefits with small groups, but it is effective for all group sizes. Wieman has found similar positive effects [4]. In addition to active-engagement methods, also self-regulatory skills are also often connected with active learning. Research has shown that when mastering own learning process, learning outcomes are typically better [5, 6].

2 ARRANGEMENTS AND CONTENTS OF THE PEDAGOGICAL TRAINING

2.1 Participants

The module was offered to teaching staff of LUT University. From the applicants, 22 were chosen based on the urgency of the need for the training and on their ability to commit to the working on the module. Despite the commitment requirement, the number of participants dropped a little after the beginning and 20 participants continued to the end of the first semester. When the semester changed, 17 participants continued studying on the module. Figure 1 presents the overall activity on the module, based on the weekly sum of log events in Moodle, together with the number of active participants. The activity is found to be strongly correlated with the assignment deadlines and contact days, which are show later in Fig. 2.

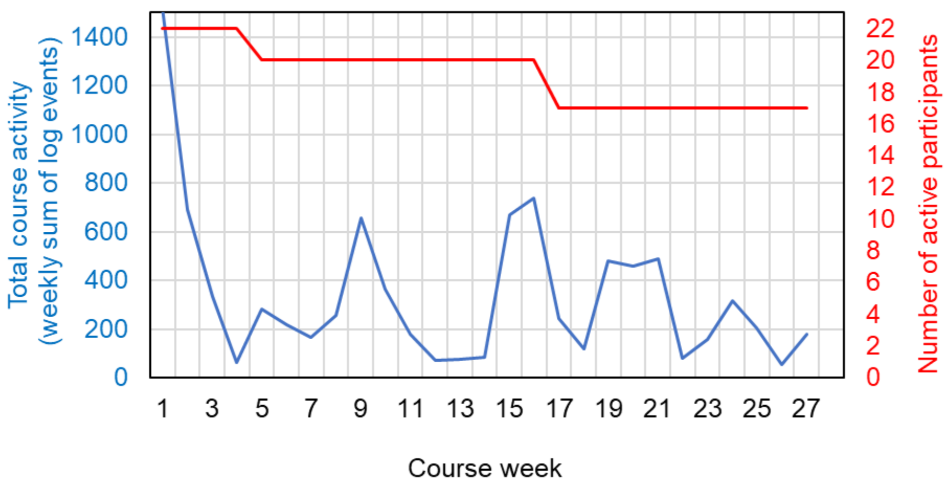
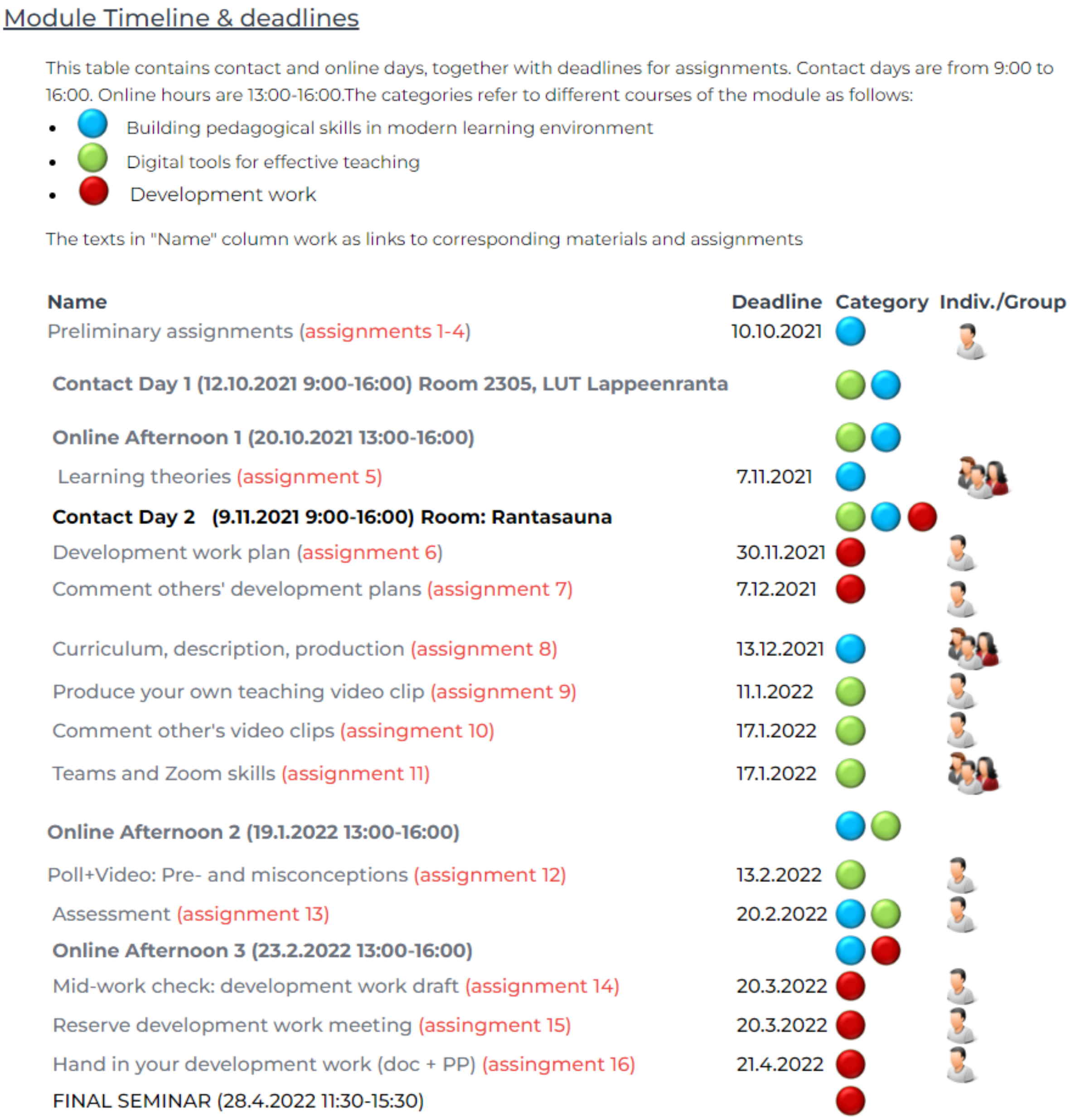


Fig. 1. Weekly sum of Moodle log events (left axis) and the number of active participants (right axis) as a function of course week.

2.2 The module: "University Pedagogy, Basic Module (10 ECTS)"

The first part of the pedagogical training was arranged as a 10 ects module, called "University Pedagogy, Basic Module". Teaching consisted of three contact days, three online afternoons and online guidance sessions. Studying was mostly done online in groups and individually between the contact days and online sessions. For clarity, the materials were divided in three parts and collected under the following titles: "Building pedagogical skills in modern learning environment", "Digital tools for effective teaching”, and “Development work”. All these three themes formed an intertwined and coherent entity, and they couldn’t be accomplished separately. Instead, participants were expected to accomplish the whole study module of 10 ects as a whole. To help the participants to keep on track and to meet the deadlines, all assignments were shown as a timeline list in the beginning of the Moodle contents. The lines of the list were links to the corresponding material, assignments or site in the Moodle. A screenshot of the timeline is shown in Figure 2.



Module Timeline & deadlines

This table contains contact and online days, together with deadlines for assignments. Contact days are from 9:00 to 16:00. Online hours are 13:00-16:00.The categories refer to different courses of the module as follows:

- Building pedagogical skills in modern learning environment
- Digital tools for effective teaching
- Development work

The texts in "Name" column work as links to corresponding materials and assignments

Name	Deadline	Category	Indiv./Group
Preliminary assignments (assignments 1-4)	10.10.2021		
Contact Day 1 (12.10.2021 9:00-16:00) Room 2305, LUT Lappeenranta			
Online Afternoon 1 (20.10.2021 13:00-16:00)			
Learning theories (assignment 5)	7.11.2021		
Contact Day 2 (9.11.2021 9:00-16:00) Room: Rantasauna			
Development work plan (assignment 6)	30.11.2021		
Comment others' development plans (assignment 7)	7.12.2021		
Curriculum, description, production (assignment 8)	13.12.2021		
Produce your own teaching video clip (assignment 9)	11.1.2022		
Comment other's video clips (assingment 10)	17.1.2022		
Teams and Zoom skills (assignment 11)	17.1.2022		
Online Afternoon 2 (19.1.2022 13:00-16:00)			
Poll+Video: Pre- and misconceptions (assignment 12)	13.2.2022		
Assessment (assignment 13)	20.2.2022		
Online Afternoon 3 (23.2.2022 13:00-16:00)			
Mid-work check: development work draft (assignment 14)	20.3.2022		
Reserve development work meeting (assingment 15)	20.3.2022		
Hand in your development work (doc + PP) (assingment 16)	21.4.2022		
FINAL SEMINAR (28.4.2022 11:30-15:30)			

Fig. 2. Moodle timeline, assignments and deadlines.

The learning objectives were described as skills – after completing the module the participants are able to: 1) Use an interactive and instructive working method, 2) Build courses and material in pedagogically meaningful way, 3) Select suitable pedagogical methods, 4) Select suitable education technology for the students depending on the situation and learning environment and Justify the choice of this technology, and 5) Assess learning and competencies in varying ways.

The topics covered were (at the title level):

- Learning Theories
- Activating teaching methods
- Curriculum development
- Different aspects of assessment
- Video tools
- Polling as an activating method
- Learning analytics,
- Pre- and misconceptions,
- Learning management systems
- Own teaching videos.

The idea of the “Development work” was to take the learned skills and the acquired knowledge into use immediately. The participants were asked to choose one of the courses they are currently teaching or will be teaching in the near future. They needed to make a plan how to improve the course contents, arrangements, teaching methods etc. according to their own needs. First, they were asked to describe the current status and define the needs for improvements concerning the course. Second, they needed to describe the pedagogical background behind their decisions for improvements. And finally present their solutions for tackling the challenges they had on their course setup.

2.3 Teach as you preach

“Teach as you preach” means that you use the same activating methods with your students (participants) in practice what you expect them to use later in their teaching career. Rather than lecturing or delivering information about engaging and activating teaching practices through traditional approaches, the very same methods are in use on the course and thus the participants can have own experience of the methods from students’ point of view. When starting a new topic, the facilitators first gave a brief introduction. This was accompanied by polling the prior understanding of the topic. Anonymous polling was used to create a safe learning environment in which every participant felt safe to bring her/his opinion to the discussion. When contradicting points of view emerged, group discussions were initiated to widen the perspectives of all participants, including that of the facilitators. Many of the assignments included group working, discussions in small groups, self- and peer evaluation of the participants outputs etc. For example, when dealing with different learning theories, the participants were first asked to study individually, then collect a summary of the characteristic features of different theories in small groups. After this they were asked to evaluate different parts of the ongoing course “University Pedagogy, Basic Module” and the actions of the facilitators from learning theories perspective. Which parts of the teaching were based on socio-cultural learning theory? How can you tell? Which actions and assignments had characteristics of connectivism? How can you tell? etc. Similarly, when discussing about how to build a clear and pedagogically planned Moodle site, the participants were given an evaluation rubric and asked to use it to evaluate the very course “University

Pedagogy, Basic Module”. This was then again followed by a discussion of the findings and different points of view. Since the participants came from engineering departments, many of the activating demonstrations and examples were picked also from engineering education.

3 RESULTS

3.1 Feedback survey

Microsoft Forms was used to collect the feedback about the module and participants’ personal perception of their own learning of the topics. Most of the questions were presented on 7-point Likert scale accompanied with optional free text field. The number of questions was purposely kept low and thus the average answering time was 13 minutes. The answer rate was 65 %, calculated from the active participants at the end of the study module.

3.2 Learning gains

The perceived learning gain was measured by asking the participants two questions about the course contents and topics: 1) “How much do you feel that you know about the following topics/skills at the moment?” 2) “How much do you feel that you knew about the following topics/skills at before this 10 ects basic module?”

The answer distribution to the first question is presented in Fig. 3. Most of the participants seem to consider their current knowledge of the topics to be way above neutral (4), some even at the level of expert.

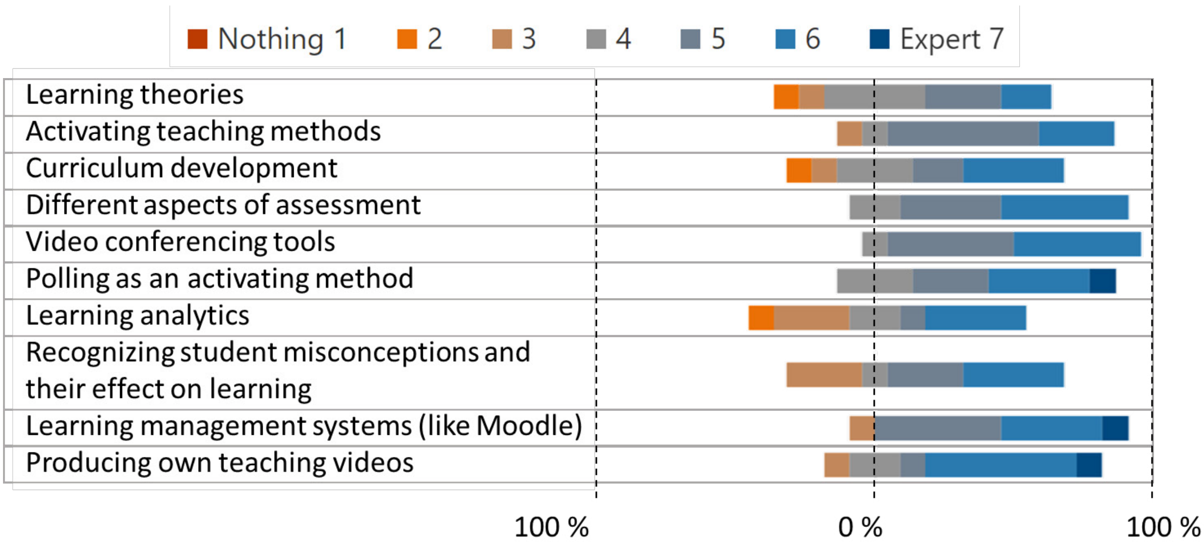


Fig. 3. Answer distributions to question “How much do you feel that you know about the following topics/skills at the moment?”. 1= Nothing, 7=Expert.

The perceived knowledge before the module is presented in Fig. 4. Not many of the participants were familiar with the course topics and many of the answers are either 1 or 2 (nothing or almost nothing). Thus, the study module served its purpose and the participants feel that they have learned a lot. This perceived learning gain is presented in Fig. 5. It is calculated by taking the averages of answers to different topics from figures 3 and 4. The beginning of the arrow represents the answer average before this study module and the end represents the average after it. Thus, the length of the arrow shows the average perceived gain in a certain topic.

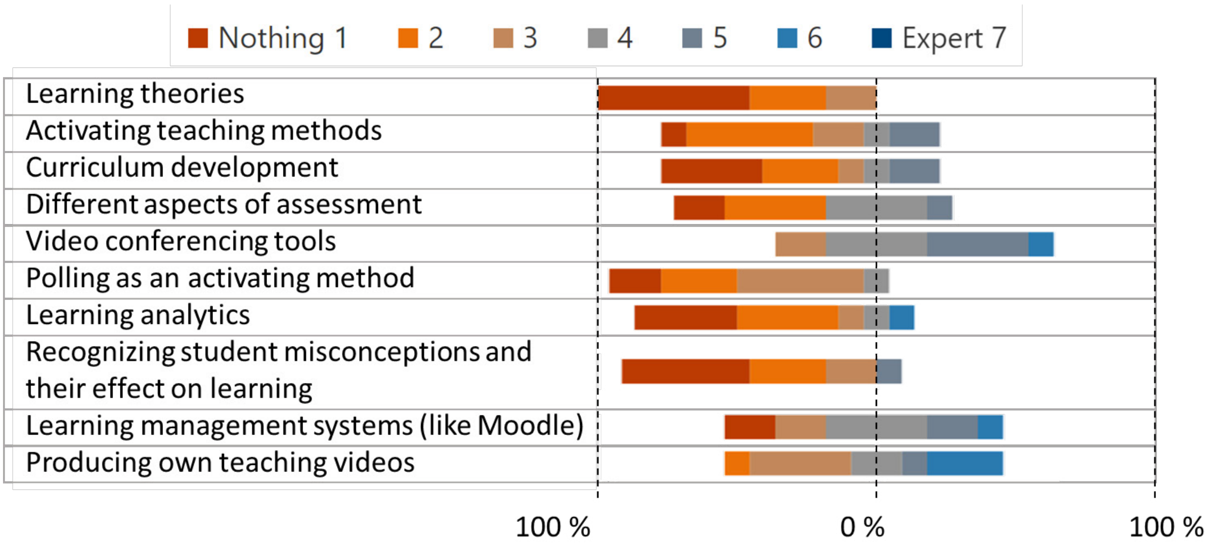


Fig. 4. Answer distributions to question "How much do you feel that you know about the following topics/skills before this 10 ects basic module?". 1= Nothing, 7=Expert.

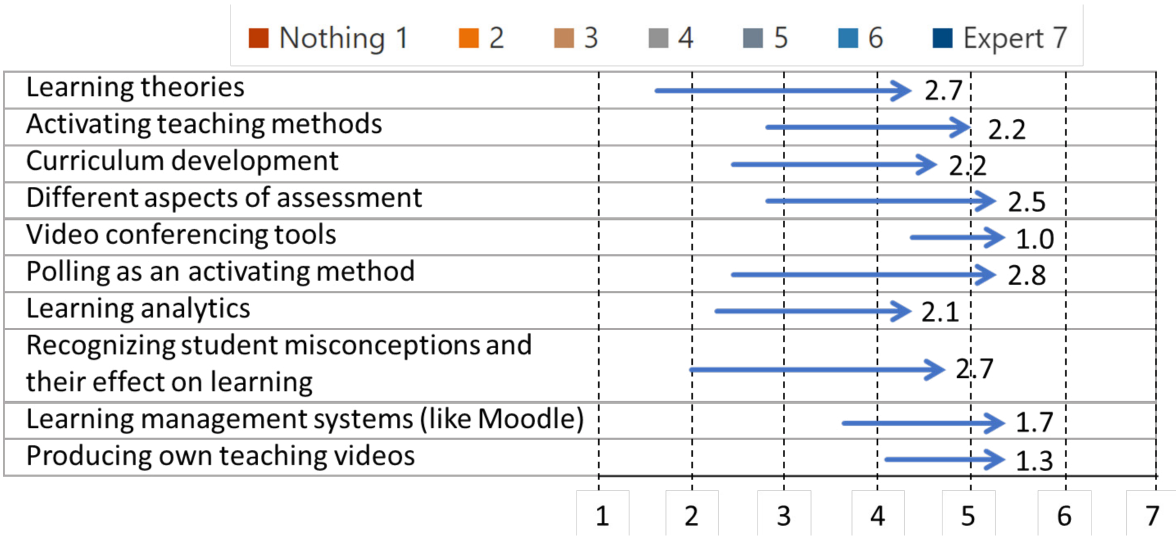


Fig. 5. Perceived learning gains on different topics of the study module.

In many of the topics the gains were remarkably high: polling (2.8), learning theories (2.7) and misconceptions (2.7). On the other hand, video conferencing tools and producing own educational videos were already familiar to the participants, probably due to the Covid-19 pandemic, and thus the gains were the smallest.

3.3 Importance of the module topics

The participants were asked to evaluate the importance of the different topics covered in the training in a scale 1 (not important at all) to 7 (very important). The answer distributions and averages are shown in Fig. 6. The two most important topics were Moodle and production of own educational videos. These choices are quite natural, since Moodle is used to deliver courses, teaching contents and assignments and videos are one main content delivery method. In these topics the learning gains (Fig. 5) were not the highest, but at the same time the levels were high. This tells that these topics are considered very relevant and necessary even though the participants were already rather skilled in them before the training module. The two topics that the participants were the least familiar with were learning theories and student misconceptions. The latter gained also rather hight score in the importance rating (6.0) and its learning gain was among the top three (2.7). Thus, it seems that the participants realized how much of a barrier misconceptions form to learning - an essential point of view in constructivistic learning theory.

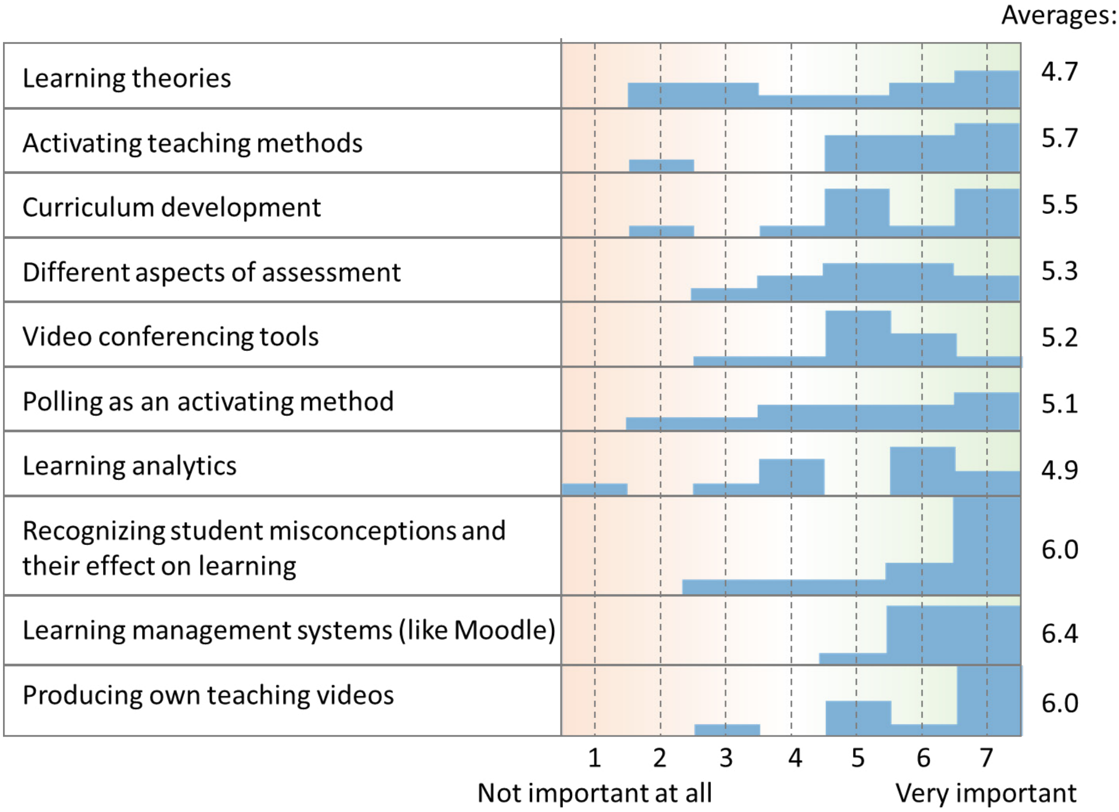


Fig. 6. Participant answer distributions and averages importance of the different topics covered in the pedagogical training.

4 SUMMARY AND CONCLUSIONS

We have briefly shown what kind of elements the pedagogical training had, what kind of topics were covered and how the “teach as you preach” principle was applied in facilitating the course. The participants’ experienced learning gains were found to be rather high and the participants found the topics relevant for their teaching career. It would be interesting and informative to interview the participants after a couple of years of teaching career: how would they then see the course and the skills it provided? What impact the pedagogical training had on their teaching career? Etc. Unfortunately, these questions can be answered only in the future.

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CHALLENGES TO THE HIGHER EDUCATION TO ENSURE SUSTAINABLE DEVELOPMENT

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ABSTRACT

New challenges in the field of digital transformation and content conveyed in the education process, in particular engineering sciences, triggered a discussion on the identification of issues focused on forms of cooperation with recipients using the available tools and taking into account the individual predispositions and knowledge of students related to their soft and hard competences. The subject of the paper is an attempt to identify students' soft competences on the basis of observations during the digital transformation period in 2020-2021.

Technology has a significant impact on education, but also human and social factors have a significant impact on shaping the new future of universities, especially those with an engineering profile. The experience of the last 2 years shows the need for an integrated approach to the education process, which should take into account the content provided in combination with a properly selected form of cooperation with recipients using the available tools and taking into account the individual predispositions and knowledge of students (attention should be paid to the so-called soft and hard skills).

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1 INTRODUCTION

Educational processes, in particular in the field of engineering sciences, are clearly associated with the digital transformation in the life of societies on a global scale, as well as with changes taking place in industry and broadly understood business. An important document indicating the occurrence of various types of changes in the world and the need for systemic action is included in the United Nations 2030 Agenda for Sustainable Development (SDG, 2015).

Digital transformation is the result of a combination of information, communication and artificial intelligence, which is associated with transformation in thinking and acting, as well as interoperability and a transdisciplinary approach to perceiving and solving engineering problems. In (Guerduer et al, 2022), the authors state that the skills of students and educators in the learning process are key. There is a shift away from classical skills (reading, writing, arithmetic) to new skills and competences focused on big data (data mining, sharing, modeling) and related to critical creative thinking and the possibility of human interaction with intelligent machines. Moreover, it has been found that students are currently able to obtain specific knowledge from sources other than traditional forms of communication at the university and are able to pass the exams of the course without having to attend formal classes.

In the paper (Guerduer et al, 2020) it was stated that the currently developed cyber-physical systems (CPS, Cyber Physical Systems) are a significant challenge for the education process with an engineering profile. It was found that solutions aimed at a different form of delivered content should be sought in connection with the interdisciplinary integration of data and data labels with digital programs and educational methodologies, taking into account the need for quick adaptation to changing working conditions.

The paper (Doyle-Kent & Watson, 2021) proposes the idea of a global engineer type who works in an international socially diverse environment requiring hard (technical) and soft (non-technical) skills. Related to these challenges are the need for lifelong learning, in particular the need to learn in real work environments.

The paper (Pursula et al., 2005) presents the concept of the development of virtual universities in Europe. It was found, inter alia, that with virtual teaching, new pedagogical issues will be released, as the work environment will be significantly different from that to which lecturers and students are used to.

In the paper (Miranda et al, 2021), the authors formulate conclusions regarding the challenges for the engineering education process in the period of digital transformation. The conclusions concern the development of: competences (especially critical), new learning methods, digital tools (information and communication technologies), infrastructure for education.

Technology has a significant impact on education, but also human and social factors have a significant impact on shaping the new future of universities, especially those with an engineering profile. New challenges in the field of digital transformation in the field of content conveyed in the education process, in particular engineering sciences, triggered a discussion on the identification of issues focused on forms of cooperation with recipients (students) with the use of available tools and taking into account the individual predispositions and knowledge of students related to their soft skills and hard. The subject of the paper is an attempt to identify students' soft competences on the basis of observations during the digital transformation period in 2020-2021.

The paper presents the observations of the effects of introducing a new learning environment (digital, and earlier learning process and achievements) in connection with the psychophysical properties of the student and the acquisition of knowledge and good practices in the new complex reality. Formulating the methodology of education in the new reality is not an easy issue and constitutes a significant challenge for educators in connection with new business models. Development of the presented issues is planned in the future.

2 OBSERVATIONS AND RESULTS

The global pandemic situation forced in 2020 a rapid digital transformation of educators and the available infrastructure for the education process of students. An additional effect of the situation that has arisen is the discussion on a new approach to education processes perceived jointly in relation to: the addressee (the resources of available knowledge, competences and skills, their health and mental state, educational susceptibility and motivation), evolutionary changes in the labor market in a global system and anticipated needs in terms of the competences and skills of employees and academic teachers (resources of substantive knowledge, competences and skills, health and mental condition, knowledge and practice in the field of methods and tools useful in the education process, motivation). This paper presents observations and conclusions from the period of rapid transformation of the process of training engineers from traditional (in-presence) to remote digital (on-line).

The following research issues were identified::

1. strengths and weaknesses of remote or mixed learning (limitations in the implementation of practical and blackboard classes, targeted debates, consultations, distribution of educational materials, lecture formula);
2. methods of activating students to the learning process, ways of becoming interested in a specific topic of classes;
3. selecting appropriate methods for conveying the educational content;
4. digital techniques in the education process and digital competences of the teacher and student;
5. planning classes / training;
6. the essence of the pedagogical approach to students in the education process;
7. personality characteristics of students and educators;
8. loneliness of the educator and participant of didactic classes / training;
9. fatigue and burnout of partners in the education process;

It was noticed that the formula of webinars and online meetings allowed for the construction of a new space for conveying specific content, and also for group debates focused on good practices in the education process, getting to know meeting participants, the possibility of being listened to and positively motivated to act. The formula of debating and educating with the use of digital techniques was the expected solution after a long period of physical isolation of the participants of the education process and a specific form of social therapy.

A new digital community of academic teachers and students was created, who together began to discover new issues (phenomena, areas for development) important in the process of education and professional work. For example:

1. difficulties in reading and listening to the transmitted content with comprehension and assimilation. The expectations of students in terms of special substantive care, targeted counseling and shaping and supporting the process of making targeted decisions are observed.
2. personal competences of the educator and student expressed, among others, by: self-awareness (recognizing emotions, self-esteem), self-management (stress, coping with stress, self-motivation and self-discipline), building relationships with the listener (communication, conflict resolution), empathy (emotional type: the ability to feel other people's mental states, cognitive type: the ability to adopt the way of thinking and perceiving reality by other people), assertiveness (having and expressing one's own opinion without aggressive behavior while maintaining good social habits), the ability to make decisions (problem solving, analytical thinking, responsibility).
3. methods of activating educators and students to the learning process, building a relationship between the student and the teacher, appreciating the pedagogical aspects of the teaching process, intergenerational communication.
4. storytelling in education. Building a specific targeted plot around the product / technical object (object, operation, functions, power supply, disturbances) using the commitment and emotions of the recipients (students) and their positive associations or creating specific needs among them.
5. procrastination in education. Voluntary, deliberate delay in carrying out the intended actions resulting in a short-term improvement in well-being, followed by time stress in connection with the ability to accurately and correctly perform the planned activity. Emotions and impulsiveness (including the desire to obtain immediate reward) negatively affect the concentration and own management of the perception and time senses (the consequence is postponement of the task and possible negative emotions). Depressive and dysthymic disorders as well as anxiety disorders associated with possible failure (expressed inability) are observed, which lead to frustration (specific protection of self-esteem), passive-aggressive behavior and the phenomenon of professional burnout.
6. living under stress and seeking strong sensations resulting in the illusory awareness of mobilization to meet a difficult challenge with perfect implementation.
7. anxiety about failure or success, helplessness or isolation and intimacy.

8. digital wellbeing in education (digital wellness). Digital well-being of lecturers and students who implement the educational process, related to the promotion of maintaining their healthy lifestyle with the use of available digital technologies. Example of negative impact of digital technologies: abuse of social media, educator and student productivity (maintaining the balance between work / education and private life).

The presented selected issues require the development of solutions (methods and tools), and then the formulation of a methodology for transferring knowledge and practice in a systemic manner that fits into the current and future business requirements.

The paper has a reflective character in which digital and soft student skills are analyzed.

Today's reality forces us to look for teachers who teach new advanced technological systems. In particular, trainers who teach how to code human behavior, clarifiers that link technology and practice, leaders who can explain the technology used, supervisors who maintain advanced twin systems oriented towards sustainable development in practice.

Education changes people and infrastructure, ensures people's well-being and is a source of intellectual and economic development. A systemic approach to education and safe human activities in a specific environment is related to sustainable development. Education for sustainable development should be a source of knowledge and conscious human action focused on the individual and community, prepare young people for the ability to undertake transformational activities for sustainable development

3 SUMMARY

Education never ends. The experience of the last 2 years indicates the need for an integrated approach to the education process, which should take into account the content provided in combination with a properly selected form of cooperation with recipients using available tools and taking into account the individual predispositions and knowledge of students (pay attention jointly to the so-called soft and hard competences). The proposed systemic approach to the issue is in line with the United Nations 2030 Agenda (in particular, goal 4: good quality of education) in terms of promoting a sustainable lifestyle and educating about sustainable development throughout life. The cooperation between educators inside and outside the university is easier, their joint purposeful mobilization is easier. The learning paradigm and teaching methods require improvement with a focus on digital transformation of educators and infrastructure in the process of educating students. New digital technologies should also be taken into account, for example: mobile computing, the Internet of everything combined with machine learning.

Engineers with specific knowledge and competences are key in achieving the sustainable development goals set out in the 2030 Agenda. New integrated technical, social, environmental and economic challenges are formulated before the engineering staff. Meeting the new challenge is possible as a result of implementing holistic engineering education combined with innovations oriented towards sustainable development. The consequence is the need to build engineering programs that inspire creativity and new creative thinking.

With the process of technological development, the society and its successive generations are also changing as they interact with the Internet and its services and, to a certain extent, autonomously. Noticeable psychophysical changes in society translate into the need to pay attention to the so-called soft skills of students and lecturers, which require improvement. The article attempts to identify students' soft competences on the basis of observations during the digital transformation period in 2020-2021 that require inclusion in shaping hard competences. Moreover, attention was drawn to the necessity of lifelong learning with the use of available resources as well as digital tools and methods, a transdisciplinary approach to the educational process, and the improvement of human-technology-environment interactions.

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UNDERSTANDING AND UTILIZING STUDENTS' ATTITUDES TOWARD PARTICIPATION IN DISCUSSIONS BY USING EMOTION ANALYSIS

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ABSTRACT

We propose a method that uses an emotion analysis for PBL education. The emotion analysis is a method of analyzing a person's emotions from the person's remarks or facial expressions. In this method, teachers understand the situation of students from the results of the emotion analysis and give accurate advice.

PBL education often involves group activities. The students conducted groups discuss, propose ideas, select ideas, and make the products. However, not all students are able to participate in discussions and express their opinions. It is the teacher's duty to provide guidance to such students. Therefore, we propose the use of the emotion analysis techniques to identify and guide students who have problems, such as those who cannot participate in discussions. The method is possible for one teacher to grasp multiple groups at the same time and to help developing the students' ability to learn.

Under COVID-19, face-to-face classes were restricted. Online classes using Zoom etc. have also been introduced in PBL education. In online classes, it is difficult to grasp the situation of students. This was a big difference from face-to-face classes. So we looked at ways to keep track of the situation for all students. This is because the gap between students who are willing to take classes and those who are reluctant to take classes has widened due to the shift to online classes. As a result of the adaption to the classes, the number of students who actively participate in the classes has increased. The effectiveness of the proposed method was confirmed.

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1 PBL EDUCATION UNDER COVID-19

The educational environment has changed a lot under the influence of COVID-19. The Japanese government issued the first state of emergency and expanded it all over the country in April, 2020. Figure 1 shows the poster that explains the items that should be followed to prevent the spread of COVID-19. The important instruction is "Avoid the three Cs"! Which means to avoid Closed spaces, Crowded places and Close-contact settings. In response to the state of emergency, Kanazawa Institute of Technology (KIT) forbade the student from coming into all the campuses. Classes were started as online classes on April 20. Group discussion in the classroom indispensable for PBL became impossible.

In the Covid-19 vortex, PBL education changed its teaching format from face-to-face to online classes. The problem there was so the difficulty of group activities in online classes. The problem with group activities was that when students were divided into several groups and worked in groups in breakout rooms, the teacher could not fully grasp the students' situation. The teacher can check each group in turn in the breakout room, but the teacher cannot see the whole group at once. To solve this problem, we built a system to support PBL education called "automatic meeting minutes creation system," which is part of AI teacher [1, 2]. AI teacher has a function to keep audio recordings of group activities as text. By utilizing this function, the teacher can give appropriate advice to each group [1, 2, 3]. However, it is time-consuming to understand students' situations from texts. Therefore, we added emotion analysis [4] to this function to improve the teacher's ability to grasp the situation visually.

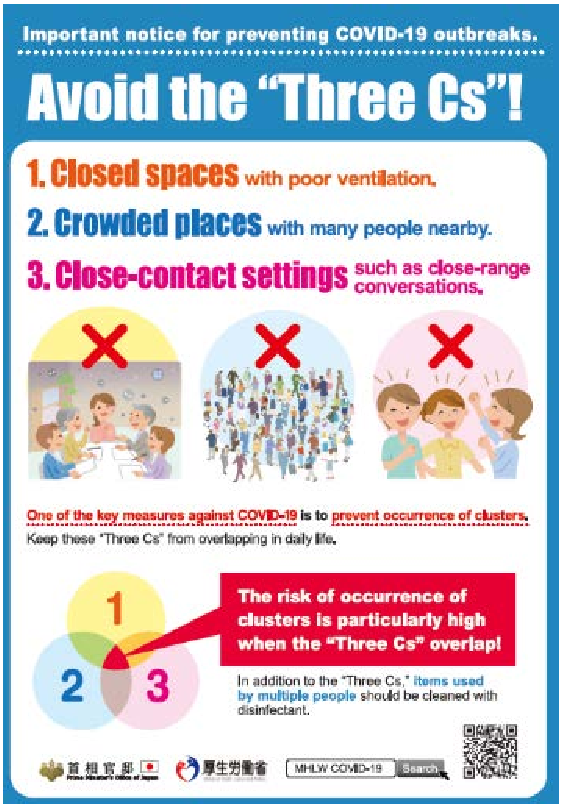

Fig. 1. Items that should be followed to prevent the spread of COVID-19

1.1 “AI teacher” system configuration

We are developing "AI teacher" for Project/Problem Based Learning (PBL) education using coaching technology. Figure 2 shows the overall structure. The goal of AI teacher is to provide all students with the best possible support and help them reach their full potential. Since it is difficult to increase the number of teachers in charge of classes, we decided to use AI technology.

Students can use chatbots of AI teacher as virtual teachers. They can ask questions that they wonder about in class. Students can also request advice when students are not sure what to do next. The chatbot will provide suggestions based on accumulated past examples. The faculty member checks if the answer is given correctly and registers the answer if there is a problem. This process will help to ensure that good answers are given.

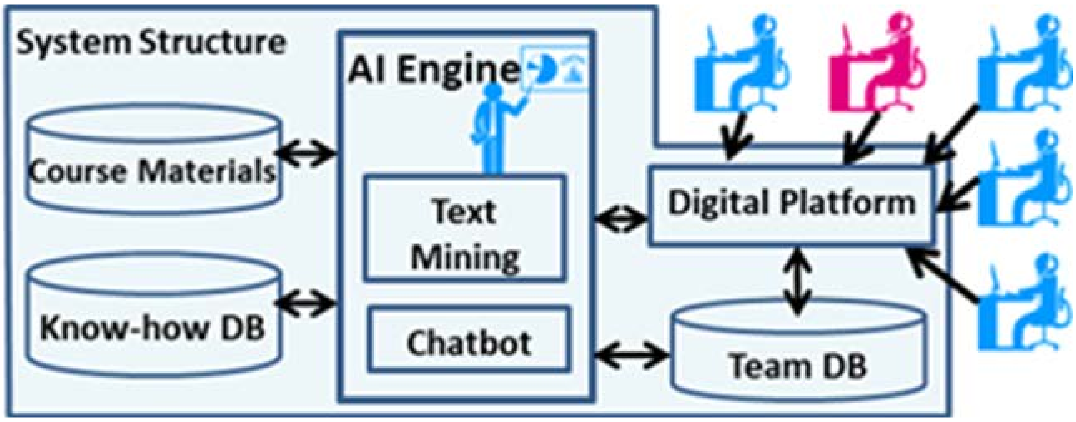

Fig. 2. “AI teacher“ configuration

We used AI teacher's minutes function to solve the difficulty of understanding students' attitudes toward the class, which was a problem in online PBL classes [2]. The minutes function allows teachers to keep all of students conversations in text form. It also records who said what. This makes it possible to keep track of the situation even if the teacher is not present. The ability to create a summary from the minutes also makes it easier to understand the content. In addition to these functions, we have added the ability to understand the students' situation through the emotional analysis. Figure 3 shows an image of the emotion analysis results displayed on the screen. Teachers can monitor student status at a glance.

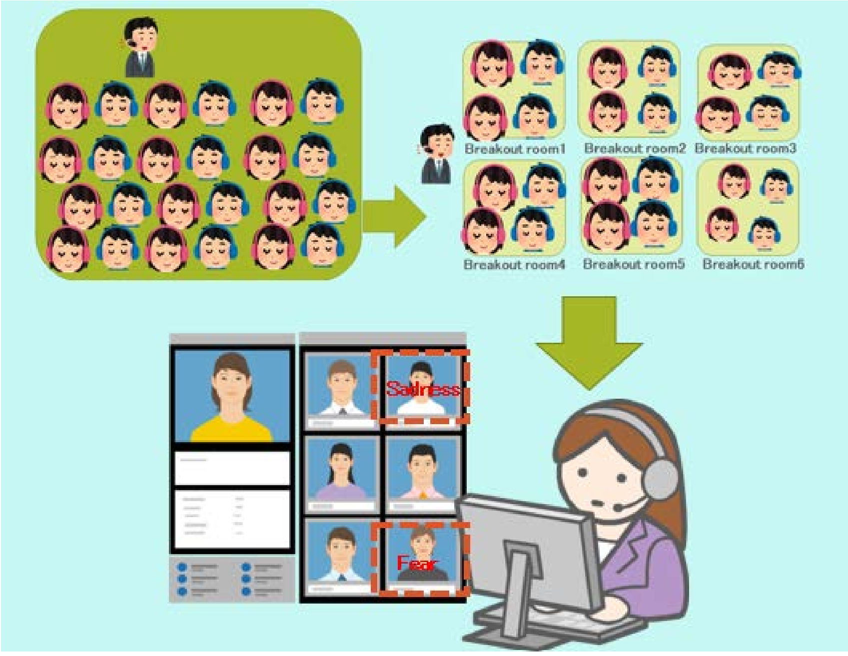

Fig. 3. Using emotion analysis to solve the difficulty of understanding students' learning attitudes in online-based classes

1.2 Emotion analysis

There are four main types of emotion recognition AI today as follow.

- "Voice emotion recognition AI" is a mechanism that recognizes emotions by analyzing physical features such as "voice intonation" and "voice loudness" without depending on a specific language such as Japanese or English.
- "Sentence emotion recognition AI" is a mechanism in which AI reads and analyzes sentences (text) input by humans by natural language processing to judge emotions.
- "Facial expression emotion recognition AI" can read the emotions of the other person from the facial expressions, just like humans do in normal communication. The mechanism is to use a camera that can capture small changes in movement to read the size of the line of sight and pupils and infer human emotions.
- "Biological data emotion recognition AI" is an AI that recognizes human emotions based on data such as biometric information, brain waves, heart rate, and vitals.

We used the sentence emotion recognition AI because it was easier to use online[4, 5, 6, 7, 8].

For the emotion analysis, 8 emotion scores of "anger, fear, disgust, joy, sadness, anticipation, trust and surprise" are extracted and normalized based on the positive and negative evaluations that evaluate the positiveness of students and the basic 8 emotional ideas. We use two popular theories of motivation: the“hierarchy of needs” of Maslow (1943)[6] and the“basic motives” of Reiss (2004) [7] to compile 5 coarsegrained and 19 fine-grained motivation categories, shown in Figure 4. Our system allows them to check the state of the discussion using colors.

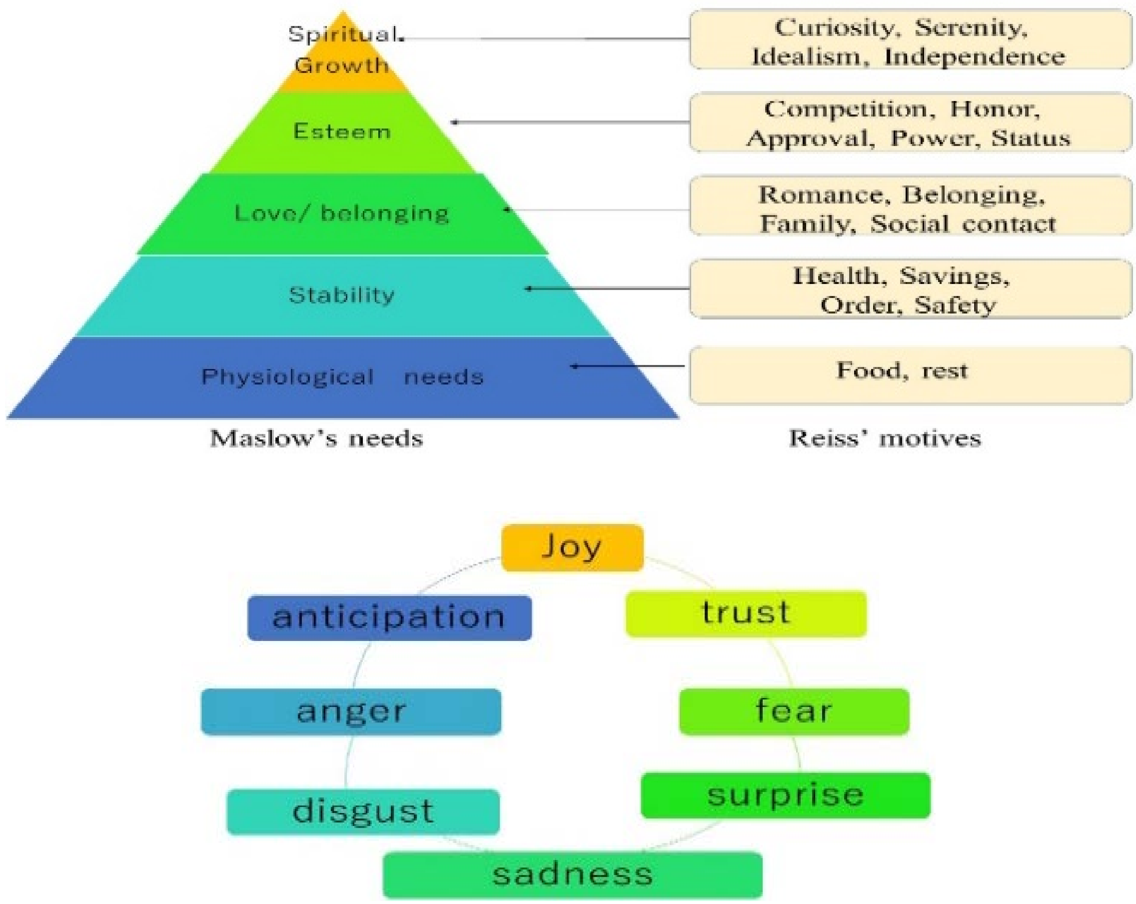

Fig. 4. Theories of motivation (Maslow and Reiss) and emotional reaction (Plutchik)[5].

2 EMOTION ANALYSIS FUNCTION OF AI TEACHER

In this paper, we will introduce the mechanism and effect of group activities supported by AI teacher. And we explain the automatic meeting minutes creation system which is a part of AI teacher. In particular, we introduce the function of notifying the teacher of a student's emotional changes. And we explain the results of its use.

When actually using the automatic meeting minutes creation system, it was difficult to grasp multiple groups at the same time by reading the texts of meeting minutes, and we came to the conclusion that a mechanism that can grasp the situation visually and intuitively is necessary. Therefore, we examined the application of emotion analysis technology.

Automatic meeting minutes creation system performed emotion analysis on the text data, and visualize the results by color. The teacher looks at the screen, If there are many negative colors, teacher read and understand what the students are saying and gives advice. Figure 5 shows the Image of the results of positive and negative evaluations. Figure 6 shows the flow of the automatic meeting minutes creation system for evaluating the student's attitude to participate in the meeting. Students had a meeting by Zoom.

Speaker	Utterance
A	Today I would like to consider an idea.
B	OK。 Where do you start?
C	How about listening to ideas in turn?
D	Eh. I don't like it.
E	It's not good.
A	It's my turn at first.

	Positive
	Neutral
	Negative

Fig. 5. Image of the results of positive and negative evaluations

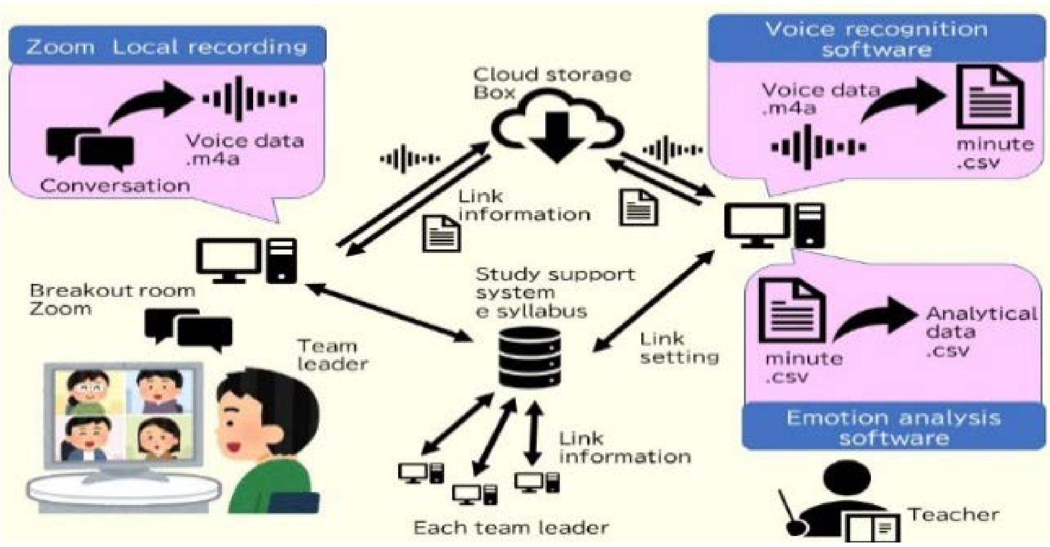

Fig. 6. Flow of Emotion Analysis in a class using Zoom

3 EVALUATION RESULTS

We used an AI teacher automatic meeting minutes creation system in an actual online class. We took a questionnaire at the end of the class. The results are shown in the figure 7. It is a comparison of the class that taught with the AI teacher and the class that did not use the AI teacher. The red bar indicates the degree of satisfaction with the class. We can see that the class using the AI teacher is more satisfying. The teacher commented, "I understood the content of the discussions in each group and it became easier to proceed with the classes." He also says, "Students seem to feel that the teacher supports all the students in detail, and the students are very satisfied." Another teacher noted, "The minutes made it easier for teachers to keep track of what was going on with each team. The assumption that minutes would be taken encouraged reluctant learners to speak up. It increased the involvement of reluctant learners in team activities."

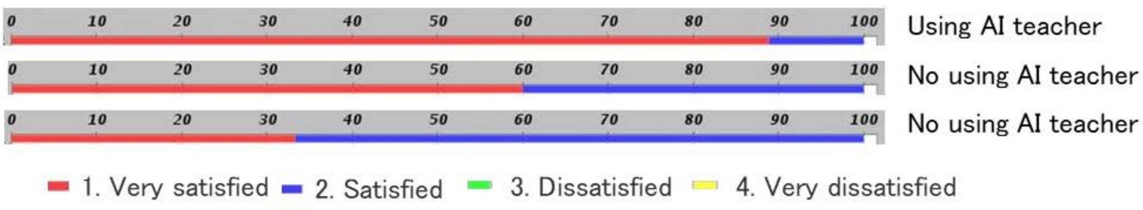

Fig. 7. Questionnaire results regarding classes satisfaction

We asked the teacher to use the emotion analysis function of the AI teacher after the end of semester. The teacher commented, "It is necessary to consider how to use the results of emotion analysis, but I think it is effective for grasping the situation of students."

4 CONCLUSION

We have built a system to support PBL education called AI techer and are currently testing its effectiveness in actual classes. We have also introduced the emotion analysis technology into PBL education and examined methods for evaluating students' attitudes toward participating in meetings.

From 2020, due to COVID-19, we have been going to use online communication tools such as Zoom to provide online PBL education. The problem at this time was that when students were divided into multiple groups and working in groups in breakout rooms, teachers could not keep track of what was going on with the students. The teacher could check in with each group in turn in the breakout rooms, but could not see the whole group at once. This was a major difference from face-to-face education.

Therefore, we used the AI teacher automatic meeting minutes creation system to record all conversations in the breakout rooms. This enabled teachers to check the progress of each group to see who was taking the initiative and who was not participating well. In addition, by utilizing emotion analysis, it is now possible to understand students' emotions. From the evaluation results, it was confirmed that the system is effective in grasping students' attitudes.

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PERCEPTIONS AND EXPERIENCES OF ONLINE INTERNSHIP

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ABSTRACT

Remote working enables organisations to have location- and time-independent business processes. Working life practices should also be applied in higher education. Lapland University of Applied Sciences' ICT education in Finland met the challenge by developing an online internship concept that improves cooperation between the university and industry and promotes the content and quality of education. This paper describes the experiences of the research project of online internship models. Oral feedback from students (N = 12) and companies (N = 6)

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were analysed along with the online internship concept during 2021. The concept includes three types of process models. Based on the idea that business and industry representatives are active players in the process. The supervising teachers and technical support staff of Lapland University of Applied Sciences (UAS) acted as a support network. Results confirmed the notion of the usefulness and suitability of the concept for the purpose. The marketing of the concept was supported by a process website. The challenges found focused on, for example equipment resources and the pedagogical skills of industry representatives. The concept can be generalised regardless of the field.

1 INTRODUCTION

1.1 Teleworking trends

Internships are an essential part of ICT engineering studies. Digitalisation and the proliferation of telework also call for a review of the professional training included in the studies. The COVID-19 pandemic changed the research design, such that constraints on gatherings and telework recommendations, as well as the response of companies to the former, increased the need to transfer student internships remotely.

In the statistics Finland 2018 Working Conditions Survey, 28% of employees said they work remotely and that 16% of jobs would have allowed them to work remotely, even if they did not do it for one reason or another. Moreover, 3%of employees said their employer did not allow telecommuting [1]. In other words, just over half (54%), or over a million employees, did not consider teleworking possible in their jobs in 2018. This was the response of most teachers, among others [1].

Telework has been exceptionally widespread in Finland during the COVID-19 pandemic, even on a European scale. It has been made possible by well-functioning telecommunications connections, a business structure that emphasises information work and, the fact that binding to the Finnish people alone has suited well.

During the great human experiment caused by the pandemic, about half of the Finnish employees as best worked remotely. In spring 2021, a further 42% were teleworking, of which 8% - including teachers - said they had worked remotely at some point during the pandemic [1].

Even before the COVID-19 pandemic, teleworking had become more common in Finland from 2013 to 2018, posting an increase of 12%. Growth certainly continued during 2019, with the digitalisation of working life accelerating the detachment of work from time and place. In five years the share of teleworkers has risen from 16% to 28% [1].

Educational institutions have begun to recognize the potential of virtual internships in gaining professional qualifications [2]. Virtuality offers organizations the opportunity to find talent globally and internationally [3]. It has been found that the advantages are the same whether the training is performed remotely or FTF (see e.g. [4]).

However, online internship poses challenges for project management and especially for the project manager [5].

1.2 The PracDis project

The PracDis (Practise at a Distance) project was launched at Lapland University of Applied Sciences, Finland, to improve cooperation between the university and companies by enabling remote internships for ICT companies. The project was implemented as a collaboration between ICT engineering and business information technology training. It was launched before the COVID-19 pandemic, but its importance was emphasised during the pandemic. The PracDis project developed a concept for distance learning that considers the perspectives and needs of both students and working life. It also expands the concept of internship to study work. This paper describes the latter part of the project, including the piloting results of the the developed concept. Its background study and concept construction are described in more detail in [6].

This publication is a continuation of a previously published study [6]. It presents experiences with the implementation of the concepts described in the previous work. The following sections describe the methodology and results of the survey. Finally, there are some reflections and recommendations for organisations that may want to try or apply the policies developed during the process.

2 METHODOLOGY

2.1 Developing the concept

The study described in this paper is the second phase of a research in which the concept of an online internship model was developed. The first phase was presented in [6]. The concept was introduced in 2021 and the functionality of the models was piloted with industry and company, the results of which are reported in this paper. To clarify the methodology, the models are first presented in this section.

The concept includes three different models (Table 1) for location-independent internships depending on the student's personal use of time. It works both in the case of one student and as a team or project work implementation. The pilot studies were implemented in 2021 following the process models of the three concept models according to Table 1. A total of 6 business pilot studies were conducted, of which 5 were micro-enterprises and one large scale enterprise. Thresholds following Article 2 of the European Commission (2020) were applied to the classification of enterprises [7].

Table 1. Pilots and number of participants

Model of online internship concept	**Description**	**Participants in pilot**
Model A Online Internship: Individual format implementation	The student completes the internship as an individual within the credits specified in the curriculum for the internship	5 companies, 5 students (2 pilots interrupted)
Model B Extended Online Internship: Individual or project format implementation	In addition to the credits allocated to the internship, the student also completes the studies of the professional subject according to their requirements.	1 company, 3 students
Model C Academy Model: Project format implementation	The student completes the professional subjects according to the curriculum during the semester. The student team is disconnected from the regular tuition and timetable for the semester.	2 companies, 5 students

The process for model C is shown in Figures 1, 2, and 3. Figure 1 illustrates the process for the starting phase of model C, in which the student team and industry representatives work together to develop plans to complete the project with the goals of both parties in mind. Communication and documentation take place on a common teamwork platform, such as MS Teams.

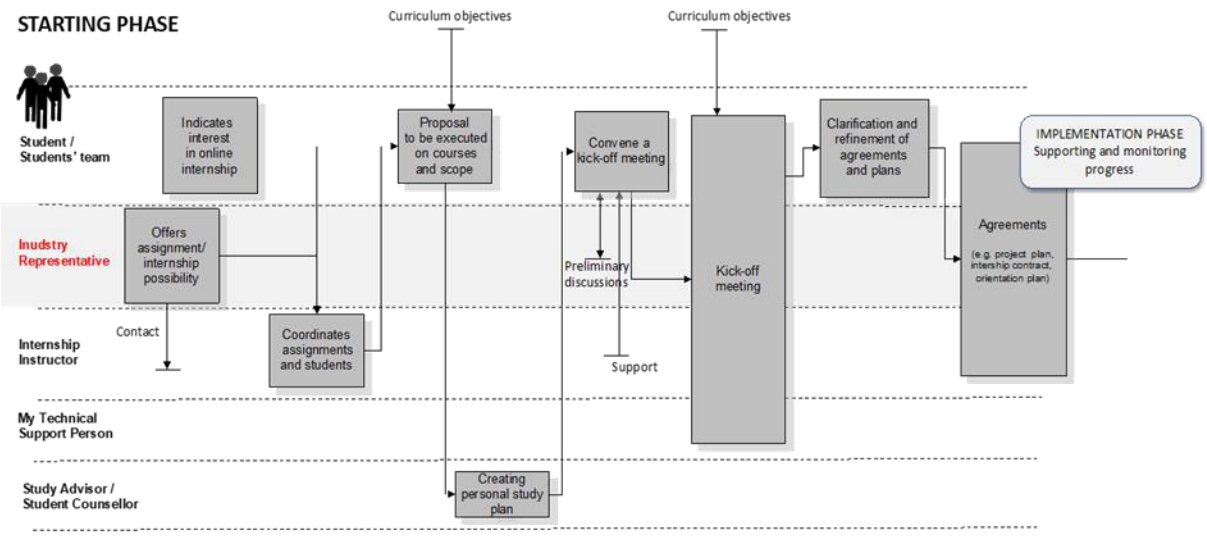

Fig. 1. Process model of the starting phase [1]

In Figure 2, the project is carried out iteratively using agile methods such as Scrum [8]. In addition to the teamwork platform, version control tools and digital development tools are shared. Progress is regularly monitored through reviews. The university's technical support person and internship instructor will support project implementation and process when necessary.

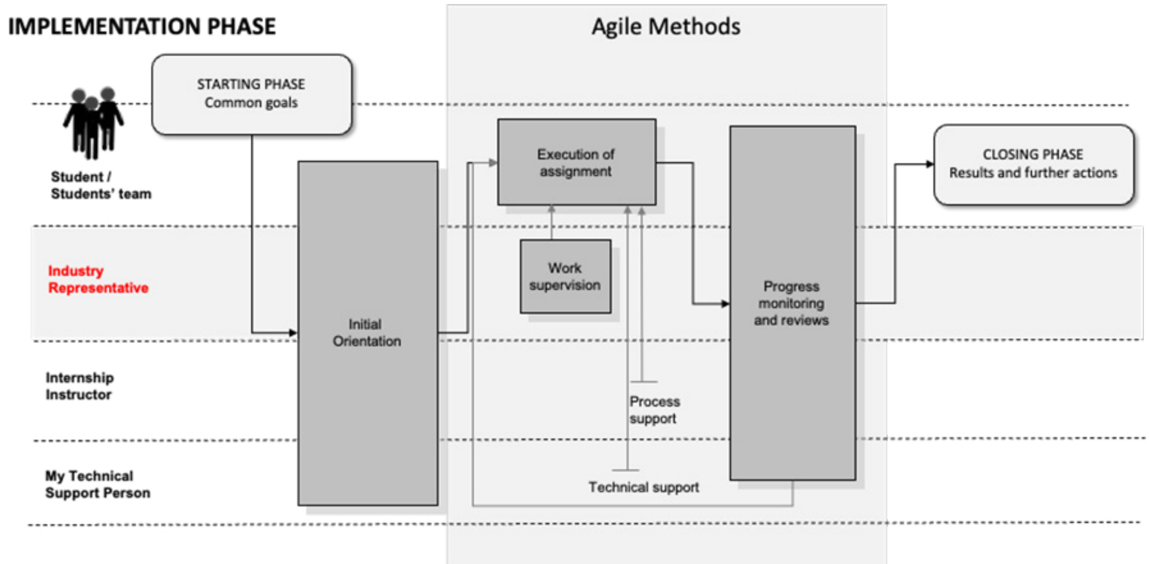

Fig. 2. Process model of the implementation phase [6]

Figure 3 shows the closing phase of model C, which includes, in addition to the evaluation, a decision seminar or event in which, in addition to the summary, mutual feedback takes place. Furthermore, students are encouraged to create a demonstration, such as a video trailer, poster or brochure, that will be published on the organisation's page or another service for students to use as a reference in their job search. For the institution, it works, for instance as a merit for university industry cooperation.

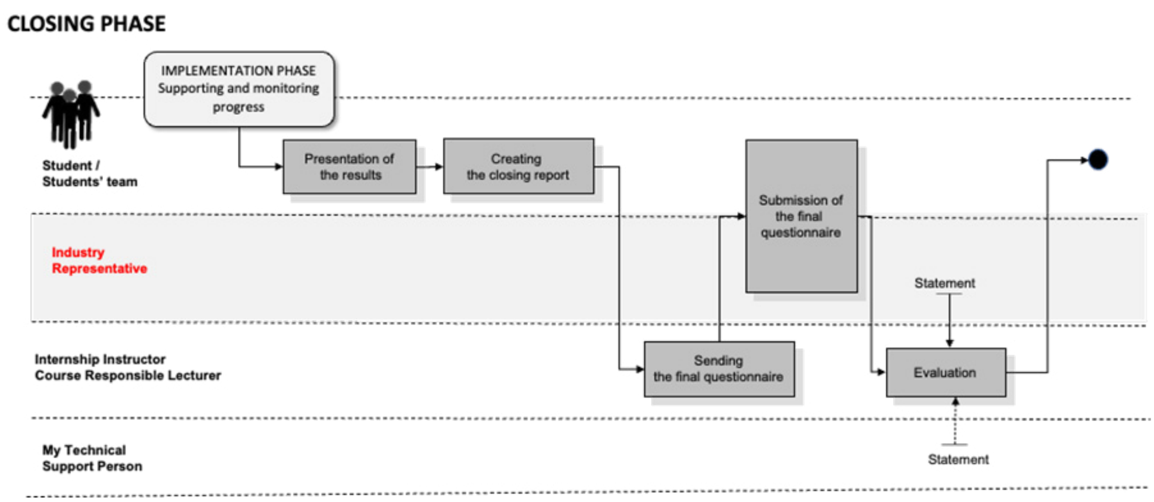

Fig. 3. Process model of the closing phase [6]

The thoughts, expectations, and experiences of the students and the participating companies were collected throughout the process. The majority of feedback and experiences were received orally at the progress review or in the final seminar included in the processes. Students and company representatives were free to share their experiences, successes and failures, as well as ideas for developing concepts. A memorandum was prepared for each session, in which comments and suggestions for improvement were recorded. The contents of the memos were compiled into a single document and the material was analyzed using content analysis methods.

3 RESULTS

3.1 Model A

According to the feedback from the student concerning model A, the internship period went well and the employer was committed to the activity. Students perceived receiving enough information about the internship but had only a few situations where support from the institution was needed. They were particularly pleased to be able to complete the internship online, but some of them felt that their personal computers were not efficient enough for the purpose smooth editing videos requires a powerful graphics controller. thus, the availability of necessary equipment during the internship should be agreed upon with the employer.

According to the employer's representative, the internship likewise went well. Information was sufficient on how the internship was progressing, what was happening at each stage and what the goals were. The process models were clear to understand. According to the company representatives, students’ adaption for online work proceeded smoothly. However, companies may not be able to act in online learning if they lack the understanding and ability to provide, lead and operate communication activities. The suggestion was that online working and communication should further consider an introduction and orientation phase for the industry representatives, for example, through a training package/information.

Two of the model A internship periods were interrupted for the students' reasons. In addition, the interruptions may have been affected by the initial challenge and lack of necessary support.

3.2 Model B

In the case of model B, students reported gaining more experience in project work, programming, taking responsibility and interaction skills. Their expertise also deepened, especially in considering the needs and requirements of the end-user. The students suggested that the educational institution and the companies should further increase their cooperation. Indeed, the pilot led to the recruitment of one student. The challenges mentioned were that the online support provided by the institution was not used at all during the pilot, though the possibilities for its use on the team communication platform existed. The existence and importance of support and the institution's stakeholders must be further emphasised in the future.

3.3 Model C

The students and companies were also satisfied with the implementation and results of the pilot of model C. Students received positive feedback. There were no specific suggestions for improving the process. However, one company suggested that ICT education should pay even more attention to the security aspects and management in all courses. On the basis of the research results, the following areas for development will be examined in more detail in the further development of the model:

- Extent and coverage of initial orientation
- Deeper involvement of the company in the initial orientation
- More extensive presentation of tools and methods
- Clarity of objectives
- Increased number of reviews and feedback opportunities

4 SUMMARY AND ACKNOWLEDGMENTS

The online internship concept was piloted in six separate pilots by ICT students of Finnish UAS in cooperation with companies. Pilots followed the processes of all three models. Support was provided by the supervising teachers and selected technical support persons of the institution. Pilots were conducted using MS Teams as the team collaboration platform with all parties involved. The results of the pilots conducted were positive. Students and companies were satisfied with the process and the results, and no special development targets occurred. Some of the the challenges focused on the equipment resources available for students and the online supervising capabilities of entrepreneurs.

To prevent interruptions, it is necessary to provide adequate support and guidance and ensure social contacts, especially in the initial stages. Model A is particularly sensitive to interruptions because the student works alone without peer support and a project team. In model C, the team support that comes with project formality can help the student. Lack of social contacts or threshold may prove to be a risk to model A. According to a Nordic study by real estate expert [9], the extended COVID-19 period has reduced the popularity of large-scale telework and partly taken away its benefits. The study also found that productivity initially increased, but the lack of social interaction began to feel heavy [9].

The role of companies in the concept is emphasised not only in the role of the substance expert but also in the roles of the employer, mentor, reviewer and motivator. Experienced employees in companies act as mentors to students. Company representatives have also been recruited as volunteer mentors for students [10], in which case, the company does not seek or achieve business added value.

Giving and receiving regular and constructive feedback promotes learning, increases motivation, and produces a positive learning experience [11]. Regular progress reviews provide regular feedback [12], allowing support needs to be identified and potential problem areas addressed early.

The introduction and generalisability of the concept under study in higher education depend on many factors. This particular concept is likely to be directly transferable or adaptable to educational cultures where teleworking and distance learning are already widely used in business. Additionally, cooperation between companies and universities in teaching or research should be strong so that cooperation at the level of organisations, especially individuals, works naturally. At best, distance learning can serve the common interests of business and higher education. A highly educated workforce is expected to integrate into companies and higher education institutions can leverage corporate knowledge and expertise, as well as update their teaching and research content. The results of the study are compatible with earlier publications [13].

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TEACHING ENGINEERING STUDENTS HOW TO DESIGN A PROOF-OF-CONCEPT: A WAY TO EXPERIENCE THE VALUE OF REFLECTIVE PRACTICES FOR ENGINEERS?

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ABSTRACT

Industrial companies expect engineers to take an external and critical look at their activities through reflexive practices. Recognising the criticality of reflexivity, Project Based Learning approaches include assignments for students to implement reflexive approaches on their projects. However, it remains unclear in the literature whether those assignments help the students experience the value of reflexive practices or if students consider them as academic exercises. In this concept paper, we present a new teaching module that intends to make students experience the value of reflexive practices for engineers.

In this module, an industrial partner asks a group of master engineering students to design and implement a Proof-of-Concept (POC) to help the company explore an innovation field. This eight-week project is mainly conducted within the company. Teachers act both as coaches through regular meetings and as experts through lectures focusing on specific engineering reasoning (statistics, modelling, simulation, design of experiments…) that are necessary to design a robust POC. At the end of the module, students present conclusions drawn from their POC to the company which explain to students the next steps envisioned from their contribution.

The module is two years old : so far, the authors supervised twelve students split into four industrial projects. Feedback for both companies and students were collected, as well as the lectures and the final presentations. Based on these, we conducted a preliminary analysis that suggests that students experience the value of reflexive practices for engineering work during the module.

1 INTRODUCTION : FOSTERING REFLEXIVE PRACTICES IN PROJECT-BASED-LEARNING

The ability to take an external and critical look at one's professional activity has been regarded for years as crucial for engineers. This ability was coined by Schon [1] under the term of reflexive practices[1]. Recognising the criticality of reflexive practices, engineering education literature regularly calls for pedagogy that can encourage students to adopt a more reflexive attitude toward the work they are undertaking [3].

Fostering engineering students' reflexive attitude is often an objective of Project-Based Learning (thereafter PBL) approaches. PBL is an interesting approach as it confronts students with real open-ended problems where reflexive practices are particularly needed [1], [4]. However, reflexive practices are not naturally implemented, neither by students, nor by practising engineers. Therefore, teachers often impulse students' reflexive reasoning through specific assignments such as diaries, debates or reflexive questions on the journey followed during the project. These assignments often trigger original student reflections on topics he/she would have neglected otherwise [4].

Nevertheless, however good the reflection conducted by students, the question of whether they understood how to conduct reflexive practices remains open. Indeed, the literature highlights that conducting a complex engineering activity through PBL does not guarantee students' learning. Thus, attending a PBL design module is not enough as such to understand how to design [5].

More precisely, as reflexive attitudes in PBL are often driven by assignments given by teachers, one may wonder whether students really experience the value of reflexive practices for their future work. Indeed, the literature focuses more on assessing the reflexive skills mastered by students than assessing students' perception toward the value of reflexive practices [6]. Hence, our research question: how to make students experience the value of reflexive practices for an engineer in a Project-Based-Learning module ?

To answer this question, we conducted an exploratory case study based on a two-year-old teaching module of Mines Paris – PSL University, where students are asked by an industrial partner to design a Proof-of-Concept on an innovation subject.

Section 2 presents the methodology used to conduct the case study. Section 3 presents the teaching module of our case study. Section 4 explicits our findings. Section 5 displays our conclusive remarks on our research.

2 METHODOLOGY

We adopted an exploratory case study methodology to analyse how to make students experience the value of reflexive practices for engineers. The case chosen is the two-year-old module "Proof of Concept for a responsible industry" (thereafter POC module)

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[1] Defining reflexive practices is a challenge for the literature and it is beyond our scope to provide a definitive answer. In this paper, reflexive practices include technical rationality, reflexion on action and reflexion in action as defined by Hatton and Smith [2]. We thank an anonymous reviewer for providing this reference.

in Mines Paris – PSL University, that we supervise. So far, we supervised 12 students split into 4 industrial projects. Our experience provides us with anecdotal evidence that students experienced the value of reflexive practices thanks to the POC module hence the choice of this module as a case study.

To conduct the case study, we collected as many evidence as possible to understand whether students and industrial partners highlight reflexive practices as valuable for engineers. We also gathered all the documents related to the POC module in order to identify the features of the module that helped students understand the value of reflexive practices for engineers. The data collected and the analytical approach are indicated in table 1.

Table 1. Data and data analysis of the case study

Data	Analytical approach to the data	Data gathering
Final presentations and company reactions	Assess whether students rely on reflexive practices during final presentation	Recorded (n=4/4)
Evaluation and debriefing of the POC module by students	Assess whether students highlight reflexive practices as a key aspect of the module	Questionnaire (n=12/12) Field notes
Evaluation and debriefing of the POC module by the company	Assess whether companies highlight reflexive practices as a key aspect of the module	Questionnaire (n=1/4) Field notes
Documents related to the POC module (lectures, flyers…)	Identify features of the POC module that may help the students understand the value of reflexive practices	All documents

The evaluation of the POC module by the students takes place through a questionnaire students fill at the end of the module. The questionnaire is composed of several quantitative questions such as *"Did you like the project that you were entrusted with?"* and of several open questions such as *"What were your expectations at the beginning of the module?"* The issue of reflexive practices is never directly raised; however, some questions make room for students to provide answers related to reflexive practices, for example "*Do you think that the POC module enable a better comprehension of what is an engineer ?*"

The debriefing of the POC module with students is an informal one-hour debate on the module. We also met the students after the POC module, in particular when they explain it to undergraduates. We included the informal exchanges we had with them on this occasion as an element of the debriefing.

The evaluation of the POC module by the companies is conducted through a questionnaire composed of six open questions. Four questions relate to the work conducted by the students on their specific projects. The last two questions relate more to engineering reflexive practices: "*Do you think that a teaching module* *dedicated to the design of a POC is important for the training of an engineering student and why?*" and "*Do you think that a teaching module dedicated to the design of a POC could be relevant for working engineers and why?*"

Our analytical approach to the data is to uncover whether students or industrial partners mention that reflexive practices as a key aspect of the POC module. As we do not raise the question of reflexive practices, a mention of theses from students or from companies would be considered as very informing.

3 CASE

This section presents the "Proof of Concept for a responsible industry" module as it was structured in 2021 and 2022 in the master engineering programme at Mines Paris – PSL University. Section 3.1 presents the module from a content perspective and section 3.2 exemplifies one project that took place in 2022.

3.1 Presentation of the POC module from a content perspective

In the POC module, industrial partners entrust groups of engineering students to design and implement a Proof-of-Concept (POC) to explore a particular innovation field the company is interested in. Students are split into small groups, typically three students per group, and work for eight weeks on their project.

To select the projects, the teaching team look for three requirements. First, the subject has to be linked with a current innovation project within the company. Second, the company must be willing to conduct an experiment of some sort on the innovation field. Third, the company should agree to host the students as interns and make them meet experts of the innovation field explored.

At the end of their eight-week project, students are asked to present their work to the company and to provide two deliverables. First, they must issue a grounded recommendation to the company concerning what Proof Of Concept is to be implemented to explore the innovation field. Second, students are asked to present the analysis of a limited experiment they conducted during their project. Thus, they are put in the position to analyse the results of an experiment. Generally, they cannot analyse the POC they recommend due to time and resource constraints. At the end of the presentation, the industrial supervisor comments on the work of the students.

Before starting their eight-week project, students follow two introductory courses[2] : one on production and logistic management and one on innovation management.

During the eight-week project, students participate in three interrelated learning activities. First, they work on their project as interns in the company during two and a half day per week. Second, students attend lectures and associated tutorials for a total of four hours per week. Third, each group of students have a one-hour meeting per week with two academic tutors. The organisation of a week is given by table 2[3]

[2] These two courses are not specific to the POC module, they are open to other engineering students.

[3] The shaded cells relates to slots dedicated to sport

Table 2. Organisation of a week during the POC Module

	Mo	Tu	We	Th	Fr
am	Project		Project	Coaching	Tutorial
pm	Project	Lecture	Project		Project

During the project, students are interns in the company: they work as an autonomous group that mimics an industrial project organisation. They receive supports both from their industrial supervisor that entrusted the project to them and from experts of the subject within the company.

The lectures focus on classical reasoning mobilised by engineers. In 2022, the lectures were the following : (i) Engineering Modelling ; (ii) Machine Learning ; (iii) Simulation ; (iv) Inferential Statistics ; (v) Design of Experiments ; (vi) Economic evaluation under uncertainty (vii) Risks associated with POC design. All the lectures are followed by a tutorial. The lectures and the tutorials are designed to show how classical pieces of engineering reasoning can be used to design a POC. Students are free to use or not these pieces of reasoning for their own project.

The coaching meeting is a favourable moment for students to present their work and to elaborate on what they need to do during the following week. The coaches are two academic tutors who belong to a lab where state-of-the-art research is conducted on POC and on POC design. Thus, the guidance of students is particularly well informed with insights on the usual pitfalls encountered by POC in industrial settings [7].

Presentation of the POC module with a project example : Improving glass wool stock management through image analysis. One of the 2022 subjects took place in an international company producing glass wool. The industrial setting of the subject was a leading plant of the company for the implementation of industry 4.0 technologies. In this plant, glass wool is stocked outside which leads to several stock management activities, one of which being regular inventories. The company has installed a 4D camera that is able to take pictures of the stock. The subjet given to the student was : "*How to improve stock management thanks to image analysis algorithms?*"

During the project, students tested, on real data provided by the company, several image analysis algorithms, mainly to count glass wool pallets. During their final presentation, they presented their best performing algorithm as well as all the research paths possible for the company to improve the algorithm. After their final presentation, the industrial partner highlighted : "*The subject enable an exploration of the expectations we have on image analysis technologies for industrial purposes, subject on which we have a lot of progress to make [in our company]*". (Industrial partner, Questionnaire, 2022).

4 RESULTS : EVIDENCE SUGGESTING THAT STUDENTS EXPERIENCE THE VALUE OF REFLEXIVE PRACTICES DURING THE POC MODULE

Several evidence suggests that students experience the value of reflexive practices for engineering work during the POC module. First, due to the innovative nature of the subject they tackled, students were confronted to open-ended problems for which companies were unable to indicate what students should do. Several students highlighted that these situations made them realise that a specific reflexive approach had to be implemented. For example, one student stated that "we quickly realised that, in our company, they did not know how to solve the problem they gave us. We had to set up our own method" (Student, Debriefing, 2021.) The idea that the innovative nature of the projects was the root cause for the need of reflexive approaches is well shared among the students : "The exploratory nature of the subjects calls for a permanent critical approach on what we are doing" (Student, Questionnaire, 2021). Some students even link their reflexive attitude to engineering practices : " I developed a critical approach to solve problems which now change the way I depict my missions [as an engineer]" (Student, questionnaire, 2022).

Second, students highlight that the weekly one-hour-long coaching sessions are moments to reflect upon their projects as well as key success factors. We received a lot of oral feedback from the students that indicate that coaching sessions were critical for the success of the project and 9 students out of 12 gave similar indications in the questionnaire. When digging into why students find the coaching session critical, the answers converge toward the following quote : "*Thanks to the project, we learn a lot of useful things as engineers and thanks to the coaching sessions we learn how to consider our subject with a different perspective*" (Student, Questionnaire, 2022). Therefore, it seems that students identify the coaching sessions as moments of reflection and found these moments useful for engineering work.

Third, the final presentations make students realise that other engineers conduct reflexive practices. Indeed, the final presentation is an opportunity for students to take part in discussions with other engineers. One example is provided in 2022 by a group that had to design a POC of a continuous inventory process. One of the main findings of the group was that there were different formulas that could be used to conduct such an inventory. As one of the students stated :"*Clearly, they [the company] had not realised that there were different formulas. The discussion [after the presentation] makes it clear that they need to reflect upon these formulas before implementing any continuous inventory process*" (Student 2022, debriefing)

Fourth, feedback from industrial partners also provides evidence that the POC module helps students realise the value of reflexive practices. According to the industrial partner, this understanding is achieved because the design of a POC leads the students to "*explicit the experiments conducted, the lessons learned and the recommendations derived from the experiments*" (Industrial Partner, Questionnaire, 2022). This feature of the POC module "*is probably even more interesting for engineers with 2-3 years of experiences of conducting industrial projects*" (Industrial Partner, Questionnaire, 2022).

Last but not least, through their final presentations, the students triggered reflexive practices of engineers of the company they were working with. For example, one presentation explicitly encourage the company to debate and agree on the mathematical formula that should be used to assess stock deviation (Students, Final

Presentation, 2022). Industrial partners admitted that this reflection was of critical importance for the project they were pursuing. Thus, students experienced the value of reflexive practices as they witnessed their importance for working engineers.

Thus converging evidence suggests that the POC module allows the students to experience the value of reflexive practices for an engineer.

5 CONCLUDING REMARKS

In this concept paper, we conducted a preliminary analysis of a two-year-old teaching module where students are asked by an industrial partner to design a Proof-of-Concept on an innovation subject. Our aim was to strengthen our feeling that the POC module helps students understand the interest of reflexive approach. We therefore gathered several evidence indicating that students experience the value of reflexive practices [1] for engineering work.

As a concluding remark, we would like to highlight that the question of the features of the POC module that make students experience the value of reflexive practices still have to be investigated. To do so, we would like to relate the features of the POC module to engineering education literature to see whether such features are reported to be linked with reflexive practices.

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INTRODUCTION TO MOLECULAR MODELING OF MATERIALS IN AN UNDERGRADUATE ENGINEERING DEGREE

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ABSTRACT

Molecular modeling is a chemistry tool that has been widely used in the last decades to mainly support the basic concepts of general chemistry and organic chemistry, in both undergraduate programs of basic sciences and some technological careers. Despite its use, except in some very specific cases, it has been extensively employed as illustrative examples of the chemical concepts that were being demonstrated. Despite the numerous existing applications to comprehend the phenomena behind the development of new materials and biomedicine, it is difficult to find a conceptual introduction of molecular modeling applied to specific problems on the modern engineeries within the undergraduate programs. In the present work, it will be shown the introduction and adaptation of molecular modeling concepts within a new optional course for students coming from materials engineering, chemical engineering and biomedicine engineeries. Different approaches to problem-based and small project-based learning are presented to encourage the scientific spirit of students using techniques of molecular modeling that had not been visited throughout their studies and, thus, to discover their potential appliacation in a more specialized context.

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1 INTRODUCTION

Interdisciplinary teachings such as molecular modeling, which involves mathematics, physics, chemistry, computer science and biology, are still scarce both at high school and at the general College level [1]. However, it is observed a shy wave of change in the last decade due to easier access to powerfull desktop installed in the computer classrooms, as well as to a more accessible simulation software [2]. Indeed, subjects where the use of computer programs is predominantly present, such as molecular visualization, bioinformatics, molecular modeling, and computer simulations, are almost absent from high schools, and in the University are offered only to very specific science majors or as a complement to other disciplines, in the most advanced years [1]. However, there is some simple activities such as those devoted to introduce fundamental chemical concepts regarding molecular shape and atomic orbitals, which can be easily included in the curricula of secondary schools able to involve an students' profile with very little background in chemistry [3].

On the other hand, in the University it is common to find undergraduate physical chemistry programs integrating molecular modeling into their quantum mechanics curriculum [4]. Also, undergraduate life science programs such as the biochemistry [5], pharmaceutical [6], and medicinal chemistry [7, 8], among others, have been gradually emboiding most of the molecular modeling techniques to predic biological outcomes and elucidate details at atomistic level. Indeed, currently molecular modeling is being incorporated as an important part of the research in areas ranging from physics to chemistry to structural biology, as well as the drug design in the pharmaceutical industry.

Regarding undergraduate engineering programs molecular modeling usually is not explicitly included in the syllabus even though implicitly is present in many topics developed in the curricula. Altarawneh and Dlugogorski [9] show the importance of strategic applications of quantum chemistry in chemical industries and present an easy way to introduce chemical engineering students to illustrative case studies that deploy molecular modeling in the design of reactors and derivation of thermochemical functions. In fact, there are reported in the bibliography different experiences incorporating the molecular modeling into the chemical engineering curriculum with specialized curses presenting a comprehensive overview of the use of simulation techniques, including thermochemistry and reaction rate data, physisorption equilibria and diffusion rates, and transport properties [10]. Other initiatives were more in the way to build specialized front-end application to deal with quantum mechanical calculations exploring applications more focalized to the thermodynamic properties of molecules, thermochemistry of chemical reactions, and the optical and chemical properties of doped nanodiamonds [11].

In the present work a new optional course in molecular modeling of materials is offered to students coming from materials engineering, chemical engineering and biomedicine engineeries is shown as an ongoing project. Tuvi-Arad [12] presents three different models for including computational chemistry in the undergraduate program: the specialized course model, the augmented course model, and the islands of computations model. Here, an specialized course is the way chosen to incorporate the theoretical and practical concepts. Along the course several problem-based and small research project-based learning were conducted. Students participating in an undergraduate research (e.g., in a computational molecular modeling lab) have shown to be able to develop better novel and independent projects later [5]. The development of critical thinking and the communication of scientific ideas in oral and written formats that are expanded in these types of projects are essential to ensure that students evolve into a greater understanding of basic scientific knowledge and the research process. Currently the molecular modeling research/training is less dependent on ‘home-written’ programs than it used to be, existing a large number of well-written and well-supported open source packages available to the user. Thus, facilitating and shortening the initial learning curve. In fact, Allen [2] shows a succesfully experience using such software packages for teaching molecular modeling to non-specialists students in a relatively short time.

2 IMPLEMENTATION OVERVIEW

2.1 Material and Methods

The main practical challenges to develop this course lay on both the computing environment and the computational tools that are involved in the computation chemistry applications. Independently of the science branch in which the course should be inserted, the main challenge is to shift the minds of the student from an application’s-based environment (either *Windows* or *Apple*) to an intensive computing-based environment, i.e., *Linux*. Most students have never had contact with Linux Operating System (OS) and require building up the proper computing tools to emulate Linux OS within a Windows or Apple (*OS X*) environment. Two potential options may arise to achieve this goal, either building a dual mode configuration, with the inherent problematic of running two different and often incompatible, OS or building a virtual machine able to run in any given home-focused OS. In that regard, our university developed a universal web-based platform [13], which is a desktop virtualization solution developed from free software. This platform provides the user with a personal virtual desktop that runs on the remote server independently of the device (Windows, OS X, or Linux computer) from which the connection is made. Through this platform the students can emulate a Linux environment inside any personal platform that they may be using, either classroom desktops, personal laptops or even tablets.

Within this context, each virtual desktop contains all the Linux tools that the students will require to achieve the course goals. Moreover, their virtual machine allows an easy connection to our small computer cluster via ssh protocol (security shell connection [14]). The use of a computer cluster is a necessity in order to carry out simulations of actual meaning. One of the main drawbacks of computation chemistry, especially when performing Quantum Chemistry simulations (QM), is the necessity of using multiple computing threats to finish those simulations in acceptable time frames. Solving thousands of complex non-liniar equations at the time implies the need of huge amount of RAM memory and many CPUs working in concert to achieve calculations speeds suitable for acceptable time costs.

The computational tools used for the proper development of the course will be distributed between the virtual desktop used by the students as main terminal and the advanced programs used in the cluster. The virtual machines will have all the resources of *Debian GNU/Linux10*, which includes *Mozilla Firefox* for internet access and scientific tools such as *Python* scripting, *GNUplot* for results graphical plots, *jmol* [15] for visualizing chemical structures, and *VMD* [16] for analyzing simulated trajectories. In the computing cluster, students will find all the scientific programs and suits necessary to learn and explore the basic approaches used in computational chemistry. This pool includes computer programs to perform Quantum Chemistry (QM) calculations, which consist in *NWChem* program [17] and Molecular Mechanics (MM) based programs. For the latter case, *AMBER* suite is preferred, version 20 [18], because not only performs all kinds of simulations within MM approach but also allows performing hybrid QM/MM simulations.

2.2 Course development

The structure and contents of the course are organized on active learning and solving problems. Each lesson is based on learning and assimilating new concepts through solving practical problems or performing realistic simulations. While unfolding the contents of each chapter, the students are engaged to solve specific problems and exercises that illustrate each new explained concept and at the end of each part the students must solve a final realistic simulation problem organized as an individual directed work (hereafter “practice”) that applies the acquired knowledge to a practical exercise, which at the same time would constitute a part of their academic evaluation. The final grade will be averaged over all the accumulated of individual grades, complemented with an oral presentation of a chosen subject (commonly a review of a scientific article), performed in small groups of 2 or 3 people. This methodological approach allows a progressive and integrative acquisition of new concepts based on a global vision of the subject and a direct practical application into the academic fields from which the students come from, since this subject is a multidisciplinary class and the general field of molecular simulations is used in a great variety of scientific applications.

3 RESULTS AND DISCUSSION

3.1 Subject implementation

The overall structure of the course and the timeframe used for each section is listed in Table 1.

In the initial sessions of the first section the students are introduced and familiarized with Linux Operating system, its basic commands, and the use of scripting as programming tools and execution of simulations. At the end of this section, the students are required to solve practical applications by using scripting, all gathered in

Practice 1: *Introduction to Linux. Based on scripting programming*. Most of the focus lies on a practical approach, in which the students are engaged in applied challenges to be solved using the commands they are introduced. For instance, the students are tought to use bash scripting to manage different commands within real simulation environment, which allows for multiple solutions to solve the same problem.

Table 1. Course structure and the timeframe section

#	Section	Time[a]	Assessment[b]
1	Introduction to molecular modeling	12	P
2	Classic model: conformational studies of materials and proteins	12	P
3	Quantum model: heterogeneous & enzymatic catalysis studies	12	P
4	Applications. Advanced simulation of materials	22	PJ
5	Research papers. Real cases under study.	2	RO

[a] Time in hours; [b] P, Problem-based; PJ, Project-based; RO, Report & Oral exposition

In the second section, the classical model applied to chemical structures is presented, showing the computation of structural energies using a Classical Force Filed, followed by the definition of simulation concept and the two main kinds of simulations used within the framework of *Molecular Mechanics* (MM), *Molecular Dynamics* (MD) simulations and *Monte Carlo* (MC) simulations. It is also at this point where the students are introduced to visual tools that allow the representation and visualization of crystals, amorphous materials and proteins. The final activity of this chapter is summarized in Practice 2: *Structural study of a polymer, crystal and/or protein*. In this final practice the students are challaged to study the effect of several enviromental factors, such as ionic strength or temperature, over the conformational stability of an small protein using AMBER program (Fig. 1)

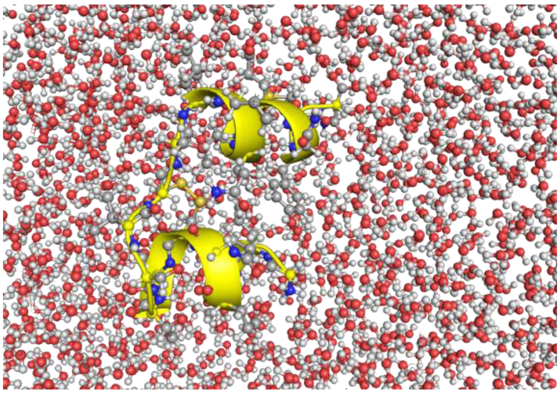

Fig. 1.- Human Insuline immersed in water filled box

In the third section of the course the students are presented with the challenges of modeling of thermodynamic properties, chemisorption on different materials and chemical reactions, which implies solving Schrödinger Equation. A quick review to its exact solution for the hydrogen atom is used to present the conundrum of setting the proper Hamiltonian in polyelectronic systems, leading to the exploration of the different quantum simulation techniques, going from Hartree-Fock based methodologies, their approximated solution through Semiempirical methods and finally the introduction to Density Functional Theory and its applications. This section is completely self-guided through different exercises of growing complexity starting with the atomic properties such as the atom multiplicity, solving the IR spectrum of some molecules, studying the geometry of organometallic complexes, and ending by obtaining the transition state of a reaction in gas phase. The chapter is closed by solving Practice 3. *Simulation of a heterogeneous and/or catalytic process* (Fig. 2).

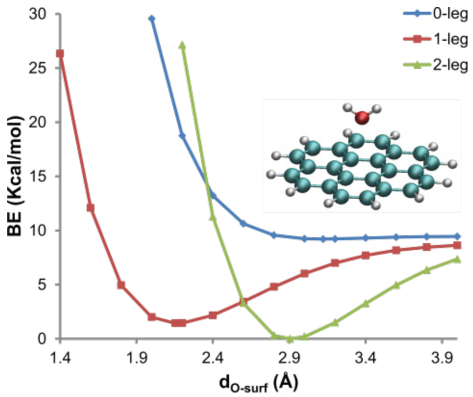

Fig. 2. - Chemisorption of water in graphene[19]

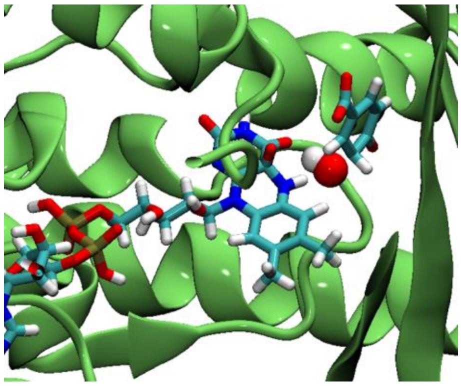

Fig. 3. - Oxygenation reactions catalysed by the enzyme p-hydroxybenzoate hydroxylase[20]

The fourth section of the course is divided in two different parts. A first section showing other computational tools used in the Biological and Material sciences, e.g., polymer and biopolymer simulations, enzyme catalysis (Fig. 3) and structural bioinformatics. This part is organized in demo-pills with all the material and files made available to the students, thus allowing a later reproducibility. Structural bioinformatics is emphasizing the techniques involved in homology modeling, fast threading (Fig. 4), and computational aided drug design. A second and last part, that revolves around solving a practical scientific case using the tools and techniques learnt throughout the course. This application is organized in a final simulation project (see section 3.2) that constitutes Practice 4.

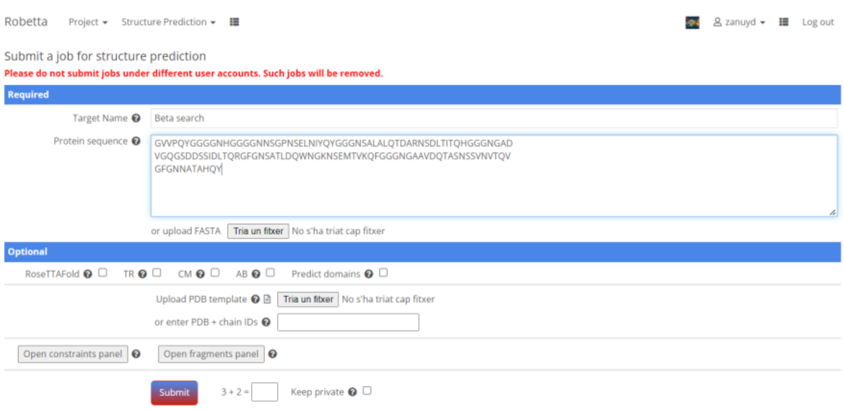

Fig. 4. - Online interface for Robetta project computations for fast threading.

The last section is devoted to studying different research works on molecular modeling, published in peer-reviewed journals, to complement the learning of those new methodologies not explored throughout the course. The students, organized in very small groups, choose a research project at the beginning of the course among several according to their own scientific interest. They try to understand the methodology used, the results obtained, as well as the conclusions reached by the authors of the article. On the last day, together with a report, it is exposed to the rest of the classmates, which allows a small debate to be opened about it.

3.2 Directed Learning Activity: Simulation Project

The final simulation project is the longest directed learning activity of the course and it is conducted after the students have gained most of the theorethical and practical concepts. Each student choses one topic among several projects (all with different development) and laying in different fields within molecular modeling, e.g., material science, structural biology, and bioinformatics. All the methodology to be used in this section has been acquired within the subject and the main difficulty developing the project is laying in the comprehension of the studied concepts. Usually, at this point the students get much involved in the topics, thus gaining a strong command of molecular modeling. Indeed, an improvement in critical thinking and a greater knowledge of the research process by students was observed at the end of the course, which was reflected in the work developed in Practice 4. *Advanced simulation of materials*.

3.3 Course Assessment

The subject has been conducted along three academic years involving a total amount of 29 students. One of the most difficult point that students have to face in this multidisciplinary course, beside of revive the basic buried concepts of chemistry and physics in the first years of the undegraduate program, is the missing unawareness on basic computational science. The student is very familiar with the visual informatics as common user but fails in the command and scripting languagues, which are necessary in this kind of simulation, where most of the applications are running in Linux OS. Thus, facing the Linux OS is one of the first challenges that the student has to deal with. The continous learning curve observed is mainly based in the computer lab experience, adquired along the subject development. Indeed, the subject assessment is trying to reinforce the working lab through proposing to the student different problems to be solved, as well as a small project that will be evaluated individually, coinciding with the five sections in which the subject is divided (see Table 1).

Finally, an equitable evaluation of the five sections of the subject is carried out. Considering this way, the part of individual development, both of the short problems at the end of each main topic (sections 1 to 3) and the application project (section 4). The assessment ends with the commentary in group on the research article (section 5). Spite of most of the developed work is evaluated independently, there is a common background in the problem description with a different problem development that would allow to the students to discuss and work in their own project at the same time that are working in group to obtain a final solution. Differences between their scientific background and origin (10 % students were in an Erasmus program) reinforced the collaborative work at the time that increased the group motivation.

We assessed the degree of satisfaction of our students using a enquiry that we specifically designed for this porpouse. The general level of satisfaction for this new class was between high or very high. Some students had some missgivings regarding the depth of the theoretical contents and suggested a more applied approach. However, this particular question becomes quite unfeseable due to the lack of background in statistical mechanics and quantum mechanics that they had from previous years. There is though consensus about both the utility of the applied examples and the direct applications practical of the newly accuaried knowledge. Throughout these three years most of the suggestions raised by our former students have been incorporated. However, it is really tough to only focus on practical problems when there are important lacks on their background.

4 SUMMARY AND ACKNOWLEDGMENTS

In this work the introduction of a multidisciplinary optional subject straddling different teaching programs of different engineering careers is presented. The whole subject is supported by short problems- and projects-based learning that the student carries out to complete their learning curve. The constant challenge designed to foster scientific discussions among them from different students backgrounds, working together to solve a problem, increases their motivation for the subject. As a result of these first three years has been the presentation at the end of the course of elaborate simulation projects with a high dose of independence, development of basic scientific knowledge and research process.

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TOWARDS 21ST CENTURY CITIZENSHIP THROUGH SUSTAINABLE DEVELOPMENT GOALS IN FOREIGN LANGUAGE EDUCATION

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ABSTRACT

Since learning, literacy, and life skills have become essential for individuals in the information age, the focus on education has shifted to preparation of students for the knowledge society. This is valid for all levels and spheres of education including but not limited to foreign language teaching in higher education. With this in mind, a new English for Academic Purposes (EAP) Course aiming to equip freshman level university students with necessary learning skills has been launched. A particular emphasis has been given to developing the students' English language skills so as to facilitate their communicative competence both in their academic and professional lives. The course adopts a challenge-based learning approach, which provides students with a meaningful framework for learning as it is based on solving real-world problems. In the course, the students work on real world challenges based on the 17 Sustainable Development Goals (SDGs) of the United Nations (UN) while using the learning skills (the four C's) of the 21st Century, namely critical thinking, creativity, collaboration, and communication. During the course, the students work together on the issues highlighted as challenges in United Nation's report on Turkey's state regarding the 17 SDGs, and offer solutions in groups in the form of poster presentations, academic papers and oral presentations. The course has been implemented since fall 2021. In this concept paper, the researchers will share their experiences and research plans about the evaluation of the course based on Stufflebeam's Context (C), Input (I), Process (P), Product (P) (CIPP) Evaluation Model.

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1 INTRODUCTION

1.1 21st Century Skills

The integration of 21st century skills in education has changed the nature of teaching and learning to a large extent. The replacement of conventional teaching methods with a new focus on the essential skills of the information age has led to the emergence of new practices in teaching that aim at fostering student engagement. When literature in the field is examined, it is found that all levels of education give importance to learning, literacy and life skills in their curriculum.

Due to a surplus of information and the possibility of easy access, the 21st century is agreeably called the age of information and technology. The ease to reach information and the infinite sources to have knowledge about a particular subject may sound to the advantage of individuals and societies that aspire for progress, yet it should also be noted that analyzing, interpreting and evaluating this abundance of information is much more vital to make optimum use of it. Knowing how to use information rather than reaching it has become a required skill, thereby making the integration of 21st century skills into every sphere of life essential. Moreover, the changing conditions of the world, economic structures, and social dynamics must also be taken into account. As Voogt and Rublin (2010) also discuss in their paper, the nature of jobs are changing and young people are educated for the jobs that do not even exist today, which requires individuals to compete globally while working both individually and in groups (Jacobson-Lundaberg, 2016). It would not be wrong to argue that teaching 21st century skills to young people will prepare societies for a future they cannot fully grasp.

1.2 Higher Education and 21st Century Language Teaching

The first category of 21st century skills, learning skills, are adopted in language education for the sake of a more integrated approach to teaching in higher education. Fostering the interaction of students through group work, which necessitates collaboration and communication, as well as developing their oral and written competencies with individual assignments that require creative thinking and creativity, 4Cs-oriented language teaching responds to the needs of 21st century university students. The emphasis on 21st century skills in language education also reflects the premise that individuals express themselves through language and language learning plays a key role in "professional success" as it gives one insight about the presence of different cultures and global issues (Cruz & Orange, 2016, p.2). A comprehensive language education, which encompasses all aspects of 21st century skills will ultimately give university students from different backgrounds the chance to work collaboratively and have a sense of teamwork. This will in turn develop their communicative skills as they will feel more self-confident seeing that they can communicate with people in a non-native language. Feeling the need to listen attentively in order to understand, thinking critically to make sense of what is said and giving an appropriate response to continue the conversation will develop communicative skills like listening, respecting different ideas and having empathy. In other words, teaching the language of another culture will both necessitate and develop the use of 21st century skills.

1.3 21st Century Skills for Global Citizenship and Challenge-Based Learning (CBL)

An emphasis on 21st century skills in language education inevitably paves the way for the discussion of global issues in the classroom. Cruz and Orange argue that "21st century interdisciplinary themes" are used as subjects in language classrooms to develop academic language competency of students (2016, p.2). Discussing global problems as varied as and not limited to climate change, gender inequality, decent work, and sustainable energy both orally and in writing assignments gives students a new perspective to look at the global challenges countries are faced with contributing to their global citizenship competencies. In this respect, adopting challenge-based learning (CBL) as a pedagogical approach in language teaching in higher education makes it possible to engage students in real-life scenarios by using a secondary language to understand and discuss it.

Defining CBL as "extended problem-based learning", Baloian et al draw attention to its project-based aspect. In 21st century language classrooms, the attempts to foster students' collaborative and communicative skills as well as creativity through group projects become more meaningful when real life challenges are included as subject materials in courses. Similarly, Quieng et al argue that teaching 21st century skills to students enables them to be aware of global challenges, which will in turn help them endure difficult conditions and turn challenges into advantages (2015). With this objective in mind, language teaching with a challenge-based approach will equip students with necessary skills to respond to the needs of the era and fulfill the standards of the 21st century learning framework. A student who can think critically, communicate and collaborate in another language will also develop these skills further to conduct research, analyze and interpret information in the target language. Able to express themselves about social, economic and environmental issues in their native and non-native languages, students will also feel motivated to take active part in decision-making mechanisms, a skill which is formally defined as "civic engagement" and considered one of the liabilities of socially responsible universities of the 21st century world.

1.4 Challenge-Based Learning through Sustainable Development Goals (SDGs) in Higher Education

One way of applying challenge-based learning in higher education is discussing global issues in a systematic way with real-life scenarios as course materials. With this purpose in mind, the Sustainable Development Goals (SDGs) of the United Nations (UN), may be used as the context of lectures. Since their launch in 2015, the SDGs have been addressed in various settings such as strategic plans of institutions and companies, political agendas of policy makers, theoretical framework of many scientific studies and the curricula of educational institutions. The emphasis of the UN on active citizenship and inclusive societies has been adopted in education as the basis to raise a more conscious and responsible youth with a new understanding of their role as decision-makers and drivers of change. Sustainability studies envision that collective action and learned practices for a more sustainable world have a recreative power. Dlouha et al emphasize the necessity of implementing an understanding of individual competences through SDGs in higher education (2019). In language education, SDGs function as the intercultural context in which the students are expected to have an understanding of sustainability practices in different countries. Using the target language as a tool to have debates about global challenges, do research about sustainability solutions and write reflective papers to propose their suggestions are all examples of practices for sustainability education. Indeed, a sustainability-oriented course enables the instructor to carry challenge-based learning a step further by fostering self-learning and contributing to enhancement of students' civic participation.

Although sustainable development has remained on the agenda for engineering disciplines for a long time, the broadening of the concept in the form of Sustainable Development Goals to other disciplines in higher education is a relatively new form of implementation. This is doubled by the need of integration of 21st century skills and competencies into classes to cater for the requirements of the new era. To this end, this concept paper will evaluate a relatively new course aiming at improving engineering students' academic English skills through content focusing on SDGs and equipping students with 21st century learning skills. A particular curriculum evaluation methodology will be applied for the evaluation of the course and the paper will seek responses to the following research questions: (i) What is the context behind the implementation of the course? (ii) What forms of input are available for the course? (iii) What is the process used during the operation of the course?

2 EVALUATION FRAMEWORK

Ornstein and Hunkins define curriculum development as a process comprising not only planning, implementation, and evaluation, but also people, processes and procedures (2003). It entails a dynamic relationship between the objectives, content, learning-teaching process and assessment elements of the education program where a change in one of those components affects all dimensions in the system. Curriculum is developed by designing, implementing, evaluating and reorganizing educational programs based on a needs analysis or program evaluation study, which can be defined as the decision-making process regarding the effectiveness of the program in reaching the predetermined goals and objectives. Using models in evaluation guides the evaluator not only about the kind of data that will be collected, but also when, where, and how the data collection process will take place. Without an underlying theory, the evaluator will seem to be working in the dark and will not be able to attribute the results to the program.

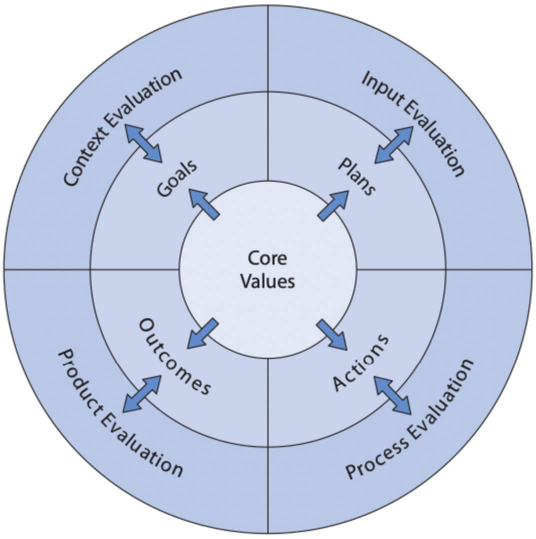

Figure 1. Key Components of the CIPP Evaluation Model and Associated Relationships with Programs (Stufflebeam & Coryn, 2014, p.318)

The evaluation model first developed by Stufflebeam, CIPP, which is an acronym for four types of evaluation: Context, Input, Process, and Product, was used during the design and evaluation of the course in this study. As depicted in Figure 1 above, while context evaluation aims to identify needs with the purpose of deciding on program goals, input evaluation is conducted to design plans involving the strategies and designs. In the process evaluation, shortcomings in a current program are explored and actions to revise implementation are taken, and product evaluation measures outcomes so as to decide about the revision or continuation of the program (Stufflebeam & Coryn, 2014). Moreover, as cited in Christie and Alkin (2013), the CIPP model defines evaluation as a cyclical practice, rather than a product, which needs to be based on a carefully designed, but flexible process.

In accordance with the CIPP methodology, the specific questions that the study seeks responses to are provided below:

Context	1. What are the needs of the 21st century engineering student? 2. What are the aims, goals, and objectives of the course aligned with the context dimension of the CIPP model?
Input	1. What are the resources and materials used in the course? 2. What strategies and activities have been used to address the needs of the students? 3. What forms of assessment have been implemented?
Process	1. To what extent are the planned activities carried out and is there a need for adjustments or revisions of the course? 2. How do the instructors perceive the course materials and teaching methods? 3. How is the teaching and learning process affected during the implementation of the course?

3 EVALUATION AND DISCUSSION

In accordance with the aforementioned evaluation model (Stufflebeam & Coryn, 2014), *English for Academic Purposes (EAP) through Global Goals Course*, which has been implemented at Istanbul Technical University (ITU) School of Foreign Languages (SFL) for two consecutive academic terms, will be evaluated elaborating on Context, Input and Process dimensions. The Product dimension of the CIPP model will be finalized after the complete set of data is collected as part of continuous quality improvement process.

3.1 Context

Regarding the context evaluation, firstly literature on sustainable engineering and the needs of the 21st century engineers was reviewed. Sustainability is a concept referring to a future that balances societal, environmental, and economic issues with the aim of achieving a higher standard of living. Hence, society, environment, culture, and economy are all interwoven components of sustainable development, which cannot be considered separately. Similarly, based on the report titled *Engineering for Sustainable Development: Delivering on the Sustainable Development Goals,* sustainable engineering adopts a multidisciplinary approach focusing on not only technical issues, but also social, political, and ethical ones while taking into account the whole system and the global context (UNESCO & ICEE, 2021). Thus, 21st century engineers have a critical role in solving global challenges related to such fields as energy, health care and environment. For this complex task, they need to adopt a multi-disciplinary approach while working in collaboration with culturally diverse teams, and develop complex communication skills. Consequently, curriculum and instruction in the 21st century integrates 21st century skills into core subjects and interdisciplinary themes, rather than focusing mostly on technical content. Based on the report of the American Association of Colleges for Teacher Education (AACTE) and the Partnership for 21st Century Skills, learning and innovation skills comprise critical thinking and problem solving, communication, collaboration, creativity and innovation, which are all to be constituent components of 21st century engineering curriculum (Greenhill, 2010).

Istanbul Technical University, which has a pioneering role in raising engineers in Turkey, is also one of the partners of the European Engineering Learning Innovation and Science Alliance (EELISA), which "is the first alliance of Higher Education Institutions (graduate engineering schools, technology universities and full-spectrum universities) from different countries in Europe. It offers high-quality programs and courses in line with the objectives of the alliance, thereby contributing to its mission to transform European higher education while strengthening links between engineering and society by re-inventing the 'European engineer'" (EELISA, 2022).

Moreover, in line with the mission of the University with its emphasis on contributing to a sustainable community, the School of Foreign Languages at ITU started to implement *EAP through Global Goals Course* for the first time in Fall 2021, so as to design language education conforming to the needs and priorities of engineering students. It is offered as a 3-credit EAP course aiming to develop students' English language skills through 21st century core skills or the 4Cs (Critical thinking, Communication, Collaboration, Creativity) and United Nations Sustainable Development Goals. As Mikhnenko and Absaliamova pointed out in their article, language education of engineers in the 21st century provides an open ground for "intellectualisation" (2018, p. 37). They argue that integrating language education with a special focus on EAP and ESP enables engineering students and specialists to develop basic skills that a professional needs such as creative and analytical thinking, communicating by using different languages and learning how to access information (2018). Not different from what Mikhnenko and Absaliamova suggest, the course at ITU also offers an academic and intellectual environment for the professionalization of engineering students. Among the objectives of the course are to enable students to express themselves using appropriate discourse strategies in written and spoken communication, to develop the 4 Cs (Critical thinking, Communication, Collaboration, Creativity) of 21st century Learning, which are core skills that the students will need in their academic and social lives, to enhance students' awareness regarding Sustainable Development Goals, to improve students' collaboration skills in multidisciplinary groups, and to develop associated academic practices and soft skills, such as goal-setting, self-reflection and time management.

3.2 Input

EAP through Global Goals Course has been taught online by 26 English language instructors to 999 first year students enrolled in various engineering departments since fall 2021. It has been offered as a compulsory course for students at a certain level of English proficiency. The textbook used in this course is licensed under the Creative Commons Attribution-Non-commercial 4.0 International License, and it is in line with the goals and objectives defined in the syllabus. To supplement the textbook to be used in the program for the first time and to better serve the goals of the course, a unit on problem-solution paper writing has been integrated. Moreover, creative/critical thinking, and teamwork skills of students have been enhanced through a case study unit. Sample problem-solution and case study papers have been created and shared with students. To provide the instructors with background information related with SDGs and 21st century skills and learning, lesson presentations have been shared. During the course, the students have the chance to improve not only their English language skills, but also 21st century learning skills while reading, listening and responding to texts about the SDGs.

Concerning the assessments, the students are to prepare poster presentations on two related SDGs, attracting attention of the audience and providing solutions to a problem.The students are expected to perform this task in pairs, in compliance with the focus of the 21st century skills on communication and collaboration. The students are also expected to write a problem-solution paper on one of the challenges in the report by Sachs et al (2021) regarding the implementation of the SDGs, which has enabled them to critically tackle real life problems of their own countries and propose solutions. To help them get acquainted with this kind of assessment, different from previously implemented formats, the students have been provided with sample problem-solution papers presenting the problem and suggesting alternative solutions. As final assessment, the students work in groups and write an essay analyzing a case scenario based on its relationship with the SDGs and deliver an oral presentation on it. As underlined in *A Core Inventory for General English (British Council/EAQUALS)*, using real life scenarios in language teaching enables the students to evaluate a particular situation using the target language and develop new perspectives by providing a “holistic setting” (North et al., 2015). Within this scope, this assessment has contributed to the students’ ability to work in teams as well as enhancing their critical thinking and communication skills contributing to their development of new perspectives. With regard to the input of the course, it is obvious that students have solution suggestions to global issues ranging from climate crisis, gender inequality, global hunger to water sanitation, education rights and innovative cities, indicating improvement in their awareness of the SDGs as a consequence of implementation of the course.

3.3 Process

As Stufflebeam emphasizes, the most foundational principle of the CIPP model is “not to prove, but to improve” (cited in Stufflebeam and Coryn 2014, p. 176). With an aim to develop the course, certain steps have been taken. For instance, since fall 2021, feedback on course materials and assessments has been collected from the instructors via an online platform. To collect feedback on course materials, the following two open-ended questions were asked: 1. What would you change in Unit XX next time you teach the Course? (pacing, videos, activities, supplementary materials, etc.?) 2. Would you like to add anything else? To collect feedback on assessments, the instructors were asked to write down their comments about each assessment’s guidelines and rubric. In addition, 30 minute informal discussions to share experiences, i. e. what went good or bad, or ask questions, suggest changes were held online.

As a result of the feedback collected and online meetings, it was observed that most of the instructors felt their students needed more input and context on SDGs before starting to work on their first assessment, i. e. poster presentation. Consequently, in spring 2022, each student was assigned one of the 17 SDGs and asked to present the details of the goals and their targets and conduct a student-led discussion, which also gave the students the chance to improve their communication skills. Moreover, most of the instructors agreed that in line with the course objectives, the problem-solution paper regarding the SDGs that remain as challenges for Turkey should be an oral assessment rather than a written one, which is considered as one of the steps to be taken for improving course implementation due to the expected focus of the course on spoken communication rather than written language production to better cater for the needs of engineering students.

The fact that the course was not delivered in person and all these assignments and presentations were carried out online contributed to another objective of the course as well. Delivering online presentations using digital tools, doing online research and preparing posters with the help of various multimedia tools obviously fostered the digital literacy skills of students, which are also among the 21st century skills. Students were expected to use their critical thinking and problem-solving skills to complete online tasks. Considering that companies are employing their workers through online exams and interviews, dissertations are presented online in academia, and the number of webinars, open access courses, workshops as well as certificate/degree programs is rapidly increasing, the online delivery of a challenge-based course has enabled students to simultaneously use various skills. Considering that a challenge-based course addresses social and cultural dynamics that lead to important transformations in societies, a language course through SDGs cannot be given regardless of the changes in technology and the acceleration of digitalization. As Gómez-Zermeño also argues, Education for Sustainable Development (ESD) cannot be “prescriptive” particularly in the age of digital learning, highlighting the potential of digital learning to facilitate “active knowledge co-creation and communities of practice” (p.579). Online delivery of the course, in this respect, contributes to the objectives of 21st century challenge-based courses to provide ample ground to share information and experiences as well as resources, inviting students and instructors to contemplate how knowledge is created.

4 CONCLUSION

This paper presents the evaluation of the course *EAP through Global Goals* in accordance with CIPP model elaborating on Context, Input and Process dimensions. It captures the background for multiple criteria in the context of CIPP providing insight and reference points for implementation. The integration of Sustainable Development Goals, 21st century learning skills and challenge-based learning in higher education undoubtedly underpins the essentials of engineering education in the knowledge society as indicated in the scope of the study. Despite information provided concerning constituents of the evaluation model in the current study, this is still a work in progress and is to be completed by the next step in which structured feedback will be collected from students. The results will then be used so as to fine-tune the content as well as assessment of the course. Sustainable Development Goals and 21st century citizenship are a critical consideration in accordance with the requirements of the current era and involve further exploration in various fields of higher education.

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STUDENT PERCEPTIONS OF STUDENT SUPPORT SERVICES FOR FIRST-YEAR ENGINEERING STUDENTS (CONCEPT)

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Keywords*: student support services, first year, student perception, study success*

ABSTRACT

To help first-year students get accustomed to university, many universities organise intra- and extracurricular support initiatives. During the academic year, student support services at the Faculty of Engineering Technology at KU Leuven offer both course-specific activities as well as initiatives focusing on study career guidance and academic skills. Yet we notice that not all students find their way to these voluntary activities – even if they would benefit from the help.

The purpose of this study is (1) to understand how first-year engineering students perceive the student support services, and (2) to understand how we can reach

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students who need the support, but do not find their way yet. This will further guide us in the development and communication of support activities.

A small-scale questionnaire was distributed among first-year engineering students, followed by two focus group discussions.

Our findings indicate that support needs are bigger at the start and end of the first semester. Crucial information such as how to study, and communication regarding support activities, should be served more than once, as first-year students still find it hard to filter out the right information. Students prefer course-specific Q&A sessions where they can hear questions of fellow students as well as the answers to those questions. A mentor for study career guidance is well appreciated. Tests and trial exams are important as triggers to start studying. We believe that these findings can inspire colleagues in other institutions.

1 INTRODUCTION

1.1 Student support activities

All first-year university students face a daunting task: besides getting accustomed at a new environment, with new friends, they also need to quickly adapt to the teaching methods and tempo at their new college [1]. Across the globe, universities are therefore seeking ways to accommodate their first-year students with support activities [1,2,3]. In Belgium, many of these activities are non-compulsory.

For specific studies, such as engineering technology, Belgian students are obliged to take a non-binding diagnostic math test before they can enroll. However, Belgian regulations stipulate an open enrollment system for most study areas including engineering technology, so the diagnostic test is low-stakes. As a result, many students start their engineering studies with underpreparedness for math [5].

Student support includes a rich variety of possible activities in response to local needs [6,7]. At the Faculty of Engineering Technology (FET) at KU Leuven, the support activities are arranged roughly into two categories: course-specific activities such as Q&A sessions and basic mathematical skill courses, and activities that surpass the course-specificity such as academic skills interventions and study career guidance. We will call the latter ‘non-course-specific support’.

FET is a multi-campus faculty. In this study, we focus on the student perception of both categories of student support activities at KU Leuven Campus De Nayer, one of the seven campuses of FET.

1.2 Student support activities at KU Leuven Campus De Nayer

At Campus De Nayer, students are divided into study groups of around 20 students who follow exercises and laboratory sessions together. Theory lectures and Q&A sessions are taken by all students at the same time, regardless of study group. Typical for the campus is the relatively high number of commuting students: 70% of first-year students in 2021-2022 travel over 10 km to the campus on a daily basis.

In Table 1, we describe the support activities that were offered to first-year students at Campus De Nayer in the first semester of academic year 2021-2022.

Table 1. First-year student support activities, KU Leuven Campus De Nayer (2021-2022)

Activity	Description
Course-specific activities in the first semester	
Q&A session	Voluntary group session. Students can ask questions about the course material. Each course offers at least two Q&A sessions per semester. Just before the first and second exam periods, an extra Q&A session takes place (‘Return Day’).
Tests	Compulsory tests in November that partially count in the exam score, depending on the result and the course.
Trial Exam	Voluntary non-binding test imitating an exam. Each course is represented with one question.
Basic mathematics skill courses	Voluntary mathematics support, consisting of a Massive Open Online Course (MOOC) and an online support trajectory on basic mathematics
Non-course-specific activities in the first semester	
Starters Days	Compulsory two-day activity at the start of the academic year. Campus life and practical tools are explained, PhD students show the link between their research and the courses, and first-year students have a chance to get to know each other.
LASSI Workshop	Compulsory test and workshop at the beginning of the semester. LASSI stands for Learning And Study Strategies Inventory. Topics include time management, study method, motivation, etc.
Workshop Time Management	Voluntary in-depth workshop following the LASSI workshop.
Workshop Efficient Study Methods	Voluntary in-depth workshop following the LASSI workshop.
Tutoring by staff	A mentor is assigned to each study group. The mentor helps with study-related questions, follow up on results, and is a coach for study-related questions. An individual mentor meeting is offered after the tests and after each exam period.
Tutoring by peers	Two higher-year students per study group help the first-year students get accustomed to university life and the campus.
Online modules	Online modules and training videos on study planning, fear of failure, procrastination, etc.

The goal of the study was two-fold: (1) Starting from the current support activities (both course-specific and non-course-specific), we wanted to know, from a student’s perspective, which are the essential building blocks. (2) Moreover, we were looking for inspiration on how we can reach students who need the support, but do not find their way to the current support activities.

2 METHODOLOGY

We used a mixed method, starting with a small-scale questionnaire to help us find the right qualitative questions. Subsequently, we ran two focus groups. As we were primarily looking for student perceptions, we relied on self-report data. Self-reports are subject to a number of biases, so insights should be interpreted with care.

2.1 Small-scale questionnaire

In the small-scale questionnaire (41 students; response rate = 42%), we explored three themes: (1) feeling of support at the beginning of the studies, (2) knowledge of and participation in support activities, and (3) support activity preference (ranking). The questionnaire was offered on a voluntary basis during a theory lecture, and was administered via PollEverywhere. The English translation to the questions in the questionnaire is listed in the Appendix.

2.2 Focus groups

Based on the questionnaire results, we explored emerging themes in more depth in the focus groups (n=10). We invited students from two study groups with different characteristics in order to have a good mix of students who attended the student support activities, and students who need the support but did not yet find their way. All students were invited to participate on a voluntary basis.

3 RESULTS

In this concept paper, we will focus on the insights that are most striking and that will guide us in rethinking student support and communication, based on student perception and self-reported needs.

3.1 Results of the questionnaire

Overall, students report they felt well-supported when starting their studies. As Fig. 1 shows, 69% of students felt supported to very supported at the start of their studies.

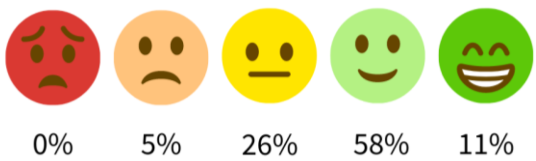

Fig. 1. First-year student response to the question how supported they felt in general at the beginning of their studies.

Table 2 shows that self-reported knowledge of the course-specific activities is high for most activities (known by 78%-95% of respondents), except for Return Day (49%). As for self-reported student attendance of these activities, we see a remarkably low reported attendance rate of Q&A sessions with respect to reported knowledge of the sessions. In the open-ended question on course-specific activities (no. 5 in Table 5), we found that 6 out of 18 students ask for ‘group Q&A sessions’.

Table 2. Percentage of students claiming to know or have participated in a selection of course-specific support activities.

Course-specific activity	Know by	Attended by
Q&A session Fundamentals of Math.	95%	63%
Q&A session Chemistry	80%	37%
Trial Exam	88%	76%
Tests	78%	78%
Return Day	49%	29%

Looking at the the non-course-specific activities (Table 3), we learn that the individual mentor meeting, which is part of the tutoring by staff, is well appreciated: it is best known and attended by students. Moreover, in the ranking question (no. 8 in Table 5), the individual mentor meeting came out as the top student preference.

Knowledge of both the compulsory LASSI-workshop and the Starters Days is low (known by 51% and 68%, respectively). In the open-ended question on non-course specific activities (no. 9 in Table 5), 3 out of 11 students reported the need for more communication regarding these activities, e.g. reminders.

Table 3. Percentage of students claiming to know or have participated in a selection of non-course-specific support activities.

Non-course-specific Activity	Know by	Attended by
Tutoring by staff: individual mentor meeting after the tests / first exam period	85%	61%
Starters Days	68%	56%
LASSI Workshop	51%	29%

3.2 Discussion of questionnaire results

The reported feeling of being well-supported at the start of the academic year stands out, in particular as it contrasts with the fact that that not all students find their way to student support activities. This raises the question how the perception of support evolved throughout the semester.

The spontaneous request for ‘group Q&A sessions’ is striking, since Q&A-sessions are organised in group by default. This suggests the need for a closer look into how these sessions are organised, and what students would need.

The high appreciation of the individual mentor meeting made us wonder if the same appreciation holds true for tutoring by staff in general and for the tutoring by peers.

As for the low reported knowledge and attendance rates for both the course-specific Return Day and the non-course-specific LASSI-workshop and Starter’s Days: we know from the attendance numbers that, contrary to what is reported by the students, most of them did attend these activities. Yet, only about half to a third of the students who participated in the questionnaire report that they have attended. This suggests that the activities themselves might be well-known, but their names are not. Moreover, we wanted to better understand why some students asked for more communication regarding non-course-specific activities specifically.

The questionnaire findings hence led to the following focus group questions:

- How did your feeling of being supported by the campus evolve during the first semester?
- In the first semester, what were reasons to go to / skip the Q&A sessions?
- Which non-course-specific activities were communicated well? Which were not communicated well? Why is that so?
- Which questions would you ask your mentor? Which would you ask your peer tutor?

Since one of the goals of the study was to look for inspiration on how to reach students who need the support, but do not find their way to the activities yet, we decided to add one more question to the focus group discussion :

- What, if anything, would make you start studying sooner?

3.3 Focus group insights

All students in the focus groups reported that the feeling of being supported persisted throughout the first semester.

The need for support decreases as the students become more familiar with the campus: *"The first time you come in a laboratory, you don't really know the teachers and you don't dare to ask a question. That is different in the last lab, when you know them and the barrier to ask questions is smaller."* However, the need for support increases again towards the end of the semester, as the first exam period comes closer. Several students report that they appreciated the information on how to deal with exam periods and the corresponding study blocks. As one student said: *"It's the first time that we have to study two weeks in a row without doing anything else."* This information should be given just in time: *"In the beginning of the semester, you don't think about the need to start studying in a few months and how you could do that."*

Yet, support can still be improved from student's point of view. Students from one focus group reported that they did not know how to study their course material. One student suggested to organize a session where all lecturers would indicate what is important and how they expect students to study, referring to similar activities in secondary school. This shows that the process of getting used to independent study is still in full swing.

Table 4 lists reasons to attend or skip voluntary Q&A sessions in the first semester. As mentioned before, Q&A sessions are organised in group, yet several respondents to the questionnaire spontaneously asked for 'group Q&A sessions'. When probed for the Q&A sessions, several students say they attend group Q&A sessions, even if they do not have any questions. Listening to the questions of fellow students – and the answers – helps them understand the course material better.

Yet, students report that in some Q&A sessions, questions are answered face to face rather than in group, so these sessions are not perceived as group sessions. Students consider this a missed opportunity: *"It's always interesting when you hear other people's questions, because then you think – Oh yeah, I did have the same question! But if you don't hear them, they can't help you. So I stopped attending those sessions."*

Students of both focus groups emphasized the need for good planning of the Q&A sessions. This is related to the relatively high number of commuting students at Campus De Nayer. As one student said: *"If the Q&A is planned at 8.15 am, I need to catch the train at 6.50 am and I have to get out of bed at 6 am, which I find hard. So I tell myself: it's just one question – why bother?"*

Table 4. Reasons (not) to attend the course-related Q&A sessions as claimed by students.

Reasons to attend	**Reasons not to attend**
Curiosity (very first Q&A session)	Too early / late in the day
To ask a question	No other activities planned before or after the session
To listen to questions of other students	No questions / haven't studied course yet
Difficult course (e.g. mathematics)	Questions are answered individually only

Students seem to be okay with the communication of non-course-specific activities in general. When asked for ways to improve, several students say they wish to receive information through multiple channels, e.g. not only a note in the digital learning environment, but also an e-mail, a calendar item and/or a mention during one of the lectures. This confirms the data from the questionnaire, which suggested the need for reminders. Students say they are swamped by information, and believe that multiple-channel communication will help them filter out the important messages.

As suggested by the questionnaire data, some activity names appeared to be lesser known than the activities themselves. This was confirmed in the focus groups where students said a few times that they did not remembered an activity, while when explained what it was, they admitted to have attended it. We believe this shows that activity names could be clearer. One activity should be referred to by one name only.

As for the interaction with their mentor (staff tutor), the focus groups confirmed the questionnaire findings as several students pointed out that they enjoy the interaction. Most students did not bring specific questions when they met individually with their mentor, yet they appreciated the information given about (trial) exam results, study tips, coaching, etc. One student reported that he checked his summaries with his mentor. The mentor has a direct impact on the wellbeing of the student: *"She encouraged me when my result wasn't good. She reassured me that there was still time, and gave tips."* Although students appreciate the individual meetings with their mentor, the mentor should also be a teaching assistant for their mentee group: *"In the first semester, we saw our mentor once or twice a week, so that we could ask* *questions in the classroom before the lecture would start. (…) This semester, we see her less often, which means we have less contact with her."*

In contrast, the relation with the peers is more ambiguous. Most students appreciate that they have access to a higher-year student to ask questions and claim that they would contact them if needed. However, for most students, the contact with their peers is limited to rare messages on social media (mostly from the part of the peer tutors). Yet, the peers are viewed as a role model: *"Every professor mentions in class that we have to start studying early, because it's a lot, it's difficult. But they say that everywhere. (…) So the effect is bigger when you hear it from a higher-year student, because they know it will backfire if you don't."*

Some students claim to have started studying early, but to have left their books as soon as they noticed that they could not keep up with everything. They decided to wait for the exam period, when they had more time to study. Most students refer to bad grades as the most reliable strategy to make them start studying in time. Without tests, it is hard to start. Several students asked for more tests during the semester, although others disagreed, saying they liked the tests as they are organised now because more tests would give them more stress.

One topic came out ad-lib in the focus group discussions. Students in both focus groups spontaneously mentioned the exam review moment, a week after the exams, when students can obtain feedback about their exam from the lecturer. This moment is viewed as valuable, but could be made more efficient. Following improvements were suggested: (1) communicate partial and mean exam results upfront, so that students who need only these results don't have to come to the review moment (leaving more time for other students); (2) hand out exams to 4-5 students at once; (3) organise an online exam review moment.

4 SUMMARY

Although first-year students have a lot to deal with in their first semester of university, the students in our study claim to feel well supported by the campus. Support needs of this group are bigger at the start and end of the first semester, due to the newness of university (October) and the first upcoming exams (December). Tests and trial exams are welcomed, as the students see bad results as the best trigger to start studying. They prefer Q&A sessions in group, to learn from the questions of other students. As for study career guidance, students appreciate the interaction with their mentors who serve as a go-to person for all study-related questions. Due to the newness of their studies and the information overload experienced, first-year students ask to be given information on specific support activities more than once. Activity names should be clear and unambiguous.

The transferability of these results to other campuses or study programs needs to be further researched. We believe it is worthwhile to do so, although a few specific findings might be related to specific campus demographics (e.g. the specific need for good planning of the Q&A sessions seems to be related to the high number of commuting students at KU Leuven Campus De Nayer).

APPENDIX

Table 5. Questions asked in the small-scale quantitative research

No.	Type	Question
1	Clickable image	Think back to the beginning of the first semester (October). How supported did you feel by our campus as you began your studies?
2	Multiple choice	Below is a list of different forms of course-specific support activities that the campus organises in the first semester. Indicate which ones you have already heard of.
3	Multiple choice	Below is a list of different forms of course-specific support activities that the campus organises in the first semester. Indicate which ones you have participated in.
4	Ranking	Rank the different forms of course-specific support activities for mathematics in the first semester. Put what you consider least valuable at the bottom, and most valuable at the top.
5	Open ended	According to you, what do we have to know if we want to improve the course-specific support activities of the first semester?
6	Multiple choice	Below is a list of other types of support that the campus organises in the first semester. Indicate which ones you have already heard of. (*)
7	Multiple choice	Below is a list of other forms of support that the campus organises in the first semester. Indicate which ones you have participated in. (*)
8	Ranking	Rank the different forms of non-course specific support. Put what you consider least valuable at the bottom, and most valuable at the top. (*)
9	Open ended	According to you, what do we have to know if we want to improve the course-specific support activities of the first semester?

(*) The tutoring by higher-year students was left out of the questionnaire list at this point. The reasons for this decision were (a) not to overload the list and (b) not to confuse students, as this form of tutoring is strictly speaking not offered by the campus staff but by students.

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THE PHANTOM MENACE: SPATIAL ABILITIES AND STEM OUTREACH TO FIGHT UNDERREPRESENTATION IN STEM (CONCEPT)

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Keywords: *spatial abilities; STEM education; intersectionality; STEM outreach; inclusive.*

ABSTRACT

Spatial abilities are an important, and often overlooked, component of Science, Technology, Engineering and Mathematics (STEM) education with skills like spatial visualisation and mental rotation being important for technical professions such as engineering. Individual differences in spatial abilities have been reported throughout the years. Factors such as being female or having a low-socioeconomic status are linked with lower spatial abilities level. Spatial abilities training interventions have proven to be effective, with some showing improvements, not only in spatial abilities level, but also in the success and retention of students enrolled on STEM degree

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programmes, especially for women. In todays' technological society, STEM outreach activities are a common method to promote STEM for children, showing them role models in the area, and improving their self-efficacy, sense of belonging and motivation to follow careers in STEM. At the same time, the underrepresentation seen in the area (e.g., women; LGBTQ+ community; ethnic minorities; and other marginalised groups) needs to be addressed in order to enhance the inclusive environment of these fields. This concept paper discusses review work in relation to underrepresented groups and how future spatial abilities studies should consider integrating the knowledge from past spatial abilities studies into STEM outreach activities. This integration can make spatial training available to more people, revealing itself to be a useful tool in helping diminish underrepresentation in STEM.

1 INTRODUCTION

When considering a career path in STEM, different factors influence someone's decision to follow that path. Not everyone starts their career path from the same position and there is a lack of representation and role models in STEM fields (e.g., visually impaired people, women, ethnic minorities, LGBTQ+ community, low-socioeconomic status, etc.) [1] and being from an underrepresented group can deter someone from following a STEM career. Underrepresentation can lead to a lack of role models in the area – making people from underrepresented groups feel like they don't belong in STEM and particularly vulnerable to dropout of STEM programs [2].

When promoting STEM as a career path, the focus tends to be placed on building a sense of belonging and self-efficacy in the area. However, spatial abilities level [3] has been shown to be another extremely important and influencing aspect which has been identified as a sleeping giant – or a phantom menace – that helps identify and develop talent in STEM domains.

Spatial abilities training programs have proved to be effective not only in improving participants spatial abilities level but also in maintaining participants in STEM degrees, especially women [4]. However, these programs are usually implemented in classroom settings. STEM outreach activities and programs are a common way to showcase STEM career paths to a variety of audiences through different delivery methods, delivered in different environments and communicating a range of scientific disciplines.

Adapting spatial abilities training tasks into STEM outreach programs that are designed for a wider audience can make spatial abilities training more accessible, allowing more people benefit from it. This paper suggests how existing outreach programmes can be adapted to improve the starting position for underrepresented populations on their journey to a successful STEM career.

1.1 Spatial abilities, STEM education and individual differences

In our daily lives, when packing a suitcase, organising objects, exploring around a city, describing where a place is, or the relation between two objects, there is a set of skills common to these tasks: spatial abilities. Spatial abilities can be defined as the performance of tasks that require (a) the mental rotation of objects; (b) the ability to understand how objects appear in different positions (i.e., if we move and look to the object from different positions); and (c) the ability to conceptualize how objects relate to each other in space [5]. They have been shown to play an important role at least in 84 different careers [6] and having 3D spatial skills are critical to success in a variety of careers, including engineering [7]. Spatial abilities are also correlated with students' achievement in STEM domains [8] [9] [10] and can predict the likelihood of students pursuing, majoring, and persisting in STEM careers [8] [11] [12]. There is a strong relation between spatial abilities and STEM performance, at all levels of expertise, because spatial abilities either limit or enhance whether a person is able to perform the kinds of spatial thinking that seem to characterize STEM thinking [12].

Within spatial abilities, mental rotation exercises are among the cognitive tasks for which the largest gender differences, in favour of men, is found [13]. Factors that have been shown to influence gender differences are stereotyping, gender role identity, socioeconomic status, and strategy selection. However, it is important to state that the majority of past studies about gender differences in spatial abilities collected and focused on gender with a binary lens, or don't state clearly how sociodemographic data regarding gender was collected and analysed (e.g., non-binary data actually being collected but not included in the analysis since that data didn't fit in the study aim). Future studies should encourage a more inclusive change on how gender or sex is studied and reported, even if gender is not a main factor in the research and it is only for demographic reporting. A researcher that is not studying gender explicitly, still has an ethical and scientific obligation to describe the demographic characteristics of their sample so that other scientists can evaluate the representativeness, inclusivity, and generalizability of the research [14].

1.2 Past spatial training studies

Recent research findings indicate that spatial abilities aren't as immutable as many people may have been led to believe [15]. Meaning that spatial abilities aren't a static skill which we are born with and can't be improved. Spatial abilities are malleable, and some forms of training can even endure and transfer to other skills. This ability can be learned and trained, with an overall size effect of training of 0.47 standard deviations, according to a meta-analysis with the result of over 200 studies on spatial training [16]. Considering what was already stated about the role that spatial abilities play in STEM education and in following STEM careers, knowing that they are malleable, gives us a window of opportunity to put this knowledge into use and help keep underrepresented minorities in STEM paths by giving them the required training in the area. Students with lower spatial abilities levels will be therefore be better supported and reduce the likelihood of them dropping out of STEM paths.

Previous studies on spatial abilities training showed that besides improving students' spatial abilities performance, training one spatial ability construct can lead to improvements in other constructs not included in the intervention programme [17]. Besides, it showed that different activities, durations, modalities (paper-based, digital-bases, or both), environments (classroom setting or not), and pre- and post-test timings, are important variables to take into consideration when developing an intervention that aims to train and improve spatial abilities.

1.3 STEM outreach: a tool for accessible spatial training

STEM outreach can be considered "the act of delivering STEM content outside of the traditional student/teacher relationship to STEM stakeholders (students, parents, teachers, etc) in order to support and increase the understanding, awareness, and interest in STEM disciplines" [18]. It provides a unique platform to reach students of all grade levels and ages, using different delivery methods (lectures; active learning problem-based learning; workshops; camps & events) and communicating different scientific areas (e.g., biology; chemistry; engineering; physics).

However, the majority of STEM outreach activities are developed with the aim to communicate a scientific concept and making science fun and accessible to everyone. This means that usually the spatial abilities dimension, or the spatial ability level of the audience, is not taken into consideration when developing an activity. STEM outreach activities that can train or develop spatial dimensions usually do it "by accident". For example, in a STEM outreach activity developed to communicate and show the work engineers do, participants are required to model the engineering design process making blueprints of their cities and create replica models showing a block of their cities using all recyclable materials. Preparing a blueprint can make participants visualise and sketch their design and, by transferring the design from paper to three dimensions, they are making a connection from 2-D to 3-D promoting spatial thinking [19].

1.4 The importance of an intersectional framework

When taking into consideration the integration of spatial tasks into STEM outreach activities, underrepresented populations must be acknowledged, with the focus changing from reducing the bias to promoting inclusive behaviours [20]. In order to adapt these tasks, previous knowledge from past spatial abilities studies should be considered as well as the knowledge on how STEM outreach activities have been made more inclusive. For example, simple gestures such as looking to those tasks used in past spatial abilities training interventions, with sighted individuals, and adapt them with the use of textures (sandpaper; Braille; etc) or haptic screens, making them more suitable for sight-impaired individuals. Or, for example, by including scientists from these different underrepresented groups presenting the scientific concepts to the audience, making the majority of people feel included by seeing all those different role models.

Spatial abilities has an important role in following a STEM career and past spatial trainings have shown that they can help keeping people in STEM degrees. However, we can't think that training someone's spatial abilities is enough to motivate them to follow a career in STEM. When adapting and integrating this training to open them to more people we must do it considering all the factors that can play a role and might interfere with the positive results of spatial training. Looking at integrating spatial abilities training tasks within STEM outreach activities considering an intersectional framework that acknowledges that each person's individual characteristics (e.g., gender, race, physical ability) overlaps with one another and affects their status in the world is essential.

2. FUTURE DIRECTIONS

Considering the previous topics, and brief literature review, we can see that there is a line of study that should focus on how spatial abilities and STEM outreach activities interact, acknowledging from the beginning that when developing STEM outreach activities spatial abilities should be taken into consideration. This integration of spatial abilities into STEM outreach can prove to be a valuable tool in improving underrepresentation in STEM fields by getting STEM concepts and spatial training closer to a wider audience. The following suggestions should be considered in future studies that aim to look into spatial abilities and STEM outreach programmes:

- ⇒ A more inclusive collection and reporting of data regarding gender. Provide participants more response options, reflecting the present knowledge we have of gender being a spectrum. Even if analysing only binary data, all the data should be reported, acknowledging the existence of those responses and why they were deleted from analysis (e.g., not enough data);
- ⇒ Always aim at making the activity the most welcoming and engaging for everyone. When developing STEM outreach activities always have an intersectional framework in mind, taking into consideration all the different characteristics of your audience and if they are being considered by the activity being developed. When facilitating a STEM outreach activity, we can be previously aware of some characteristics of our target audience, or not, but that doesn't mean we shouldn't previously think about them. For example, if we know the age range of our audience we will prepare the activity to fit that age range. But why not also consider that the audience is as diverse as it can be? And, for example, include role models of scientists that come from underrepresented groups and work on the STEM area that is being communicated. This will already allow the children from your audience that come from these underrepresented groups to have contact with a role model in the area. Or, when developing activities that have characters (e.g., games; books; etc.) have characters that represent these groups and show as much inclusion and diversity in STEM as possible.

When designing an activity that aims to be engaging to everyone, spatial abilities level should be taken into consideration. With the current knowledge we have on the relation between spatial abilities and STEM education, we must acknowledge that according to the audience spatial ability level they might find the activity harder. Although, for example, asking teachers, or parents, to pass some spatial abilities pre-test to the audience we are engaging with would be the perfect scenario so we can be aware of our audience spatial ability level, and adapt our activity accordingly. However, this is most of the times not possible. This doesn't mean that at least thinking about how this can have an effect in facilitating the activity shouldn't be considered. We know from past studies how spatial abilities level relate to some factors such as gender and socioeconomic level, by knowing the audience demographics this can help us adapt the activities accordingly. Another possibility is, by keeping always in mind that spatial abilities might affect the engagement of the audience with the activity and if having multiple outreach sessions with the same audience is possible, start with simpler spatial tasks and adapt them as the audience finds them easy or difficult. Furthermore, usually big science centers or STEM outreach facilities have a pre-defined catalog of STEM outreach activities from where they choose which ones to use, mainly according to the audience age range.

However, these centers should start considering the spatial abilities factor and think if the cataloging of these activities should also be done according to the spatial abilities level that they might require (e.g., are some activities more appropriate to an audience with a lower spatial abilities level?). By having these cataloging done these science centers could ask teachers to pre-test the kids before bringing them to an activity or – if that is not possible – and considering they have the resources, having spatial tests on tables or laptops ready to be filled by the audience before starting the activity with almost instant results (e.g., use of software such as Qualtrics ®) and choose the activity to be done with that audience accordingly to those results.

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SEFI UMBRELLA FOR TEACHING MATHEMATICS IN ENGINEERING

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ABSTRACT

Cooperation of mathematics teachers under the umbrella of SEFI Mathematics Special Interest Group (former and more proper - SEFI Mathematics Working Group) has brought many benefits and improvements of strategies adopted at various European technical universities for teaching mathematics courses. Many successful international research teams were formed during the group bi-annual seminars and SEFI annual conferences, which benefitted on grants awarded by the European commission that supported international programmes aimed to improvements in teaching/learning scenarios. Some information summarizing results and findings of 8 European projects accepted and supported in different European programme schemes (Socrates, Leonardo da Vinci, Erasmus) will be presented in a brief analysis about impact of these projects on the introduction of innovative teaching-learning scenarios of mathematics courses at the participating European technical universities. Paper will address several didactical problems revealed from students´ answers in didactical questionnaires as feedback and reactions from the "other side". The attitude of students as other actors in didactic situations who are encouraged to actively cooperate with teachers is often neglected when introducing various innovative teaching/learning methods, which are generally considered to be active.

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1 INTRODUCTION

1.1 About SEFI MSIG

Special working groups were formed within SEFI organization at the very beginning of its establishment and operation in the European higher education and research area. Mathematics Working Group appeared among the first ones, and it has always belonged to the most active groups consisting of enthusiastic maths teachers engaged in teaching basic mathematics courses at higher technical institutions and universities in the majority of the European countries. Formed Steering Committee of the group organised various interesting activities for group members, while regularly held bi-annual seminars about engineering mathematics proved to be one of the most useful and enjoyable ones. Good tradition is kept until today, next year 2023 the 21st SEFI MSIG Seminar on Mathematics in Engineering will take place in Romania. Seminars serve as a free forum for exchange of best ideas, good examples and personal experience of maths practitioners gained in their mundane didactic life. Atmosphere at these seminars is traditionally very friendly, open and inspiring. The reason is probably the fact, though not very much optimistic, that mathematics courses generally do not belong to the most favourite parts of engineering study programmes anywhere. Very similar problems which lecturers face in their everyday practice form the fruitful platform for vivid discussions, stormy debates and enable the birth of many original ideas and non-traditional solutions leading to the continuous improvement of the used didactic methods and practices.

At the same time, such busy working environment creates fertile ground for the formation of stronger international cooperation between colleagues from various institutions and for the birth of research teams seeking to submit project proposal and obtain funding from European structures and funds.

In this paper, 8 international projects dealing with teaching mathematics courses to engineering students will be presented, while all project teams were formed, developed their project proposals and successfully defended project results under the SEFI umbrella. This environment therefore proves to be really very conducive to the development of engineering education and its constant direction towards future improvements, ambitious expectations and successful achievement of the goal to maintain “*Mathematics at the Heart of Engineering*”.

1.2 About projects

Among many research and educational programme schemes provided by the European Commission, e.g. Tempus, Phare, Grundtvig, Socrates, Minerva, Leonardo da Vinci, Comenius, Erasmus+ programme that is a funding scheme to support activities in education, training, youth and sport seems to be the most powerful and centralised action managed at the European level by the European Education and Culture Executive Agency (EACEA). Most of the recent educational programmes belong to this scheme under specific sub-classification as Stategic partnerships or Partnerships for cooperation. Programmes, we are going to analyse, will be presented as they were realised in the consecutive time sequence.

1. **EU Socrates programme project No. 90196-CP-1-2001-1-NO-Minerva-M**
   Xmath, years 2002 -2004, was coordinated by Hogskolen i Buskerud, Kongsberg, Norway and there were 6 partners cooperating – Universita Potificia Madrid, and Salamanca University from Spain, University in Kuopio, Finland, Munich software company from Germany, International Centre for Theoretical Physics in Trieste, Italy, and Slovak University of Technology in Bratislava, Slovakia. Project was aimed to explore the possibility of creating a database of mathematical modules available free on the Internet. Team of researchers was formed during SEFI conference and their cooperation was successfully fulfilled with development of one basic module on Differential Calculus, [1].
2. **Leonardo da Vinci programme project No. N/03/B/FF/165.011**
   dMath, years 2003 – 2006, coordinator: Hogskolen i Buskerud, Norway, was continuation and support of the previous project aimed to finalisation of the second module of Integral Calculus. There were also first trials to develop an on-line calculator (supported by Mathematica commercial software product) providing step-by-step calculations in a remote mode. This idea proved to be not very successful due to utilisation of an expensive software solution. Anyhow, both modules developed by means of innovative presentation of mathematical formulas using MathML coding in xml pages are still used as additional instructional materials for students at the participating universities, [1].
3. **Leonardo da Vinci programme project No. SK/06/B/F/PP-177436**
   EVLM – European Virtual Laboratory of Mathematics, years 2006 – 2008, coordinated by Slovak University of Technology in Bratislava was a very successful project that aimed to develop database of on-line electronic materials available on a freely accessible platform. 7 project partners were recruited among participants at the SEFI Mathematics Working group seminars: Paisii Hilendarski University of Plovdiv, Bulgaria, West Bohemian University in Plzeň, Czech Republic, Tulossilta Company from Tampere, Finland, Technical University in Miskolc, Hungary, University of Limerick, Ireland, Salamanca University in Spain, Coventry University from the United Kingdom. During 3 years of the project life a common EVLM portal was opened storing all developed materials in English, while all of these resources were translated and available in national languages of partners at their institutions. Portal is partially functioning at some of them even today, depending on the partner institutions interest and effort to keep the created materials available even after the necessary period at the end of the project, [2].
4. **Erazmus - Strategic Partnership project No. 2015-1-FI01-KA203-009044**
   Future Mathematics, years 2015 – 2018, coordinator: Tampere University of Applied Sciences, Finland. Three partners were - Polytechnic University in Madrid, Spain, Slovak University of Technology in Bratislava, Slovakia, and Technical University of Civil Engineering in Bucharest, Romania. Project was initiated to support modern-day teachers and students by providing a platform as well as resources for teaching and learning in digital form. Moodle environment was used at the platform, and the idea of step-by-step calculations available for students to

self-testing was realised by generated stack-exercises. Project fulfilled its aims to respond to the requirements of modern society and to make mathematics' learning and teaching more digitalized, effective and accessible, [3].

5. **Erazmus - Strategic Partnership project No. 2017-1-PT01-KA203-035866**
   DrIVE-MATH, years 2017 – 2020, coordinator: PTEI Porto, Portugal, was aimed to introduction of innovative active learning methods into the basic mathematics courses in engineering study programmes. Partners – Claude Bernard University, Lyon, France, Technical University in Chemnitz, Germany, Slovak University of Technology in Bratislava, Slovakia – introduced various learning scenarios in their educational practise, as eduScrum, Problem Based Learning, Individual Projects, Gamification, Jigsaw Puzzles, Interactive lectures, hands-on-techniques. Results were analysed and compared, while all gained good and bad experience was presented in Project book with didactic instructions and recommendations, [4].
6. **Erazmus - Strategic Partnership project No. 2017-1-PT01-KA203-035866**
   RULES_MATH, years 2017 – 2020, coordinated by Salamanca University, Spain was a huge project with many partners – Paisii Hilendarski University of Plovdiv, Bulgaria, Slovak University of Technology in Bratislava, Slovakia, Ankara Haci Bayram Veli University, Turkey, Czech Technical University in Prague, Czech Republic, Polytechnic Institute of Coimbra, Portugal, Technical University Dublin, Ireland, Technical University of Civil Engineering in Bucharest, Romania, Spanish National Research Council, Madrid, Spain. The main objective of the project was to develop assessment standards for a competencies-based teaching-learning system for mathematics in engineering education. Project team was based on partnership from several previous projects, while the main goal was to bring practical ideas how to assess knowledge gained after successful completion of basic maths courses focused on development of mathematical competencies – concept developed and elaborated at the SEFI Mathematics Special Interest Group seminars. [5].
7. **Erazmus+ Partnership for Cooperation,**
   Project No. 2021-1-RO01-KA220-HED-000032258
   DIGI STEM, years 2021 – 2024, is a new project coordinated by Tampere University of Applied Sciences, Finland, and bringing together for further cooperation partners cooperating in the previous successful project Future mathematics - Polytechnic University in Madrid, Spain, Slovak University of Technology in Bratislava, Slovakia, and Technical University of Civil Engineering in Bucharest, Romania. This new project is going to develop further ideas partially elaborated 3 years ago, and its main goal is to lay the foundations of digital pedagogy and summarise experience of the two-year long distance education with heavy utilisation of digital technologies in on-line or hybrid teaching and learning during the Covid-19 pandemic throughout the whole world. Project is aimed more theoretically, its primary goal is to provide fundamental guide to maths teachers on how to adapt teaching/learning strategies to the paradigm of the 21st century – digitalisation of all aspects of social life, not excluding education and knowledge acquisition in general [6].

8. **Erazmus+ Partnership for Cooperation**
   Project No. 2021-1-RO01-KA220-HED-000032258
   PYTHAGORAS, years 2022 –2025, coordinator: Lucian Blaga University of Sibiu, Romania, partners: Aalborg University, Denmark, Karlstad University, Sweden, Porto Polytechnic, Portugal, Slovak University of Technology in Bratislava, Slovakia, University dela Laguna, and EVM Spanish Consultancy Company, Tenerife, Canary Islands, Spain, Hellenic Mediterranean University, Heraklion, Crete, Greece. This ambitious project strives to develop policies that will make learning Mathematics more inclusive, efficient, enjoyable and real, connecting Mathematics teaching with real life cases linked to the students' fields of study. All project outcomes and activities will be tailored to address the prerequisites of the partner institutions for undergraduate students regarding their fundamental mathematics background and these perquisites will be checked from all aspects: mathematical content, mathematical processes, views about the nature of mathematics, and personal and academic characteristics of students & teachers. Project expected intellectual outputs and results include: Toolbox for teachers on Education for Sustainable Development, Learning scenarios and guide for gamifying online and hybrid mathematics education at university level, and An online and open access Precalculus Course (MOOC) in English, [7].

Brief analysis of the presented projects´ methodologies and strategies, including summary of their results and outcomes articulated in published reccommendations are presented in the following chapters.

2 METHODOLOGY

2.1 Long 20 years of transformation

Time interval of 20 years between the first and the last presented projects that are dealing with almost the same problems and issues indicates how conservative might be our educational systems and institutions on one hand, while it also reveals their authenticity, stability and persistence of verified values they are representing on the other hand. Long-lasting journey and endless efforts are necessary to establish changes in the traditional educational practises that have to be overcome in order to introduce visible changes in educational approaches and used methods.

While the first two – three projects solved during 2002 - 2008 present just minor insignificant attempts to utilise information and communication technologies and available software products appearing at the scene somehow also in education, projects currently approved in 2022 bring forward a serious research efforts to define, develop and use in pedagogical practise digital methodology and didactics. The worldwide Covid-19 pandemic lasting more than 2 years was one of the main reasons of the rapid and almost complete switch from the "steady on-site" to "experimental on-line" teaching at all levels of education systems. This unexpected situation fostered the urgent need of digitalisation of all aspects of educational processes, from delivery of information, communication between teachers and students, through practising theoretical knowledge and formative assessments up to the summative assessment and on-line examination solutions. Consequences of these fast changes reflected in the knowledge acquisition will be analysed in the currently solved projects [6], [7].

2.2 Project strategies

All referenced projects were aimed to introduce innovations into traditional university learning scenarios used for ages in mathematics courses – lectures for delivery of theoretical backgrounds, practicals for training solutions of related problems, oral or written examinations. Overall digitalisation of all social processes evoked legitimate attempts and efforts to rethink how mathematics is taught to engineering students. On one hand, ICT revolution enabled experimentation with different distance learning scenarios and enabled development of more versatile modes of instructional materials - on-line modules for self-study, stack exercises for step-by-step calculation training, electronic lecture notes available free on-line, didactic videos, animations, solved examples and applications as projects´ results.

On the other hand, these strategies were sometimes leading to even more passive behaviour of students than it was the case of traditional didactic situations, as learning was more personalised and depended on the involvement of students themselves and their inner motivation to study and acquire new knowledge. Teachers became more developers and authors of e-learning materials and moderators of the educational processes than their facilitators. Anyhow, this did not automatically led to activation of students, just the opposite. Teachers were often frustrated by the enourmous amount of work they had to put into developing innovative instructional materials, which was not adequately received by students, but led to their passive acceptance and even refusal to study all this materials as another hurdle they had to overcome in other to pass the exams successfully.

In all mentioned projects, research teams strived to receive feedback from both actors in the education process. Structured didactical questionnaires were used to perform opinion poll and to receive and analyse answers of respondents in realised didactic experiments at the partner universities. Cohorts of students were chosen on voluntary basis, sometimes there was an entire traditional Mathematics course transferred into a personalised distance learning module, or into a team work solving relevant applied problems by mathematical methods. Attempts to introduce active learning methods as eduScrum, Jigsaw puzzles and PBL methods were one of the most interesting, while the overall detailed analysis of the case studies was presented in articles published in educational journals and at the didactic conferences, see e.g. [8].

3 RESULTS

3.1 Statistical overviews

Most statistical data proving the first observations that “Less seems to be sometimes more” were obtained from the project *DrIVE-MATH*, [4]. Randomly chosen cohort of students in the basic course of Mathematics at the bachelor study engineering programmes participated in the experimental teaching strategy EduScrum. This method showed students a new way of work during tutorials, a teamwork in small groups of 4-5 students, which they rated very positively. The aim of the experiment was to find out the level of knowledge acquisition and to compare abilities of students to solve mathematical problems independently, or as a collective work in the small groups. Anonymous questionnaire answered by students after completion of the experiment gave researchers a good feedback and overview of their opinions, from which they could compare their attitudes towards different teaching methods applied.

It has to be stated that students with weaker knowledge benefited more from the team work as practised in the randomly formed small group. Very good students helped their classmates to receive better marks and took a greater part of the work on their shoulders. On the other hand, team represented one unit as all members were supposed to be equally responsible for their common achievements. This was often a strong motivation and driving force encouraging both - good students and not that good ones to do their best and contribute to the team final success.

It is up to the teachers how they will introduce this method into their teaching. Team of maths teachers in the project was enthusiastic and keen to implement new active learning scenarios in their teaching practise. They worked with enjoyment and this pleasurable attitude was naturally transferred also to their students. Preparatory work and development of necessary didactic materials is a quite time consuming activity. It requires a real devotion of teachers who should plan carefully all activities in advance, support students with enough learning instructional materials and to be ready to help them with advice in mostly unforeseen situations that might occur during the activities.

Positive aspects of eduScrum method: possible continuous assessment of students' knowledge during the whole semester, from separate parts of curricula consequently; method eduScrum taught students to work in the team, to be responsible for their solutions, to be responsible for the whole team as a unit, to lead a constructive discussion about problems and to understand better the problem solution. As students pointed out in the interview, team work helped to more than 75% of them to understand learned content better.

Negative aspects of eduScrum method: random distribution of students to working teams based on their friendship after the arrival to university study, not on base of knowledge level from mathematics; weaker students learned how to "grasp" problem and how to start to solve it, appreciated help from better students with solutions of their own problems and acquired more points in their "score" from particular topics thanks to better students in their team; better students were a bit "constrained" by weaker students, they had to explain to weaker students how to solve their problems in order to receive as much points as possible for their own score so they solved entirely also problems of other students, with the same points for everybody; they often received less points on their "score" for not correct solutions of problems solved by weak students, as they could receive provided they had solved the problems themselves and correctly, or in another constitution of the working team; better students were willing to work, later during the semester, in smaller groups (2 - 3 members) and they agreed on finding solutions of all given problems in the time limit.

In connection to general recommendation for future broad general implementation of eduSrum method in teaching mathematics to the engineering students at the bachelor or master study programs, we suggest the following few ideas in order to support development of the best students:

– to recognise in each course of mathematics at least 2-3 teams of excellent students and "train" them as excellent teams to solve practical problems in their respective technical professional subjects
– to support healthy competitiveness between these teams of excellent students
– to build common worksheets for team work with problems that could be solved by these excellent teams of students, analyse the overall results consecutively, and contribute thus to better education of future European engineers in mathematics
– to organize at least one competitive teamwork session between excellent student teams inorder to support their higher need
– to appreciate achieved results of all teams, regardless their composition to support and encourage students with weaker results
– to monitor and carefully record results of all students and give them due feedback.

In general, none of the surveys carried in the terminated 6 presented projects proved that the greater efforts by teachers to support students lead to their exceptionally better results and better motivation to learn.

4 SUMMARY AND ACKNOWLEDGMENTS

We believe that, given the current state of knowledge of students, their basic working and methodical skills necessary for the study work at universities and the new roles of teachers in the educational process, the goal of teachers will continue to be focused on the quality and not the quantity of students who complete the subject.

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CONCEPT DEVELOPMENT IN MICROENGINEERING: UNPACKING UNDERLYING PROCESSES AND DEVELOPMENTAL PATHS

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ABSTRACT

Concepts are a matter of importance for engineering education. Believed to be critical for developing expertise and engineering competence, conceptual knowledge has become a focus for research and training. Despite focusing on it, engineering graduates still often do not understand core concepts for their practice. With a few exceptions, most research concerning conceptual knowledge in engineering has been developed on assumptions of cognitive psychology, which have been subject to strong criticisms. One of these criticisms points out that mainstream approaches on concepts do not account for the socio-material conditions in which concepts are used and transformed. Some researchers in engineering education have moved beyond, taking a situative perspective. These studies have shown how, compared to training, knowledge in the practice is highly contextualized, depends on tools in which it is inscribed, and is distributed among collaborators. However, while stressing the socio-material dimension of conceptual knowledge and the differences in concept use between training and practice, the situative perspective does not account for the way in which conceptual knowledge develops. Alternatively, the cultural-historical theory of concepts offers an approach that overcomes the weaknesses of mainstream approaches while addressing the problem of development. Drawing on cultural-historical theory, this paper presents an ongoing research aimed at the study of concept development in microengineering teaching and practice. I will present the

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respective methodological approach—borrowed from a French tradition of work psychology—for studying concept development from interactions in work and teaching activities. Expected results and implications for engineering education will also be discussed.

1 INTRODUCTION

Concepts are central for all human activity. Whether we are talking about the everyday concepts we learn from our earliest childhood, or the complex concepts developed through years of scientific activity, they are deeply embedded in our experience. In these concepts we can find what has become meaningful for a community over time, what is important for its activity and what it accepts as true given the current state of knowledge. Beyond being a reflection of the past, since science and technology are ongoing activities, new concepts are developed to express new phenomena and communicate about them. Concepts are commonly shared within a community (e.g., professional, disciplinary, or practice communities) where they are useful for communication, collaboration, and understanding. They have been learned at some point, and they must be taught to newcomers so that they can master the activities performed by the community.

Learning the concepts that are important for living in society is one of the main tasks of the school. Likewise, the appropriation of the concepts that guide a qualified activity is at the core of post-secondary and professional education. However, it is a well-known fact that most conventional meanings, or concepts, are difficult to learn, even for adults and after several years of instruction. One of the most salient approaches to the study of this phenomenon in education is the research on Conceptual Change [e.g., 1, 2]. It studies the early representations held by learners and those held by experts, the changes they undergo, the mechanisms behind those changes, as well as the instructional strategies to promote them. From the early 1980s to the present, a growing body of research has studied conceptual change in diverse domains, from the natural sciences and mathematics to history and the social sciences. Today there is some agreement that concepts, being embedded in more or less coherent structures that have a certain explanatory capacity and functional value, change and evolve gradually. In their different versions, the difficult of conceptual change would be due to the interpretation of scientific knowledge in terms of previous knowledge [e.g., 3], to ontological miscategorization [e.g., 4], or to the initial lack of organization of sub-conceptual units [5].

Most researchers in conceptual change would recognize these days the importance of the contexts and situations in which concepts are formed and transformed. However, some sociocultural approaches have a addressed those criticisms in a radically different approach. Rejecting or de-emphasizing most cognitive assumptions, these researchers have moved towards a *participation metaphor of learning* [6]. These perspectives, move the cognitive level to the background, to understand learning as a situated and interactional process consisting of “taking part in” or “being part of” the discourses and social practices of scientific communities [7]. Examples of these approaches are the discursive approach of Roth [e.g., 8], the sociocultural approach of Säljö and colleagues [9], and Greeno's situative perspective [e.g., 10], which has also been used in research in engineering education as I will discuss in the next section.

2 CONCEPTUAL KNOWLEDGE IN ENGINEERING EDUCATION

In engineering education, concepts have also received important attention. According to Streveler et al. [11], engineers rely upon conceptual knowledge for their practice—including intuitive expectations, not just sophisticated models or physical prototypes. Therefore, conceptual knowledge is believed to be critical to develop expertise and engineering competence, becoming a focus for research and training [9, 10]. In spite of this attention, engineering graduates often "do not understand the foundational concepts of solid and fluid mechanics, physics, thermodynamics, digital logic" among other fields [13, p. 83]. Differences between engineering students and practicing engineers in conceptual understanding of core engineering concepts [14] and in their conceptions of engineering itself [13, 14] are also described. While they are widely used in the field, the notions of *concept* and *conceptual understanding*, are not satisfactorily understood [17].

Most research concerning concepts in the engineering education rests on assumptions from cognitive psychology. Conceptual understanding is referred to as the collection of concepts (i.e., pieces or clusters of knowledge), beliefs (i.e., propositional relationships between concepts), and mental models (i.e., groups of meaningfully related beliefs and concepts that allow people to explain phenomena and make predictions) [13]. Although the different branches on conceptual change that we have discussed before are known and have been brought to the field [e.g., 13, 18–20], there is still little research on conceptual change in engineering education from sociocultural approaches, as Brown and collaborators point out [21].

On the other hand, noticing that undergraduates and practicing engineers performances are very different—with students often outperforming practitioners in concept inventories [e.g., 14]—, some researchers have highlighted the context and activity dependency of conceptual understanding [20–25]. Consequently, they have paid more attention to the way in which the understanding and use of concepts vary across school and work. For example, Bornasal and collaborators use an ethnographic approach to study conceptual growth in transportation engineering work [25]. Taking a stand near the situative approach, they show how conceptual understanding development relies on contextual constraints, on negotiated meanings with others, and material resources "such as computer software, reference books, and calculators, to address problems associated with certain features of concepts" [25, p. 336]. Similarly, Barner and colleagues [20–22] use ethnography in structural engineering workplace and undergraduate structural engineering courses, describing how the use of heuristics, use of tools and conceptual representations differ in both between the two contexts.

These researches have confirmed the differences between training and practice engineering activities, and have deepen our understanding of the way in which conceptual knowledge is embedded in those contexts, distributed among people and the tools they use. However, beyond pointing out the differences, it is critical to advance towards the understanding of how participation in these activities progress and mastery on conceptual knowledge grows.

3 CONCEPT DEVELOPMENT IN CULTURAL-HISTORICAL TRADITION

Cultural-historical theory [28, 29], developed by Lev S. Vygotsky, addresses explicitly the problem of concept development. Schematically, four key ideas are fundamental to understand this approach. First, concepts are actual thinking processes, and not mental entities. Every time we use a concept, we are generalizing, i.e., treating a unique event as belonging to a class of events. However, we do not generalize by putting linguistic labels on events or objects. Concepts are not the *tools* by means of which we classify. On the contrary, that generalizations *occurs* in the concrete uses of language. Every time we use a concept, we are carrying out such a generalization.

Second, concepts are the basic units of verbal thinking: word meanings. However, what make them meaningful is not their place in the language system, but their concrete and specific function in social life. As concepts always fulfill a function for reasoning, understanding or communication, we derive the meaning of words from the way in which they are used in social situations. Thus, the meaning of the words we use in training and practice activities, will be inevitably attached to the functions they have in those activities.

Third, while concepts as conventional meanings have the stability of language and the social practices in which they are used, they change both microgenetically and ontogenetically. Microgenetically since, as was mentioned above, every time we use a concept we are generalizing in a particular way, in relation to the specific situations in which they occur. Ontogenetically, since the meaning of the words we use changes as our participation in a community changes. Although children and adults, as well as newcomers and old-time practitioners can use the same words and understand each other, but doing so they are actually performing different acts of thinking.

Finally, the development of concepts through life is initiated as actual socio-material relations. In other words, before being appropriated by the individual, concepts were actual relationships with others. These social situations in which we take part, exchanging with others, using their language and their tools, to fulfill certain purposes, are those that will be internalized. A critical aspect in relation to the last point is that, while our lives are full of social and material relationships, not all of them will become psychological functions. On the contrary, only those that are experienced as conflicting or emotionally charged, will initiate such a process [30].

As discussed, there is much more behind the external appearance of concepts. As noted by some researchers in engineering education, concepts are embedded in the contexts where they are used, distributed among people and tools. Furthermore, following cultural-historical theory, these concrete socio-material relations will develop into internalized concepts. Although learning and development will almost inevitably occur from social interactions, to initiate a specific developmental path that ends with a particular outcome within a given time frame—as is the goal of education as we know it—will require the acknowledgment of those specific interactions to reproduce them. However, the social and material nature of concepts remains hidden behind a static appearance. Going beyond description, this research seeks to shed light on the developmental paths that concepts follow from social, discursive and material relations, to be mastered by individuals (i.e., to become psychological processes) in the accomplishment of concrete functions. In the next section, I will present the methodological approach taken by this research.

4 A METHODOLOGICAL APPROACH TO STUDY CONCEPT DEVELOPMENT

Vygotsky did not preview a method for studying concept development from work activities. Building a theory of psychological development and believing that early childhood was the privileged age to study it, he did not even focus on adult development. However, as we have discussed, since social interactions are the source of development and work activities are one of the—if not the—most important activity we carry out as adults, then it is normal to look for development in this kind of activity.

Activity Clinic [31], a French tradition of work psychology drawing on Vygotsky's work, explores precisely development in work activities. It is primarily conceived as an interventionist methodology, aimed at supporting the development of collective capacities of organizations. Activity clinicians recognize that work activity exceeds what is visible. Work activity includes not only the practitioners (with their skills, knowledge, experiences, and preferences) and the specific tasks prescribed for them (as defined by documents, procedures, and structures). Additionally, in work activity these practitioners are always addressing to other individuals, whether they are partners, managers or customers, and, to do so, they make use of a set of collective resources historically developed. Furthermore, beyond the realized activity (i.e., what is actually performed and observable by its results), there is a set of unrealized possibilities:

> […] what workers don't do although they would like to, what they do without succeeding, what they abandon doing, what they think they would do under different conditions, or even what they do to avoid doing what is expected of them. [31, p. 58]

By means of different techniques, work psychologists in Activity Clinic structure dialogues with practitioners oriented to collectively analyze and improve their work activity. Of particular interest for us is the methodology *cross self-confrontation interviews*. In these interviews, activity clinicians co-analyze with practitioners their own practice. The outcomes of these analyses are used as tools to mobilize dialogue among the different levels of the organization and to promote change in it.

The methodology that interests us is implemented in different stages. Initially, practitioners interact with the researcher at the workplace, while the latter observes the activity of the former. The researcher, by means of their questions and comments, encourages practitioners to observe their own practice. In a later stage, workers are invited to engage in the research. Later, the researcher and the volunteer practitioners conform then the “associated research group,” which will collectively choose relevant sequences of work activity to analyze. These sequences are recorded and then co-analyzed, first, in simple self-confrontation (in which a practitioner and the research discuss their own activity) and later in cross self-confrontation (in which the practitioners are asked to comment on their own activity and react to the comments of a colleague). Finally, the researcher and the volunteers will select video clips from both the activities and the interviews highlighting critical aspects and conflicts of the job, to present and discuss with a wider audience, including the different levels of the organization.

While my research in principle does not concern an organizational intervention, Activity Clinic and, particularly, the dialogic framework of cross self-confrontation interviews features a suitable setting for the study of concept development [32]. As it was discussed in the previous section, the study of concepts should (1) go beyond the external, static appearance of concepts, (2) accounting for the contexts in which they are used and change and (3) highlighting the conflicting social relationships where their development begins.

As ethnographic approaches do, Activity Clinic observes the real activities carried out by practitioners, in the concrete context in which they occur. Going beyond what is visible in those activities, in self-confrontations, practitioners themselves are invited to explicit and make sense of their own activity and those of their colleagues activities. Furthermore, confronted to the different ways of performing and to the comments and questions of colleagues and the researcher, even simple statements they know and share with their professional community can be called into question. In the observation, analysis, and comparison of similar activities performed by different individuals, cross self-confrontations trigger comments and questions.

This dialogical activity puts practitioners in the spot and create structured conflicts in a way that requires them to “go beyond well-established knowledge to be able to convince both the researcher and their colleague” [32, p. 335]. In this way, the observations and comparisons of routine behaviors, combined with thoroughly structured discussions of convergences and discrepancies, what had been packed over time, becoming invisible even to experts, is retrieved and unfolded for analysis [32].

Following the described method, this research is taking place at a Swiss university in the domain of microengineering. It concerns both teaching and practice activities which constitute two different fields of study. On the one hand, I am studying the activities undertaken in a laboratory working on microengineering. In that context, I follow a group of engineers with different levels of experience collaborating on design, development and research projects that are led or supervised by them. On the other hand, I will study a course on mechanism design for second-year students run by the same team. In the course, both the teaching activities of the staff and the activities carried out by the students in a design project will be studied.

5 DISCUSSION

Concepts, conceptual thinking, and conceptual development are important phenomena for engineering education. Despite the attention they have received over the last decades, there is still a lot of work to do. As it has happened in psychology and education, the mainstream understanding of concepts has overlooked aspects that are critical for study them. As in psychology and education, sociocultural perspectives have also reached engineering education, highlighting the importance of the contexts and instruments to which knowledge is inextricably associated. We have arrived to the acknowledgment that the way students understand and use concepts in training is quite different from the way practicing engineers do it in real contexts. Bridging this gap, however, is still a pending task.

We know that engineers in their new professional contexts will learn what they need to learn *after a certain course of development*. However, although development and learning will inevitably occur over time as a result of the participation in social interactions, to produce an outcome deliberately in training, certain processes, particular designs, or the arrangement of certain conditions are required. We need, then, to shed light on how the development of the concepts that actually interest us occurs in real sociomaterial interaction, to reproduce them in training. In that vein, I suggest that engineering education can benefit from research conducted following the cultural-historical theory.

This research is aligned with the research that has been developed using ethnographic methods from situatives perspectives, and tries to push it one step further. Furthermore, the proposed method consistently follows the rationale behind the cultural-historical theory. Nevertheless, this approach is rather experimental and pioneer in engineering education. Therefore, careful and systematic empirical research is needed.

Although it could have taken place in any context, engineering practices and engineering education are exciting environments to conduct this research. On the one hand, well-known concepts, stabilized in the community and critical for the discipline are permanently at stake. This environment offers us the possibility to address in the context of their use, to examine their sociomaterial roots. On the other hand, stabilized activities taking place within a community of practice might be available to be conceptualized. While it is still very early in my research, some aspects have already emerged concerning both, the usual ways in which these engineers address mechanical concepts in designing and in teaching, and a very particular way of doing design, recognizable by them, yet not conceptualized.

It is important to notice that the way of doing things among different disciplines and subdisciplines, but also among communities of practitioners within them will differ. Therefore, at a certain level the results will also be idiosyncratic and the translation from one context to another will not be evident. If with the cultural-historical theory, we assume that human development is a process “historically rooted, socially shared and culturally shaped” [33, p. 45], then we have to accept that fact. However, by unveiling the particularities of concept development in different contexts we can make training practices more appropriate and, in the long run, account for the regularities of the phenomena that concern us.

For the sake of my argument, I have briefly discussed here some research approaches that have been important in educational psychology and engineering education. Articulating the notions of *concept* that underlie each of the different perspective, however, may require a finer treatment. The concept of concept held by different research traditions that often rest on different epistemological underpinnings, make of this and important and challenging task. The dialogue between disciplines and research traditions is, however, strongly necessary.

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INTEGRATING SUSTAINABILITY IN AN ELECTRONIC ENGINEERING PROGRAM: INSIGHTS AND EXPERIENCES ON ACADEMIC STAFF INVOLVEMENT

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ABSTRACT

There is a growing urgency to incorporate sustainability in all facets of society to stay within the planetary boundaries. Higher education has a significant role by educating their students - our future work forces – with the knowledge and competences that are crucial for working with sustainability challenges. The development of sustainable technology thereby takes a significant place, pointing out the role of engineering education. This article presents the journey of integrating sustainability in the M.Sc programme Electronic System Design and Innovation at the Norwegian University of Science and Technology. We focus on three aspects of this journey. First, we present the approach used and the process stages for the integration of sustainability, which is a renewed version of a toolbox for integrating ecodesign in engineering studies. Secondly, we present how academic staff is involved throughout the integration process. To be able to succeed with incorporating sustainability into a study programme, it is important to engage and empower academic staff, since they have a central position through their responsibility for a study's central building blocks - the different courses. Lastly, we outline insights and experiences from the perspective of academic staff and the project team involved in the integration process. We conclude with how the approach used and the lessons learned can provide useful strategic and practical insights for other engineering programmes in their process of integrating sustainability and plans for future activities.

1 INTRODUCTION

1.1 Integrating sustainability in higher education curricula

This article presents insights and experiences from academic staff related to the integration process of sustainability in an electronic engineering programme. Through this work, we aim to contribute to the need for incorporating sustainability in all facets of society in order to stay within the planetary boundaries. Higher education has historically played a role in transforming societies, by educating decision-makers, leaders, entrepreneurs, and academics, and by serving the public good [1]. A growing number of universities gets engaged in incorporating and institutionalizing sustainable development (SD) into their education, research and outreach, and campus operations [2], [3]. The role of higher education is to educate and equip their students with the knowledge and competences that make a sustainable transition happen [1]. Growing pressure from industrial entities - asking for graduates with an engineering degree and the relevant skills to be able to handle SD - has become an important driver for higher engineering education to integrate SD in the curriculum [4].

1.2 Involving academic staff

Several researchers emphasize the importance of involving academic staff in the transformation towards education for SD [2]. This is related to the central role they have in curricular development and how to direct it more towards sustainability. However, literature also indicates that there is a strong need for support for educators that empower and involve them in the integration process [4]. In this article, we focus on academic staff involvement during the journey of integrating sustainability in the M.Sc engineering programme Electronics System Design and Innovation (Elsys) at the Norwegian University of Science and Technology (NTNU). We focus on how academic staff got involved and supported throughout the integration process of SD in the curriculum, and on experiences from involving academic staff seen from different perspectives. The results are part of a pilot project within the strategic initiative Technology Education of the Future at the university. The integration of competences for SD in all the university's future engineering and technology studies forms a significant component of this initiative.

2 METHODOLOGY

2.1 Pilot case: study programme Electronics Systems Design and Innovation

In this work we focus on a pilot case, the Elsys study programme that is currently integrating sustainability in its curriculum. The case provides empirical data as a foundation for gathering insights and experiences from academic staff on the integration process of sustainability in the M.Sc programme. The study program Elsys is a 5-year integrated Master's program within electronic engineering, with courses given mainly by the faculty at the Department of Electronic Systems at NTNU. Approximately 120 new students enroll in the program every year. Within the study program, the students can choose specializations within analog, digital and embedded design, signal processing, radio communication, nanoelectronics and photonics, and acoustics. Traditionally, the program has had a limited focus on sustainability. This may be linked to the past and current focus of the program and its associated academic community on fundamental and enabling technologies, and to a smaller degree on end products, thereby distancing the technology development from end users and society.

2.2 Toolkit for integrating sustainability in engineering education (ISE toolkit)

The *toolkit for integrating sustainability in engineering education* - shortly ISE toolkit - that is used in this work aims to support the integration process of sustainability in M.Sc programmes and has been applied in the Elsys study program. It is based on the EHE toolkit, a toolbox for integrating ecodesign in engineering studies [4] and has been updated, amongst other by including the UN Sustainable Development Goals (SDGs), and adapted to the context of the university. The new elements and adaptations of the toolkit have been tested throughout several stages of the development process and applied in the pilot case.

2.3 Data gathering and analysis

Students and academic staff have been involved in the integration process of sustainability in the pilot case, thereby applying the toolkit, its approach and elements. In order to gather insights and experiences on academic staff involvement, the project team gathered qualitative data, including a *questionnaire* that provides feedback from academic staff on specific steps of the integration process, *interviews* with academic staff that provide insights on opportunities and barriers for integrating sustainability in the curriculum, and *reflections* that offer insights from the project team on experiences from participants and facilitators during different stages and activities of the integration process. A thematic analysis has been used on the pilot case data to gather insights on how academic staff got involved and supported throughout the integration process of SD in the curriculum in practice, and on the experiences from involving academic staff seen from different perspectives.

3 RESULTS

3.1 Approach for integrating sustainability in M.Sc programmes

In this section we shortly present the ISE toolkit's approach for the integration of sustainability, the main process stages and the toolkit's main elements, before we present how the process took place in practice in the pilot case.

The aim of the ISE toolkit is to facilitate study programme management, academic staff and other stakeholders to integrate sustainability in the curriculum. It does this through *informing*, *motivating*, *inspiring* and *connecting* academic staff and other relevant stakeholders throughout the integration process, thereby supporting *collaborative learning* around SD and how it fits into the curriculum [4]. Moreover, the toolkit *combines a bottom-up with a top-down approach*, whereby initiatives and ideas from academic staff are warmly welcomed and get supported, whilst simultaneously engaging the head of department and other leadership positions in order to provide driving forces in the integration process.

The toolkit provides guidance in getting an overview of SD in the whole curriculum (*programme-driven approach*), as well as it offers the opportunity to look at specific courses and how sustainability fits in. It does this through dividing the work in different process stages, which can be represented in two main stages of the integration approach: 1) Mapping sustainability in study programme and 2) Opportunities for further integration.

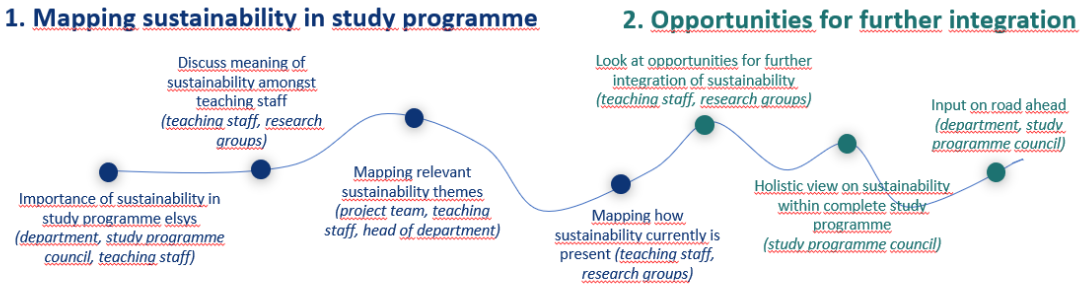

Fig. 1. The process stages of the integration of sustainability

Lastly, the toolkit brings together different pedagogical elements that are crucial in education, thereby combining knowledge on relevant *learning content* related to SD, *competences* for SD and student-active *teaching methods*. These elements are presented in the form of learning theme cards, competence cards, work sheets and guidelines for the integration process.

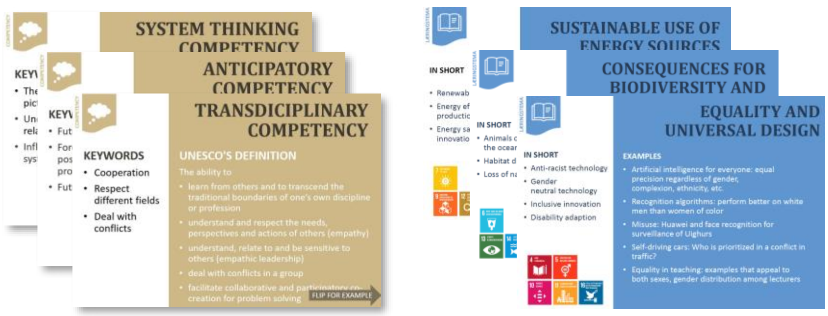

Fig. 2. Examples of the competence cards and the learning theme cards

3.2 Academic staff involvement in the integration process at Elsys

In this section, we present how academic staff at Elsys is involved throughout the integration process so far. To be able to succeed with incorporating sustainability into a curriculum, it is important to engage and empower academic staff, since they have a central position through their responsibility for a study's central building blocks: the courses that make up the curriculum. Creating an environment that values SD is thereby essential to create lasting changes and sustained educational improvements [5]. The academic staff have been, and will be, involved as active participants in completed and future workshops, training seminars and other activities. Fig. 3 presents a timeline of the activities in the pilot case.

Fig. 3. Timeline of activities involving academic staff

Thus far, one webinar and two workshops have been held in the period between the spring semester of 2021 and 2022. In the webinar, the staff were introduced to SD in higher education and asked to reflect upon the role of SD in electronic engineering. In the first workshop, the staff were asked to map the current status of integration of SD in the programme and identify opportunities for further integration. The second workshop focused on looking forward by making plans for integrating SD in specific courses, course groups and the whole study programme.

In preparation for both workshops, a smaller group of the staff has been invited to test versions of the workshops, allowing the project team to observe the staff, getting feedback and enabling improvements to be made. For example, the learning content and competence cards along with the webinar introducing education for SD came as a result from the first test workshop, where we realized that the staff's knowledge of SD was insufficient to complete the work sheets.

Lastly, between the first and second workshop, the staff were invited to sign up their courses as pilot courses for integration of SD, entailing that they were willing to make smaller changes to their courses to facilitate integration of SD and serving as exemplars for the rest of the staff by sharing their plans at the second workshop. In addition, any staff willing to start integrating SD into their courses have been promised support and extra resources in order to enact these changes.

3.3 Insights and experiences from the pilot case

In this section, we share insights and experiences on the integration process from the perspective of the academic staff and the project team. We frame the results in terms of how the toolkit's approach supports the integration of sustainability in the curriculum.

Inform: Based on the interviews with staff and reflections from the project team, the lack of knowledge on SD in education is found to be an obstacle, which gets supported in literature [6]. This came forward especially when staff tried to connect fundamental technology courses with its application in and impact on society and environment. This opened up for reflections from the staff on the role of their study program to society and is illustrated in the following quote: *"... there exists nearly no product today that doesn't have electronics in it, so it's a really important field for everything happening in society […]. So-called enabling technology".* In the pilot case, information has been shared with the staff on SD in higher education and electronics in general, the student perspective on the importance of SD, SD learning content relevant for electronic engineering and competences for SD. Information has been given through the webinar, workshop presentations and material, and in staff meetings not organized by this project. The importance of discussing and working actively with the shared information was mentioned by staff in the questionnaires to be indispensable in order to get a shared understanding, as well as to challenge and inspire each other.

Motivate: Based on the data from the questionnaires and interviews, the staff indicate that there is agreement on the importance of integrating SD in the curriculum. The following quote from a staff member exemplifies this: *"sustainability is important for all, it is good that we also started talking about it"*. However, when it comes to working with specific courses, several educators reacted that SD does not fit into their course, and pointed out other courses where it would fit better. Through exemplifying in the workshops and with pilot courses, we aimed at overcoming this hurdle. The mapping of and reflection on how SD already is present in the curriculum and different courses was mentioned by staff in the questionnaire to be a motivator for taking further steps. Simultaneously, further activity needed to be initiated by the project team and management, thereby pointing out the need for a change agent to lead the integration process forward. Next to that, we experienced that support from management, thereby emphasizing the importance of integrating SD in the curriculum, was important to motivate academic staff. It turned out to be difficult to stimulate them to join workshops related to SD, on top of other teaching and research activities. We encountered that we managed to motivate a part of the staff to actively get involved in the integration process of SD, whilst a group of the academic staff has not been triggered to join (yet).

Inspire: For changes to occur as a consequence of the information and motivation efforts, the staff needs to be inspired to take action, thereby facilitating a bottom-up approach driven by staff in addition to the top-down driven by management. Through the discussions at the first workshop and associated test workshop, statements were made that indicated one hindrance being a limited view by staff on how integrating SD in a course or a programme practically can be done. Simultaneously, while the staff can understand the context and importance of SD in education, they can lack inspiration and the awareness to take action. The following quote from one of the interviews illustrates this: *"... I think that the biggest challenge may be being conscious and thinking of it, and actually doing things for it as well. Because I don't think it's very difficult to implement more of it in my course".* The pilot courses and examples from other programmes aim to illustrate practical integrations of SD in education. These show that the choice of teaching methods is important for the activisation of students and SD competence development, and lower the barrier for action. We also aim to create awareness on the need for a programme-driven approach, in order to succeed in creating a holistic integration of SD, where courses build onto each other in order to meet the curriculum's intented learning outcomes. Through working collaboratively in workshops we intent for the staff to inspire and support their colleagues.

Connect: The main workshops have the goal of providing arenas for discussions and reflections on SD and the own teaching, and creating a shared understanding among the staff, thereby framing the structures of courses, curriculum and their own role as educators with a responsibility towards students and society. Based on the questionnaires and reflections, both the teaching staff and the project team experienced that these activities support collaborative learning on SD for the attendees. The test workshops offered us insights into how the workshop activies shaped these reflections, allowing us to make meaningful changes before inviting all academic staff.

However, in order for connections to be formed, as well as informing, motivating and inspiring the staff, participation in the process is important. A challenge we have seen is a lack of attendance at the workshops, with significantly less than half of invited staff joining some of the workshops, which reduces the effect of the ISE toolkit on the integration process. The underlying reason for an academic staff member to choose not to attend, can stem from a multitude of reasons. From the interviews and our own reflections from observing the staff, we have indications that a large group of the staff does not prioritize to integrate SD in their courses due to fear for the extra workload, a conviction that SD should be in a separate course rather than in their course, and/or a lack of believe that their field is relevant to SD. Understanding how to overcome these barriers is one of the most important goals moving forward.

4 CONCLUSION

Based on the pilot case, we believe the approach used and the lessons learned can provide useful strategic and practical insights for other engineering programmes in their process of integrating sustainability through involving academic staff. However, one should keep in mind that the ISE toolkit provides guidance for the start of this process, whilst the entire integration process runs over a longer period of time. Next to that, assigning someone for the role of a change agent to lead the process is crucial, together with support from management. All in all, it is the academic staff that makes a transition happen, whereby much effort goes to motivating and inspiring them.

Further steps related to the integration of SD in the curriculum of the Elsys study programme entail the further development and teaching of the pilot courses in 2022, taking up competences for SD in the intended learning outcomes of at least three course in the coming year, including SD in the intended learning outcomes of the study programme, and designing structures that allow courses to build on one another to reach these intended learning outcomes. The long-term goal is to have SD integrated in the complete study programme by 2025. Further development of the toolkit entails incorporating the lessons learned from the pilot case. Next to that, we aim to pilot the toolkit in another study programme before making it publicly available.

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MULTI-, INTER- AND TRANSDISCIPLINARITY IN CHALLENGE-BASED ENGINEERING EDUCATION

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ABSTRACT

Challenge-based learning (CBL) offers students in engineering programmes an opportunity to develop communicative and collaborative skills, apply disciplinary knowledge and develop boundary-crossing competencies. Mono-disciplinary approaches to CBL are generally regarded too limited, but whether multi-disciplinary, interdisciplinary, or transdisciplinary approaches should be used is open to discussion. Often, these concepts are used interchangeably, but there are notable differences. In literature, knowledge integration is mostly mentioned to make a distinction, but because of difficulties in applying this concept to education, we focus on tangible differences in educational practices, related to learning objectives, assessment, and the design of challenges. The different forms of CBL are illustrated by three case-studies carried out at a research university in the Netherlands. We found similarities, but also some subtle differences between multi-, inter- and transdisciplinary approaches to CBL. Multidisciplinary CBL projects are relatively pre-structured, with an indication of the knowledge that is to be applied, deepened, or combined. Interdisciplinary CBL is more open-ended, with students made responsible for connecting their disciplinary backgrounds to the project and for integrating disciplinary perspectives. Transdisciplinary CBL focuses more on impact than on integrating disciplinary contributions. Challenges are open-ended from a content and stakeholder

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perspective, while structure emerges in the interactions between students, teachers and stakeholders. Which form of CBL can best be employed in a course or programme is dependent on the intended learning objectives. Educators should be aware of trade-offs and of the specific teacher competences required to design and support these different forms of CBL.

1 INTRODUCTION

Challenge-based learning (CBL) is gaining popularity as an approach to engineering education. By working in groups on authentic, wicked problems of real-world stakeholders, students can develop transversal competencies and learn to apply disciplinary knowledge and skills in the analysis and solution of complex engineering problems [1] [2]. If supported well, students can also develop competencies to cross boundaries between academic cultures and disciplines [3]. Challenges, which are often related to Sustainable Development Goals, are complicated and require the involvement of several disciplines. Mono-disciplinary approaches to CBL are still used frequently [2], but the incorporation of different perspectives is generally considered to lead to richer and more creative ways of tacking societal challenges [1]. However, there is less consensus on whether multi-disciplinary [1] [2], interdisciplinary [4], or transdisciplinary [5] approaches are to be employed in challenge-based education. The terms are often used interchangeably, but on closer inspection there are notable differences. These relate, for instance, to how far students go beyond their disciplinary knowledge base, to knowledge integration, and to societal stakeholder involvement [6] [7]. In this paper we will explore how multi-, inter- and transdisciplinarity are different and how these differences show in challenge-based engineering education. The different approaches to CBL will be illustrated empirically by case-studies from a research university in the Netherlands.

2 CONCEPTUAL BACKGROUND

To distinguish between multi-, inter- and transdisciplinarity, education literature often refers to knowledge integration [6] [8]. In multidisciplinary projects students divide problems into components which they solve through disciplinary means, without any substantive integration of their approaches. The integration of disciplinary views and the arising of new, combined perspectives remain limited. In interdisciplinary projects, students do integrate knowledge from different academic disciplines. Transdisciplinary projects go a step further in integration, breaking down disciplinary boundaries and incorporating knowledge from ‘non-academic’ practioners and local stakeholders. In studies on interdisciplinary or transdisciplinary education it is noted that knowledge integration that pervades the whole process, from challenge definition and theoretical models to the choice of methods and proposed solutions. This integration complements processes of bringing in disciplinary insights, critical reflection and establishing the purpose of a project [6].

However, the concept of ‘knowledge integration’ is not without challenges. Pinpointing it empirically is difficult [9]. It is embedded in various activities of a complex problem-solving process and can often only be identified indirectly through reflections and explanations of participants [8]. Besides, the integration concept appears to assume a unification of models, approaches, etc., in a coherent whole. This oversimplifies the iterative, emergent and diverse ways in which fields of knowledge may interact in problem solving and learning processes. In these interactions, there may be all kinds of misfits, conflicts and incommensurabilities, especially when knowledge from engineering disciplines is being combined with that of social science, humanities and (non-academic) stakeholders. The process may then be better characterized as tinkering and bricolage [10] than as integration and synthesis. Given these complexities, disciplinary knowledge integration and the kind of novel combinations this entails may be beyond reach in student projects. Furthermore, interdisciplinary and transdisciplinary ways of working have their own models and approaches [11], which go beyond the integration of models and approaches of separate disciplines.

In this paper we will not focus on the somewhat elusive concept of knowledge integration to distinguish between multi-, inter- and transdisciplinary CBL, but look at differences in educational practices, showing for instance in learning objectives and problem-solving processes, to characterize these distinctions for educational purposes. Typical for *Multidisciplinary* CBL projects is that they start with the identification of the disciplines of participating students. Learning objectives are primarily related to the application and deepening of disciplinary knowledge in a complicated context and to the development of skills to collaborate and communicate with other fields of expertise. To be able to reach these objectives, decomposition of the challenge along disciplinary lines is important. Final products contain different disciplinary parts, which are aligned and aggregated in an overall solution. To avoid marginalization of certain participating disciplines, the challenges need to be designed or specified in such a way that all participants can reach their learning goals. This asks for careful alignment with involved stakeholders and limits the open-endedness of the challenges [12].

Alternatively, *Interdisciplinary* CBL projects start from more open-ended, unstructured, ‘real-world’ or wicked problems, which are more loosely coupled to the disciplines of participating students. Learning objectives are primarily related to collaborative teamwork and other transversal skills [4], less to the deepening of disciplinary knowledge. Students also learn to identify new knowledge they need for tackling the problem. Solutions may include of disciplinary parts, but students work actively on synthesizing or linking these. Stakeholders are involved as challenge owners, who bring in the problem, provide information and feedback, and to whom the solution is being presented or ‘sold’ [12]. Student teams act as problem solvers [13] and as interdisciplinary problem-solving goes beyond their disciplinary training, scaffolding by teachers is crucial [4].

In *transdisciplinary* CBL, an extra layer of complexity is being added. Stakeholders are seen as part of a heterogeneous learning community rather than as challenge owners. Challenges, processes and solutions are being co-created by students, teachers and (multiple) stakeholders [14]. The problem-solving process is focused on societal impact or transformation rather than on the application of academic models or techniques [7]. This implies that students' learning goals highlight the development of societal collaboration, communication, co-creation and other boundary-crossing skills. They also learn to deal productively with situated knowledge and input from non-academic sources [15]. Interdisciplinary scaffolds are being complemented by scaffolds targeting understanding and collaboration across academia-society boundaries [16]. Table 1 gives an overview of the different characteristics.

Table 1: Characteristics of multi-, inter-, and transdisciplinary educational practices.

	Multidisciplinary	*Interdisciplinary*	*Transdisciplinary*
Learning objectives	• application and deepening of disciplinary knowledge in a complex context • collaboration and communication with other disciplines	• identification and use of new knowledge from various academic sources • collaboration and teamwork across disciplines • transversal cognitive skills	• identification and use of new knowledge from academic and non-academic sources • collaboration and teamwork across disciplinary and societal borders • impact oriented skills
Challenge design	• relatively prestructured • carefully balanced disciplines	• open-ended • loosely coupled to participating disciplines	• open-ended and ambiguous • loosely coupled or not coupled to participating disciplines
Problem-solving	• decomposition along disciplinary lines • alignment and aggregation of disciplinary contributions	• synthesizing and linking disciplinary contributions	• bricolage of disciplinary and non-disciplinary contributions
Stakeholder involvement	• providing challenges that are carefully aligned with learning objectives	• providing challenges that are relevant for their practice • providing information and feedback on process and product	• providing challenges that are relevant for society • co-learning, co-creating, co-assessing

3 METHODOLOGY

To get a better understanding of how multi-, inter- and transdisciplinary approaches to CBL work in practice, they will be illustrated by three case-studies of educational modules, carried out at the University of Twente in the Netherlands. Table 2 gives an overview.

Table 2: Overview of cases

Approach	*Case*	*Involved Disciplines*	*Level*	*Kind of module*	*# ECs*
Multidisciplinary	Consumer products	Industrial Design, Mechanical Engineering, Industrial Engineering	Bachelor	Mandatory course	15
Interdisciplinary	Science to Society	Various technical and social sciences	Bachelor	Minor module	15
Transdisciplinary	Shaping Responsible Futures	Various technical and social sciences	Master	Extra-curricular programme	30

Data were collected through semi-structured interviews with module coordinators, teachers and participating students. Besides, study materials (such as project assignments and rubrics) and products of the challenge-based projects were collected. Educational prospectuses, course manuals and module pages hosted on the learning management system provided further sources. For this concept paper, a comparison was made on the basis of data on learning objectives, assessment, and design of CBL projects. These elements provide a first idea of the differences in educational practices.

4 RESULTS

In the description of the learning objectives of the three cases the terms multidisciplinarity and interdisciplinarity were used to a large extent interchangeably. The multidisciplinary module even talked about ‘interdisciplinary teams’, while the interdisciplinary and transdisciplinary modules used ‘multidisciplinary teams’ to describe student collaborations. However, there was a difference in the composition of student teams. In the multidisciplinary module ‘Consumer Products’, students from three bachelor programmes participated and each team included participants from these different backgrounds. In the interdisciplinary case ‘Science to Society’, which is part of a minor, the involved disciplines varied over the years and over the teams. Students self-enrolled in teams and were encouraged to mix gender, disciplines, etc. The extra-curricular transdisciplinary ‘Shaping Responsible Futures’ also included varying disciplines. However, as it was selective the coordinators could steer on heterogeneity of the influx. Students formed their own teams as long as these represented the disciplinary, gender, cultural variety. Learning to communicate and collaborate is these teams was a learning objective in all three cases.

When regarding the learning objectives of the cases there was clear overlap, but when looking more closely, two differences became apparent. First, in the multidisciplinary module the application and combination of disciplinary knowledge was much more specified (*Integrate and employ knowledge from different fields of expertise (like marketing, styling, CAD/CAM, intellectual property, packaging, production, supply chains, research methodology, etc.),* while the interdisciplinary and transdisciplinary modules left this open. The interdisciplinary and transdisciplinary cases dedicated seperate learning objectives to integrating knowledge and needs (*Composing requirements that integrate the needs of different stakeholders and different domains*) and to transcending disciplines (*Transcending disciplinary perspectives in creative, systemic and responsible designs*) respectively. A second difference was that the latter two more strongly emphasized stakeholder engagement. In the interdisciplinary case this was phrased as collaboration and communication with stakeholders, in the transdisciplinary case as boundary crossing (*Collaborating and communicating across disciplinary and social boundaries*).

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When regarding the rubrics used to assess the final products of the CBL project there were also subtle differences between the cases. In the multidisciplinary project rubrics, the terms ‘coherence’, ‘multiple dependencies’ and ‘balance’ were used to describe how contributions of the three involved disciplines and of the sections in the report should be related. A high score, for instance, was for final reports in which “*the sections are very well balanced and of high value. A wide range of mutual dependencies and important consequences is correctly presented*.” In the interdisciplinary project, the student disciplines varied and it was up to the students to integrate their disciplinary contributions. According to the rubric, a good project ”*includes all the disciplines present in the group and integrates them optimally, using supporting literature*” and “*the most relevant requirements from various disciplines are present and nicely integrated into a coherent requirement specification,…*” Stakeholder interaction was also part of the assessment. The result should “*reflect frequent and clear collaboration with the target group and the problem provider*”. In the transdisciplinary case, a single point rubric was used to provide feedback on the final product. It stated that the presented innovative solution should be “*clear, well-argued, original, transdisciplinary, realistic, with potential to contribute to SDG, based on academic literature and other sources*”. There was no reference to the specific disciplinary contributions of the participating students. Extensive engagement with different kinds of stakeholders was also valued in the transdisciplinary assessment rubric.

When looking at the design of the challenges and the problem solving process, there were also differences. In the multidisciplinary case students went through specified stages of a product development cycle (*from portfolio analysis, via market research to the presentation of mock-ups and manufacturability*) to develop a consumer product. They interacted with a real-world customer and had autonomy to develop a solution within certain boundaries. In the interdisciplinary case, the challenge and process were more open-ended. Students could choose a challenge and a client based on their interests. The end product was a prototype of a product, which would be further developed in a subsequent module. The transdisciplinary case was even more open-ended, in terms of framing of the challenge, design process the form of the final product. Scaffolding was provided, but to a large extent the challenge and process were shaped along the way by students in interaction with teachers and stakeholders, inspired by ideas, models and theories brought in by the different participants. Stakeholders were approached as co-learners, sparring partners and as starting-points to connect to the broader societal field.

5 DISCUSSION AND CONCLUSION

In this paper we explored the differences between multidisciplinary, interdisciplinary and transdisciplinary ways of shaping challenge-based engineering education. Rather than taking the often employed but somewhat elusive concept of knowledge integration as a starting point for distinguishing between multidisciplinary, interdisciplinary and transdisciplinary CBL projects, we focused on differences in educational practices. These were exemplified in learning objectives, assessment rubrics and designs of challenges and CBL processes. We do not deny the relevance of knowledge integration, but approach it as embedded in multi-faceted, context-specific, social processes of learning and teaching rather than as the outcome of a more abstract process of disciplinary aggregation, synthesis, or transcendence.

In our study we found clear resemblances between multi-, inter- and transdisciplinary approaches to CBL, but also some notable differences. The challenges and CBL process in multidisciplinary projects were more pre-structured, by teachers and stakeholders, with a careful balance between the contributing disciplines. There was a clear view on which knowledge was to be applied, deepened, or combined, which was reflected in learning objectives and assessment rubrics. Interdisciplinary challenges were more open-ended, offered choice, and gave students the responsibility to link their disciplinary background to the project. Integration of disciplinary perspectives was expected and assessed. Transdisciplinary projects were open-ended from both a content and a stakeholder perspective, meaning that neither the framing of the challenge nor the stakeholder constellation were fully set beforehand. Structure emerged along the way in the interactions of students with teachers and stakeholders, and there was no obligation for students to apply 'their' discipline. The relevance of the output was valued over the disciplinary input. Learning objectives were formulated at a more abstract level and rubrics were open to tailored evaluation and feedback.

It may be tempting to regard transdisciplinary projects as the ultimate form of CBL, as they take on the most complex and ambiguous challenges, have the richest student-stakeholder interactions, and are most strongly impact-focused. However, challenges can also be approached in multidisciplinary and interdisciplinary fashions. It depends on the intended learning outcomes of the courses and programmes. Educators should be aware of trade-offs (what is won in open-endedness may be lost in disciplinary depth) and of the different teacher competences needed to design, organize and scaffold these different forms of CBL. Interdisciplinary and transdisciplinary CBL also require the teachers to cross boundaries and get out of their disciplinary comfort zones. Engineering programmes may consider to offer their students multi-, inter- as well transdisciplinary forms of CBL in their curriculum, in order to provide them with richer learning experiences needed to prepare for jobs as professionals or researchers in a complex society.

This paper offered an exploration and illustration of three different forms of challenge-based engineering education. This is meant as a first step. Further conceptualization of multi-, inter- and transdisciplinary education is needed. Also the empirical analysis is to dive deeper into the communalities and differences in educational practices and learning processes. What do student actually learn from these different kinds of CBL, how can they deal productively with the different kinds of knowledge and how can teachers effectively scaffold the more open-ended processes? These pressing questions ask for further research.

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WHERE'S THE VALUE IN ENGINEERING, AND IN TEACHING IT?

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ABSTRACT

New theoretical perspectives on how engineers generate economic and social value have emerged from research on engineering practice, complementing the conventional entrepreneurship emphasis on innovation and start-up enterprises. This

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research demonstrated, apparently for the first time, how most engineers generate significant economic value with limited if any opportunities for innovation, research and development in their work.

In the absence of appropriate theory, students acquire limited understanding on the contributions they will make to society as engineers. Observations from engineering practice provide a more compelling research-based narrative that could attract a more diverse student population, and help graduates secure well-paid employment.

Many engineering faculty share uneasy feelings that their students will rarely use the advanced mathematical analysis techniques taught in classes. Research explains how practice solving traditional textbook problems builds tacit knowledge that enables rapid technical decision-making in engineering practice. The research also provides insights on how typical engineering science research supports engineering practice.

We argue the benefits from widely disseminating the findings presented in this paper to help faculty staff and students better understand how they will contribute to our collective future. This can help overcome current significant engineering performance shortcomings in sustainability and productivity growth without major curriculum changes.

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1 ENGINEERING PRACTICE AND ENGINEERING VALUE GENERATION

Research on engineering practice, the work of engineers, has provided a rich body of evidence for engineering educators over the last three decades. References cited in this paper provide reasonably comprehensive coverage of research published in recent decades. For example, among many other findings, this research demonstrates that the common notion that engineers are expert technical problem-solvers needs adjusting. While solving problems will always be part of engineering practice, expert engineers aim to avoid problems by adopting systematic organizational processes and compliance with standards.

Research helps to demonstrate three complementary types of engineering activity [1] and the career roles associated with them:

1. Interact physically with artefacts and tools, mostly individually, occasionally with others;
2. Interact cognitively with abstract objects and tools, concepts and ideas, mostly using information systems; and
3. Interact with people to plan, organise, collaborate in, and coordinate type 1) and 2) activity, also advocating for and securing required finance and material resources.

In this paper, our main focus is on professional engineers who mainly specialise in type 3 activity, with periods engaged in type 2 activity and occasional type 1 activity.

Technicians develop skills and expertise mainly for type 1 activity. Many also develop aptitudes and skills for type 2 activity to support their type 1 work, and for type 3 activity as supervisors.

Technologists mainly specialise in type 2 activity, often with knowledge acquired through type 1 activity. Examples include drafters, coders, network engineers, plant operators, air traffic controllers, designers, and many others.

As they transition from education focusing mainly type 2 activity to practice that requires mainly type 3 activity, professional engineers need to rapidly acquire skills and knowledge that receive little if any attention in formal education. Many companies provide highly developed infrastructure in the form of supervision, standards, systems and work processes that support competent performance by early career engineers.

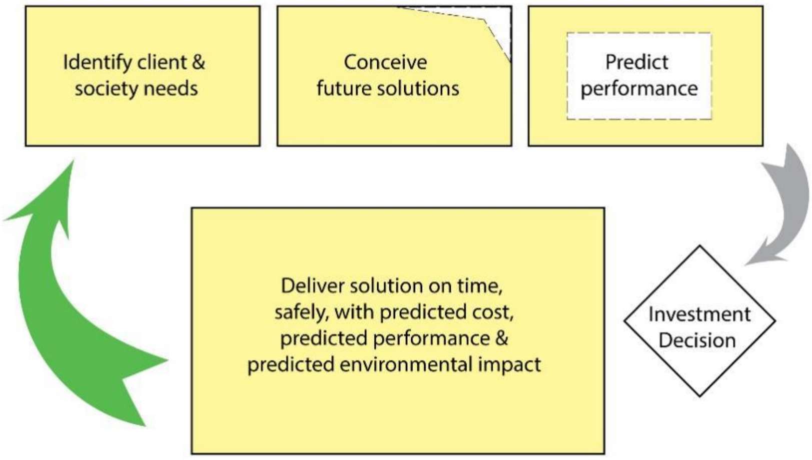

Figure 1: Sequence of engineering activities required for projects. Dashed areas in upper thread denote formal education focus [2].

Looking more closely at type 2 and type 3 activities that characterise the work of most professional engineers we see two threads shown in figure 1 [2, Ch3]. In the upper thread, engineers ascertain needs and requirements, and conceive solutions for clients in the form of engineering possibilities. They then define one or more favoured solutions and prepare plans, budgets and performance predictions to help investors raise sufficient finance. After an investment decision to proceed with the project, engineers organize procurement, delivery, implementation and operation of the required solution with the intention of meeting the anticipated performance predictions within financial and regulatory constraints. In performing this activity they acquire knowledge that improves their capacity for similar work in future, symbolised by the large arrow.

Innovation provides the principal conventional explanation for economic growth and value generation based on work by 20th century economists such as Joseph Schumpeter. This idea has led to the contemporary emphasis on entrepreneurship and start-up enterprise that often seem to attract far more interest and investment than much larger traditional firms. As a result, many educators have recently advocated entrepreneurship education for engineers.

However, both government data and ethnographic observations of engineers help to demonstrate that most engineering involves rather limited opportunities for innovation, research, and development. Nevertheless, most engineers aspire to innovative work with significant technical challenges. As one engineer exclaimed in an interview “the only two times in my entire career that I really enjoyed myself was when the client forgot to ask – has this been done before?”

In our research we observed that many engineers, perhaps most, have difficulty explaining how their work creates economic and social value [3]. This inspired a series of studies to understand how engineers generate significant economic and social value from routine activities that do not necessarily require innovation [4], complementing existing entrepreneurship models [5].

I. Engineers *create* value by differentiating products from competitors and producing plans and predictions that justify significant investment decisions to provide financial and material resources.
II. Engineers then *deliver* the potential value from these investments by engaging in highly disciplined collaborative activity. They coordinate performances by many other people, helping to ensure that original technical intentions are implemented with sufficient integrity. Mutations are inevitable as different people necessarily re-interpret technical intentions. For example, original designs are re-interpreted by construction and manufacturing firms to suit their particular expertise, along with financial, safety, environmental, regulatory and technical constraints.
III. Many engineers *protect* accumulated value through sustainment and maintenance activities. Maintaining a social licence to operate by active and supportive engagement with communities and regulatory agencies protects accumulated value created by ongoing investment in engineering operations. Investment in defence equipment provides assets that can deter or limit destructive activities by other people, again protecting accumulated value.

Reduced to the simplest possible terms, engineers generate value by conceiving and delivering artefacts that enable people to be more productive: to do more with less human effort, time, material resources, energy, uncertainty health risks, and environmental disturbances. This summary addresses sustainability as well: the need to enable the full scope of human existence while keeping well within the limits imposed by a finite planet Earth [6].

2 NEED FOR PERFORMANCE IMPROVEMENT

Historical engineering performances have been impressive in many ways, helping to emancipate and relieve billions of people from hardship, poverty and destitution. However, we now face existential threats because planet Earth cannot sustain the current rate of resource depletion, pollution and natural habitat destruction [e.g. 7].

Two significant engineering performance deficiencies compound these difficulties.

I. Most large engineering projects fail to achieve their financial objectives by a large margin and a significant proportion involve a complete write-off for investors [8, 9]. This data, available in confidence to most investors, continues to show further performance deterioration. Most projects fail because of collaboration weaknesses and overconfidence by project owners. Trevelyan [2] provides a detailed case study that illustrates how major projects can fail.

II. During the last two decades, most countries have reported significantly lower productivity growth than in the 20th century [10-12].[2] Productivity here refers to macro-economic indicators that measure the value of goods and services produced relative to labour, capital and material resources needed to produce them. This has led to stagnating or declining real incomes for many people and major political unrest in some countries. Productivity in low-income countries remains, on average, five times less than wealthy countries and this ratio has changed little in recent decades [13].

   As explained above, engineers significantly influence national productivity because productivity relies on infrastructure, tools and equipment conceived and implemented under the guidance of engineers. Yet, many engineers today do not understand the connections between their work and national productivity. Sustainability and addressing climate change rely significantly on reducing material and energy resources needed to provide goods and services, in other words, productivity improvement.

Understanding these engineering performance deficiencies can point out ways to improve engineering performances and hence sustainability.

3 INSIGHTS FROM RESEARCH FINDINGS

We argue here that applying engineering practice research findings in engineering schools could lead to significant engineering performance improvements. For example, improving the understanding by engineers on how to generate economic value could lead to improved value generation performances by engineers and productivity improvements.

We suggest that awareness on the links between engineering performances and financial outcomes has receded, as evidenced by our findings on engineers' awareness on economic value generation from their work performances. In the 1950s, this link was explicit in the definition of engineering adopted by the ASEE Grinter report [14]. Contemporary definitions of engineering make this link much less explicitly. For example, New Zealand engineers were asked to define engineering as part of a recent study by consultants to estimate the contribution of engineering

[2] See for example US Labor Productivity in Manufacturing: https://alfred.stlouisfed.org/series?seid=MPU9900063&utm_source=series_page&utm_medium=related_content&utm_term=related_resources&utm_campaign=alfred

towards that country's GDP [15]. None of the comprehensively reported engineers' responses mentioned the need for minimizing cost.

Therefore, we argue, educators have opportunities to rebuild awareness on the economic and social benefits arising from engineering and the need for performance improvements by drawing on the research we have referred to. We suggest there are three significant benefits.

3.1 Attracting more diverse student enrolment

It is well known that more women enrol in biomedical, chemical, and environmental engineering programmes [16] because they can readily appreciate the social benefits and applicability of disciplines that enact altruistic goals and values [e.g. 17, 18]. We suggest that providing a more compelling narrative for prospective students that explicitly engineering with its social and economic benefits in terms of enabling people to do more with less effort, resources, health risks and environmental disturbance may help to attract more women and students from diverse backgrounds into other engineering disciplines.

3.2 Improving graduates' career outcomes

We suggest that graduates who have a clear understanding on how their work creates economic value for firms and social value for communities are more likely to provide benefits for their employers. In the long run, these graduates may attract higher remuneration in recognition of the value they provide for their employers, in accordance with the marginal revenue productivity theory of wages in labour market economics [19].

3.3 Faculty motivation

Many engineering faculty staff experience identity conflicts and an unease that few students will ever directly apply the knowledge they acquire in engineering science and mathematics classes [20-23].

Recent work on how mathematics is used in engineering practice could provide reassurance. While it is true that engineers rarely apply the methods they learned in class directly, they often make instinctive decisions based on that knowledge. In other words, they acquire substantial tacit knowledge from solving numerous textbook problems which helps them make rapid strategic decisions that rely on knowledge of mathematics and engineering science [24]. Furthermore, many engineers rely on software that incorporates advanced techniques, often far beyond those learned in school, so they apply classroom knowledge indirectly, without necessarily being aware that they are doing so. That is the nature of tacit and embodied knowledge: it is knowledge that one is mostly unaware of [25].

Faculty staff can gain further reassurance by understanding that engineering science research builds knowledge that finds its way into practice through software, data libraries, standards and sometimes new technologies and products. All these contributions enable more accurate performance predictions, faster diagnoses and more reliable artefacts and materials, generating considerable value in the hands of engineers. Again, practicing engineers are not necessarily aware of all the knowledge embodied in the products and software they use in their work.

4 SUGGESTIONS FOR ACTION

Despite more than two decades in which graduated competencies have shaped engineering education, the gaps between education and practice remain, and graduates are surprised by the emphasis on type 3 activity when they start work [26]. While many would argue that education can never provide a complete preparation for practice, overcoming significant engineering performance deficiencies outlined in this paper requires urgent actions.

We first suggest that engineering schools help students learn from research-based explanations on how they will contribute economic and social value as engineers as outlined in this paper. This can help rebuild awareness on the critical nexus between technical engineering and economics [5]. This could be reinforced by helping faculty staff understand how their work contributes economic and social benefits, so that they can, in turn, better inform students on how their classroom learning will contribute to practice. Accordingly, we advocate substituting commonly repeated explanations with research-based explanations provided in this paper and the cited references.

For example, the common notion that ‘engineers are expert problem-solvers’ is only partly true, as explained above, and fails to distinguish engineers from many other occupations in which practitioners use their expertise to solve problems. We advocate using research-based explanations specific to engineering such as delivering artefacts and systems that enable other people to be more productive with less effort, time, materials, energy, health risks, uncertainty and environmental disturbance are specific to engineering.

We also suggest that engineering schools ensure that students are aware of significant contemporary engineering performance deficiencies as outlined in this paper. Students also need to know that they can contribute to performance improvements through their work, at the same time improving productivity and sustainability.

In engineering schools with entrepreneurship courses, we suggest complementing material on innovation and start-up businesses with explanations on how engineers also create social and economic value through routine, everyday engineering that does not involve innovation.

We further suggest that educators work at reducing the many misunderstandings on engineering practice that have arisen because there has historically been little understanding of practice among faculty staff. Trevelyan [2] lists around 100 such misunderstandings.

We suggest that engineering schools encourage collaborative pedagogies [e.g. 27] with known educational benefits in order to better prepare students for the collaborative type 3 activity that characterizes most engineering practice.

We suggest that all of these actions could be achieved without significant curriculum changes. The authors are happy to help engineering schools implement these suggestions.

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6 DISCLOSURE STATEMENT

No conflict of interest was reported by the authors.

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AUGMENTED REALITY FOR LEARNING MATHEMATICS: A PILOT STUDY WITH WEBXR AS AN ACCESSIBLE TOOL

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ABSTRACT

One of the concerns in service mathematics courses, such as calculus for engineering, is students' interest in these studies. Research suggests that engineering undergraduates' lack of awareness about the importance of mathematics for their study success and for their careers contributes to their low motivation for mathematics. An approach to increasing student motivation is to take advantage of technological tools to provide students with more engaging learning experiences. Recent studies showed that augmented reality (AR) enhances student engagement, motivation, and knowledge retention. However, implementing AR can be challenging since it can be quite costly and technically complex. The current paper describes a case study in which an AR application was designed and developed using WebXR, in the context of a service mathematics course for teaching calculus. The AR content involves drawing of level curves and the visualization of a volcano and the flow of lava to support students' learning of directional derivatives. A pilot study was conducted to examine engineering undergraduates' perceptions of using AR for learning mathematics. Results show that students perceived using AR for learning math as enjoyable and motivating. Students reported that AR content adds value to their classes by making the mathematical concepts clearer and helping them apply what they have learned to real life. However, the AR content did not work well on all mobile phones and all versions of web browsers. Lessons learned from the design and development of AR using WebXR as well as recommendations for future studies are discussed in this paper.

1 INTRODUCTION

1.1 Service Mathematics in Higher Engineering Education

Mathematics is often service-taught by mathematicians to students who are not majoring in mathematics as a foundation for science, technology, and engineering in higher education. Research shows that engineering students' motivation to study mathematics is low and many perform poorly in service mathematics courses, despite the importance of mathematics for academic success and professional practice [1]. One of the reasons is that many engineering students do not perceive mathematics as their primary interest [2]. This leads to procrastination of tasks for learning. Another reason is that students are not aware of the importance of mathematics as the foundation of the subjects in their field of study, nor are they familiar with how mathematics is applied in their subject of interest [3].

At the Delft University of Technology, the Program of Innovation in Mathematics Education (PRIME, https://www.tudelft.nl/en/eemcs/the-faculty/departments/applied-mathematics/education/prime) was introduced in 2014 to redesign service mathematics courses. The goals of PRIME are to improve study results, enhance the connection between mathematics and engineering, and increase students’ active participation and motivation. Over the years, a number of innovative practices, such as pre-lecture videos, interactive quizzes and online exercises, have been introduced. To better meet the needs of engineering students, PRIME continues to examine ways in which various technologies (e.g., augmented reality) can be leveraged to enhance the teaching and learning of mathematics in higher engineering education.

1.2 Using AR to Support Learning of Mathematics

The technology of Augmented reality (AR) gives users the opportunity to see digital information superimposed onto the real world, and hence, offers a novel experience and interactivity with the learning content. Research on AR in education has been rising over the last 25 years and one of the trending topics is the use of mobile devices for deploying AR learning experiences [4]. In a recent systematic review on the use of AR for learning mathematics [5], AR was shown to be an effective tool for learning mathematics by increasing confidence and understanding, enhancing visualization, and making learning interactive across all educational levels. To date, research examining the effect of AR on mathematics learning in the context of higher education is relatively scarce.

In [6], a combination of 3D tools (i.e., augmented reality, virtual environments, and 3D printing) was used in the process of mathematics teaching and learning to enhance spatial visualization and orientation skills. The study showed that students in the experimental group who took the multivariable calculus course under the new methodology scored seven points higher than those in the control group. There was a 14% drop in the experimental group’s failure rate. Furthermore, the new methodology helps students to improve the way they described objects in space using mathematical language. In another study [7], AR content was integrated into the Mathematical Analysis class for electrotechnical engineering. Students in the study perceived the AR tool as a way to better understand and access knowledge. Moreover, they were curious and interested in the prospects of the software.

More recently, a “Vector AR3” app was developed as a means to shift from a theoretical approach to teaching math to an approach that focuses more on the application of the learning content [8]. While the app has won the International eLearning award 2020, the impact of the app on teaching and learning has yet to be evaluated due to Covid-19. The studies described in this section suggest the potential of AR to enhance mathematics teaching and learning. In order to reap the potential benefits of AR for mathematics education at universities, it is important to explore ways to ease the use of AR for the growing student population.

1.3 Current Study: Using WebXR to

Pitfalls of AR include accessibility and scalability. To address these pitfalls, the current study employs WebXR for the AR tool. Unlike mobile applications that require different codes for android and ios, WebXR allows the AR tool to be embedded into the learning management systems and can be deployed as a web application and accessed through a mobile browser [9]. Moreover, students will not be required to download an application through an app store via Google or Apple, bypassing the procedure of downloading and logging in. To our knowledge, very few studies have examined WebXR as an AR tool for teaching and learning math. The aim of the current study is to examine the feasibility of using WebXR to develop an AR tool for learning mathematics. The study consists of two parts: 1) designing and developing the AR tool, and 2) examining the usability of the AR tool.

2 DESIGN AND DEVELOPMENT

2.1 Designing the AR tool

When designing the AR tool, meetings were conducted between the developer, math lecturer, course coordinator, and educational researcher. During the meetings, the team members brainstormed ideas for the math topics and ways in which the AR tool can be implemented. The math lecturer proposed a math application question that was already covered in the existing math lecture as a task for the AR tool. Figure 1 illustrates the math application question. Two design features were proposed to deliver the math application in the AR tool:

1) Drawing level curves that will be transformed into a 3D volcano.
2) Visualizing lava flow as a connection to directional derivative.

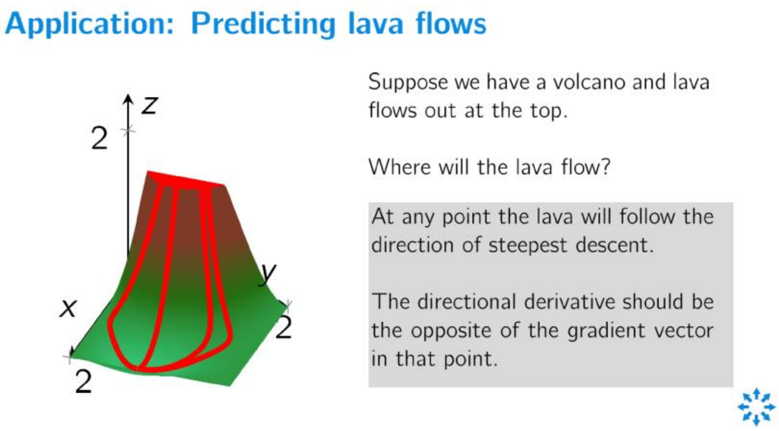

Figure 1. Mathematics application taught in the course

2.2 Developing the AR tool

Figure 2 illustrates the technical infrastructure of the AR tool. A web application that has been developed through a 3D JavaScript library, ThreeJs, was employed. This library enables developers to create 3D web applications using WebGL API, which supports WebXR to create AR content. The AR tool features an empty drawing screen where students can draw the outline and level curves of the 3D volcano by using touch input. The first shape that the student draws is an outline of how the 3D volcano should be shaped in general. This outline shape is used as a ground level to build the volcano geometry. To recreate an organic volcano formation from an outline, multiple points are scattered randomly inside this outline and Delaunay triangulation [10] is performed to create a triangulated mesh. From this point on, students can draw multiple level curves on top of the triangulated mesh which is used to calculate how the mesh should deform in height. The final step of generating a 3D volcano is by starting the AR view, where the tool will calculate the final shape of the 3D volcano by combining all drawn level curves and taking account of a set of parameters; Height, noise, crater size and crater depth. With AR view started, the 3D volcano is displayed in AR and following the camera movement. The volcano can be placed on any surface by pressing on the screen. With the volcano in place, the student can touch any volcano surface to start a lava flow trail. Gradient descent is used to calculate the path of the lava and is then projected on the volcano. With these features in place, the application is packaged and hosted online to be accessed through a browser.

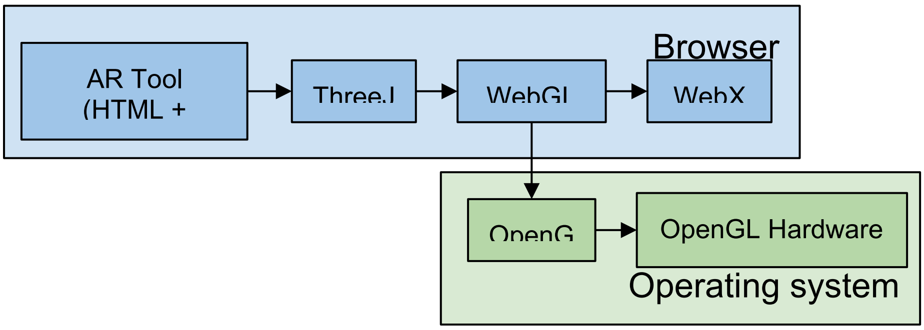

Figure 2. The technical infrastructure of the AR tool

3 PILOT STUDY

3.1 Method

The aim of the pilot study was to examine how students perceive the utility of the AR tool for learning math. Students taking Calculus I in Applied Earth Sciences were invited to take part in the pilot study. Nine students (four males and five females) participated in the pilot study. The average age of the students was 18.6 years old. Students were directed to a web link (https://sbayoumy.github.io/threejs-test/) that enabled them to use the AR tool on their mobile phones. In addition, students were provided with a set of questions to aid their exploration of the AR tool. Figure 3 illustrates an example of a volcano drawn and visualized using the AR tool.

After exploring the AR tool, students were asked to complete a survey consisting of 14 Likert-scale questions and three open-ended questions. The Likert-scale questions included 5 items measuring *student satisfaction* with the AR tool, 3 items measuring *engagement in learning* concerning whether the AR tool promotes active learning, 3 items measuring *enhancement of learning* addressing the question of whether the AR tool helps to enhance their understanding, and 3 items measuring the *extension of learning* concerning whether the AR tool helps to extend the learning of math to other contexts. The survey items were adapted from [11], [12], and [13]. Students were asked to respond to each item on a 5-point Likert scale from 1 (strong disagree) to 5 (strongly agree). The open-ended questions were used to gather students' perspectives on what they liked or disliked about the AR tool and how the AR tool supported their learning.

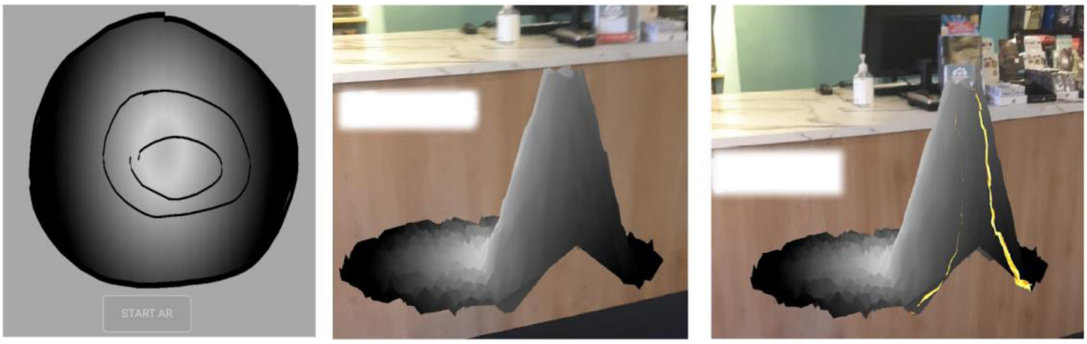

Figure 3. An example of a volcano drawn and visualized using the AR tool

3.2 Results

Table 1 provides an overview of students' satisfaction ratings of the AR tool. The results show that students generally agree that using the AR tool was enjoyable and entertaining. As for user-friendliness, students' ratings varied. This reflected the instability of the AR tool and the challenges of making the AR tool work on all mobile devices. Diverse ratings were obtained on the two items measuring satisfaction with the AR tool as a study tool and overall satisfaction with the AR tool.

Table 1. Students' satisfaction rating of the AR tool

	Strongly disagree	disagree	neutral	agree	Strongly agree
I was satisfied with the AR application as a study tool.	1	3	4	1	-
I found the AR application entertaining for me.	-	-	3	4	3
I enjoyed using the AR application.	-	-	1	7	1
I found the AR application user-friendly.	1	1	1	3	2
Overall, I am satisfied with the AR application.	-	3	1	3	1

Mean scores and standard deviations were obtained for engagement (*M*=3.79; *SD*=.67), enhancement (*M*=3.79; *SD*=.56), and extension of learning (*M*=3.93; *SD*=.49). The mean scores suggest that students were generally positive about how the AR tool can support their learning. For engagement in learning, almost all of the students (8 out of 9) agree or strongly agree that the AR tool motivates them to start learning and causes a passive to active behavioural shift. There was less agreement regarding whether the AR tool allows them to focus on the task with less distraction.

For enhancement of learning, students felt rather neutral about whether the AR tool allows them to demonstrate their understanding of learning better than other tools. Students mostly agree that the AR tool allows them to develop a better understanding of the learning content and makes it easier to understand concepts For extension of learning, three-quarters of the students (6 out of 8) agree or strongly agree that the AR tool creates opportunities for them to transfer learning to other contexts, creates a bridge between mathematics and engineering, and allows them to develop skills that they can use for their program of study.

When asked about what they liked most about using the AR tool and to what extent the AR tool contributes to their learning, students mentioned that the AR tool makes learning fun and helps them to apply what they have learned to a real-life context. They also found it helpful to be able to have a visualization of the mathematical functions learned in class. A student stated that being able to see how the math is being applied makes learning motivating. In addition, a student reasoned that if the AR tool can be implemented in a good way in the math exercise classes, it might give students an incentive to attend the classes. Some of the quotes from the students are shared below.

> *"It is very interactive. You can make your own volcano and then get your own equation."*

> *"It's fun to use and I understand the concept of level curves better with it, it helps visualize the whole thing."*

Through the survey, we also received feedback on what students disliked about the AR tool. The AR tool did not seem to work very well and did not run on different models of mobile phones. Students also experienced difficulties with the drawing tool. A student mentioned that the drawing tool was slow even when the wifi is good and another student was not able to get the drawing tool to work. The problems that students encountered when using the current AR tool could have influenced their satisfaction and engagement in learning. This can be reflected in the quote below.

> *"It doesn't work very well yet, which makes it frustrating to use. This would make me distracted from my learning*."

4 DISCUSSIONS AND CONCLUSION

The results of the pilot study show that the AR tool has the potential to enhance learning of math for applications and facilitate student engagement. Students were positive about using the AR tool to learn math. However, challenges remain with the technical deployment and design of the AR tool. As identified in a scoping review of augmented reality in K-12 and higher education [13], technical thresholds and design considerations are major limitations in studies examining the effect of AR on learning. Technical malfunctions and problems may lead to student frustrations when using the app and reduce learning effectiveness.

Developing the AR tool with WebXR is a compromise for the lack of support of the WebXR API in a set of browser versions. However, the current state of the WebXR API and its features are yet to be fully supported on existing browsers or standardized in the WebKit platform (see https://caniuse.com/webx for a list of supported browsers). Therefore, developing cross-platform web applications involve risks around having to implement specific solutions for different browsers and devices. It is crucial for future iterations of the AR tool to take the technical thresholds into account and explore ways to mitigate these risks.

One of the strengths of the current study is the participation of the math instructors in the design of the AR learning content. Therefore, the AR tool is complementary to the learning content in the ongoing mathematics course. As demonstrated by the results of the pilot study, students perceived the learning content as helpful, particularly the visualization of the math concepts that were taught in class. Estapa and Nadolny [15] reasoned that the benefits to manipulate, visualize and use authentic contexts make AR a natural fit for mathematics instruction. Despite the small sample size in the pilot study, the results suggest that implementing AR in the math course could potentially have a positive impact on student motivation. Given that learning performance was not measured in the pilot study, it is not clear if and how the AR tool increases math knowledge. To better understand the effects of AR on learning, there is a need to use multiple metrics (both quantitative and qualitative on motivation and learning effectiveness) [16]. Also, future research with a bigger sample size and using randomized controlled trials is needed to further investigate the effect of scalable AR tools on learning mathematics, student engagement, and motivation.

In conclusion, our study demonstrates the benefits of involving teachers and students in the design and development of an AR tool using WebXR for teaching and learning math. The math instructor plays a critical role in ensuring that the content of the AR tool is meaningful for the students. Similarly, students' perceptions and feedback that we have gathered in the pilot study will inform the future iterations of the current AR tool.

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RESEARCH ON MATHEMATICAL COMPETENCIES IN ENGINEERING EDUCATION: WHERE ARE WE NOW?

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Keywords: *service mathematics, engineering education, mathematical competencies, scoping review, curriculum development*

ABSTRACT

In tertiary mathematics education for engineers (hereafter called service mathematics education, SME), there is a long-lasting controversy on what and how to teach. The goal of SME is to provide a base for engineering-specific courses and to develop mathematical competencies needed for academic success and professional practice. A leading question in engineering education is how to take mathematical competencies into account when designing content. Mathematical competencies are employed to understand, judge, do, and use mathematics in a variety of mathematical contexts and situations in which mathematics could play a role [1]. Although mathematical competencies have been introduced for about two decades, Alpers [2] noted that research in engineering higher education had focused chiefly on the *modelling* competency and less on other competencies. By means of a scoping review, the current study aims to examine how mathematical competencies are investigated in higher education research. The main research question is “To what extent and in what ways have mathematical competencies been examined in higher engineering education research?” Papers were retrieved and qualitatively reviewed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A systematic search yielded 166 records, of which, 65 unique records were relevant to engineering education and screened for eligibility. A synthesis of 23 studies reviewed showed that *problem-solving* and *modelling* were the most investigated mathematical competencies and were often investigated together or with other mathematical competencies. The inconsistencies in the terminologies used suggest a need for clearer conceptualizations to advance research and inform practice on mathematical competencies.

1 INTRODUCTION

1.1 Service Mathematics in Higher Engineering Education

Mathematics is an essential discipline for many professions, and therefore, also in higher education [3]. In Science, Technology, Engineering and Mathematics (STEM) education this is even more the case since mathematics provides the basis and language for physics and engineering specific courses students need to complete. On the other side, mathematics is also viewed as a means to teach students to think analytically, to model and to solve problems in their fields [4]. Mathematics education for non-mathematics students (or major) is usually referred to as service mathematics education (SME), since the subject is being taught as a service to other disciplines and their programmes. The main challenge in this education is to tackle the question of what subjects to teach, in what depth, in how much detail, at what level, and with how much connection to applications. One way to deal with these challenges is to adapt the framework of mathematical competencies to the context of SME for engineers.

1.2 Mathematical Competencies

In 2000, the KOM (Competencies and the Learning of Mathematics) project was initiated in Denmark in response to various challenges in mathematics education at all levels. According to Niss [5], mathematical competence is defined as:

> "someone's insightful readiness to act appropriately in response to all kinds of mathematical challenges pertaining to given situations."

Eight mathematical competencies were identified that built the edifice to achieving mathematical competence. A mathematical competency is someone's insightful readiness to act appropriately in response to a specific sort of mathematical challenge in given situations. These eight mathematical competencies are grouped into two categories. The first one consists of four competencies involving posing and answering questions in and through mathematics. The second category consists of four competencies involving handling the language, constructs and tools of mathematics (for an overview, see [1] and [5]). The level of competence is defined in terms of (1) degree of coverage: to what extent does an individual possess this competency; (2) radius of action: represents the range and variety of different contexts and situations in which the individual can successfully activate the competency; (3) technical level: level and degree of sophistication of the concepts, theories, and methods an individual can bring to bear when exercising the competency [5].

Deeken et al. [6] have shown the need for instructors to consider the problems first-year students encounter after transitioning from secondary school to university. For example, *mathematical representations* are used and presented differently in terminology, presentations, and mathematical evidence. In general, if the competencies are addressed in the curriculum, e.g., in Sweden [7], secondary education focuses on communicating the right solutions. However, university curricula focus on rigorous deductive argumentations and formal proofs requiring advanced *mathematical thinking* (one of the competencies). Consequently, new first-year students must adapt to a new academic learning environment concerning the learning of mathematical competencies in SME. Besides the challenges regarding the transition from secondary- to university education, mathematical competencies could potentially foster transfer from SME to engineering. As SME could support a characterisation of mathematics and mathematical competencies which address the variety of perspectives in different disciplines [4]. It would be of immense value to employ mathematical competencies at various educational levels, and especially in SME, to foster mastery and transfer of mathematics.

1.3 Current Study

Given the potential of mathematical competencies to guide the design and evaluation of SMEs, there is a need to better understand how mathematical competencies are being examined in higher engineering research. We first searched for review studies on mathematical competencies. However, we found that only a limited number of reviews have been conducted. This seems to suggest a gap in the field in synthesising research knowledge about how mathematical competencies have been employed. The current study attempts to fill this gap by performing a scoping review on how mathematical competencies have been studied in higher engineering education. Results of the scoping review will inform the field on the current state of mathematical competencies research in higher engineering education and provide insights into potential research directions.

2 METHODOLOGY

2.1 Identifying Research Question and Relevant Papers

According to Arksey and O'Malley [8], a scoping review typically consists of five steps: identifying research questions, identifying relevant studies, selecting studies, charting the data, and summarising the results. Our main research question is: "To what extent and in what ways have the eight mathematical competencies been examined in higher engineering education research?". Accordingly, the following sub research questions were formulated to guide the reviewing process:

- What is the current state of research on mathematical competencies?
- Which mathematical competencies were researched in the studies?
- How are mathematical competencies being employed in higher engineering education?

We first conducted searches across two databases (i.e., Scopus and Web of Science) to obtain relevant papers in February 2022. Each search string consisted of three categories of key words: 1) one mathematical competency (i.e., think*, reason*, model*, represent*, problem* solv*, handl* symbol* formal*), 2) a general term (i.e., math* competenc*) to limit the search to studies related to mathematical competence or competencies, and 3) educational level (i.e., higher education, tertiary, and universit*) to limit the search to studies conducted in higher education. We did not include two of the eight mathematical competencies (i.e., communicating in, with, and about mathematics, and making use of aids and tools) as they were relatively more difficult to assess [9]. In March 2022, two discipline-related journals, European Journal of Engineering Education and International Journal of Mathematical Education in Science and Technology, were searched using the same method. Along with a snowball search, 166 papers were identified in total.

2.2 Selecting Papers and Synthesising of Data

Results from the searches were uploaded to an intelligent systematic review software (rayyan.ai) that aided the selection and reviewing of the papers. We selected only papers that mentioned engineering by selecting the keyword “engineering”. After removing duplicates, 65 unique records were identified and screened by two independent researchers. 23 papers met the four main inclusion criteria and were included in the review: 1) relevant to SME, 2) mentioned mathematical competencies or mathematical competence, 3) were written in English, and 4) had full text retrieved. All selected papers were read in detail to extract information addressing the sub research questions.

3 RESULTS

3.1 Current State of Research on Mathematical Competencies

The 23 included papers consisted of journal articles (*n*= 12), conference papers (*n*= 10), and a book chapter (*n*= 1). The first paper was published in 2002, but the rest of the publishing activity was concentrated between 2011 and 2021 (see Figure 1). The reviewed studies were conducted in 14 different countries whereas the country was not specified in four papers. Figure 2 illustrates that most of the relevant research is in European countries. Regarding the type of tertiary education institution, universities were the most prominent (*n*= 15), followed by institutes (*n*= 3) and academies (*n*= 1). Five papers did not provide information about the type of institution. The information suggests a growing interest in mathematical competencies over the last decade at the tertiary level. While the main research activities are in European universities, there is also a developing interest across education institutions worldwide.

Research in the corpus was diverse, comprising empirical studies (*n*= 12), theoretical/conceptual papers (*n*= 5), reports on programme/instruction implementation (*n*= 4), and literature reviews (*n*= 2). Within the group of empirical papers, nine quantitative (*n*= 7 descriptive and *n*= 2 correlational) and three qualitative studies (*n*= 2 case studies and *n*= 1 narrative) were identified. Most papers focused on 1st year engineering students (*n*= 10), whereas several papers did not specify the students’ year level (*n*= 6). Out of the 23 papers, 13 provided information about the type of engineering programme. The studies were conducted in a diverse set of engineering programmes, including chemical and civil engineering. Of which, the highest number of studies were conducted in Electrical, Electronic, and Technology engineering (*n*= 10), and Mechanic and Materials engineering (*n*= 6).

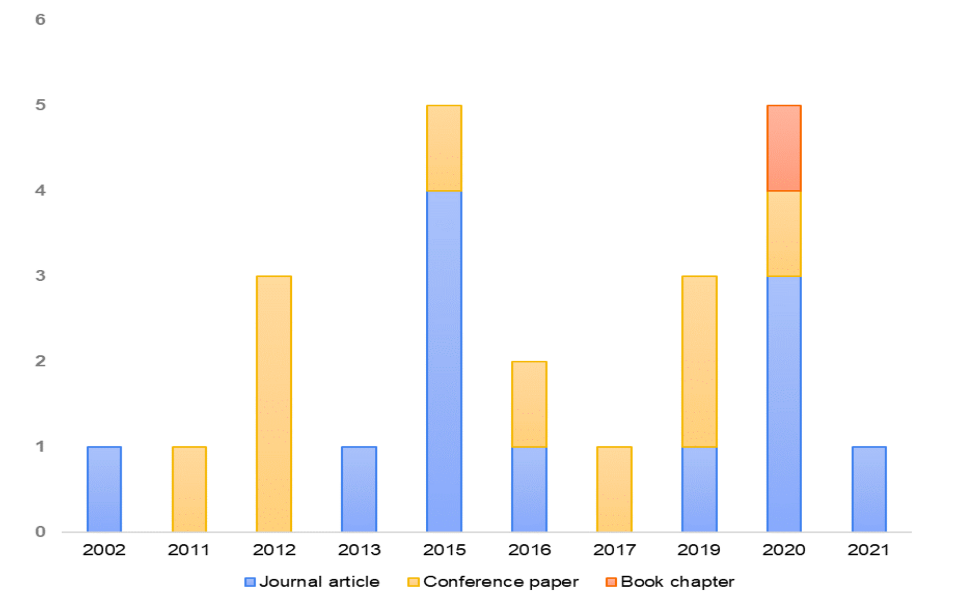

Fig. 1. Distribution of publication's number across the years

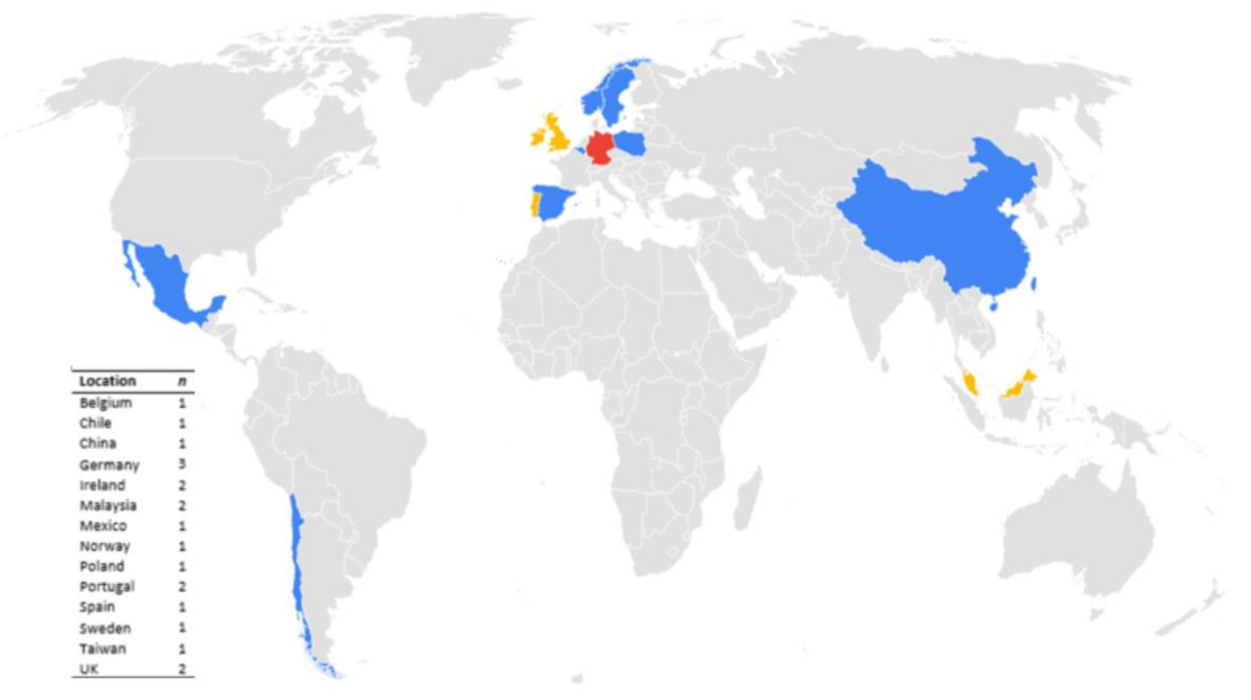

Fig. 2. Geographical locations of the reviewed papers

3.2 Mathematical Competencies Investigated in Engineering Education

A matrix table was used to map the terms employed to describe the concept of mathematical competencies and the specific mathematical competencies investigated in the papers. As shown in Table 2, two mathematical competencies, namely *posing* - and *solving problems* (C3) and *modelling* (C4), were the most investigated mathematical competencies. Not only were the two mathematical competencies individually investigated by the highest number of studies, but the two mathematical competencies were also frequently investigated together [10] and alongside other mathematical competencies [11]. There were no studies that explicitly investigated *representing math entities* (C5). Six studies (26%) investigated more than one mathematical competency (i.e., mixed). The investigation of more than one mathematical competency in a study suggests the interconnectedness of certain mathematical competencies.

Many studies did not use the term "mathematical competencies" when referring to a specific mathematical competency. For instance, *mathematical modelling* was referred to as skills [12] and competence [13]. Table 1 shows the diverse set of terms used in the studies. Our review showed that six studies (26%) mentioned the term "mathematical competencies" according to Niss's [1] definition, while four studies used the term "mathematical competencies" but did not mention the framework by Niss. The term "competenc(ies)" was also often used with other terms, for example competence, skill, and literacy. Therefore, indicating a lack of consistency or clear definition for the terms used in mathematical competencies research.

Table 2. Mathematical competencies and terminologies used

	C2	C3	C4	all eight	mixed	general	Not specified	
competence		Kortemeyer & Biehler [14]	Hernandez-Martinez [13]		Othman et al. [25]: C1, C3 Quezada [26]: C1, C3	Nortvedt et al. [27]		5
competency (Niss)	Alpers [15]			Jaworski [16], [17] Pepin et al. [4]	Caridade &Rasteiro [9]: C7, C8		Carr et al. [29]	6
competency (Not Niss)		Reinhold et al. [21] Hussin et al. [22]	Huang [20]		Wedelin et al. [11]: C1, C3, C4			4
competence/ competency					Hennig [19]: C2, C4, C6			1
competency/ skill						Llobregat-Gómez et al. [28]	Carr et al. [30]	2
competency/ literacy						Lakoma, [18]		1
strategy					Gutierrez &Gallegos [10]: C3, C4			1
skills		de Laet [23]	Dan & Xie [12]					2
not specified			Lyon & Magana [24]					1
total	1	4	4	3	6	3	2	23
C1: Thinking, C2: Reasoning, C3: Posing and solving problems, C4: Modelling, C5: Representing, C6: Handling, C7: Communicating, C8: Making use of aids and tools								

3.3 Approaches in which Mathematical Competencies were Employed

For our third research question, we examined how mathematical competencies were investigated and organised the studies according to similar approaches. Table 3 provides an overview of the identified approaches to studying mathematical competencies. We first identified whether the mathematical competencies were investigated in a course context. Successively, we looked at teaching practices and student preparedness for math education.

The studies in the category of “in a course context” were further organised into three subcategories. The first subcategory consists of three studies investigating assessment and how an assessment tool measured a certain mathematical competency [14], [25], [26]. For example, in Kortemeyer & Biehler [14], student-expert-solutions were used as a tool to analyse students’ *problem-solving* process. Another subcategory consists of studies exploring how tasks can be designed to develop mathematical competencies [15], [16], [17]. Alpers [15] provided examples of tasks to illustrate how *mathematical reasoning* can be used to set up a curriculum for a practice-oriented study course in mechanical engineering. Jaworski [16],[17] also provided a clear example of how an inquiry-based task helps develop the eight mathematical competencies.

The largest subcategory comprises studies that examine various teaching practices [9], [10], [11], [13], [18], [19], [20], [28]. The teaching practices were briefly described in Table 3. Several studies examined the use of technological tools to promote the teaching and development of mathematical competencies. Lakoma [18] highlighted the need to use technology to teach mathematics. Other studies examined the use of technology to assess or teach mathematical competencies (e.g., video lessons in Caridade & Rasteiro [9] and wiki in Hennig et al. [19]. There is also a strong focus on enhancing teaching practices for *mathematical modelling* [10], [11], [13], [20]. The teaching practices investigated in the studies provide insights into how mathematical competencies can be used to better develop courses and activities to enhance SME.

Among the seven studies in which mathematical competencies were not investigated in a course context, five studies examine students’ preparedness for higher engineering education using “general” mathematical competency test in relation to basic math knowledge and skills. Two studies investigated the relationship between specific mathematical competencies and other thinking skills: 1) *mathematical modelling* and *creating thinking* [12] and 2) complex word *problem solvin*g and spatial, verbal, numerical, and general *reasoning* abilities [21]. The studies in this category suggest that examining students’ level of preparedness or state of competence is an emerging area of research focus.

Table 3. Overview of approaches investigating "mathematical competencies"

Approaches	Paper and short description	Course name
In a course context		
Assessment	Kortemeyer & Biehler [14]: Student-expert-solutions in four exam exercises	Ordinary Differential Equations
	Quezada [26]: 10 open questions designed according to three types of mathematical competences	Calculus I
	Othman et al. [25]: Rasch Measurement Model to examine the reliability and fit of exam questions	Engineering Mathematics I-Vector Calculus
Task-related	Alpers [15]: Example tasks on how *mathematical reasoning* can be acquired	not in a specified engineering course
	Jaworski [16], [17]: Analysis of an inquiry-based task	not in a specified math course
Teaching practices	Caridade & Rasteiro [9]: A project involving students developing video lessons	Mathematical Analysis I
	Gutierrez & Gallegos [10]: Modify teaching of mathematics through *mathematical modelling* to promote critical thinking	Differential Equations
	Hennig [19]: Use of wiki in lectures and supervised exercises to provide short mathematical digressions	Fundamentals of Electrical Engineering
	Hernandez-Martinez [13]: Designed innovative aspects to teach *mathematical modelling*	not in a specified math course
	Huang [20]: *Mathematical modelling* activity and instruction using a transition framework	Calculus
	Lakoma [18]: Provided examples on how technology is useful for teaching mathematics, specifically in statistics	Statistics and Probability
	Llobregat-Gómez et al. [28]: An active methodology that requires students to design activities	Mathematics I
	Wedelin et al. [11]: A course with six modules and a small set of realistic problems	Modelling and problem solving
Not in a course context		
Specific competency test	Dan & Xie [12]: 22 Multiple-choice questions to test students' *mathematical modelling* from Lingefjärd [31]	
	Reinhold et al. [21]: Complex word *problem solving* ability was measured with items from published PISA mathematics items.	
General test	Carr et al. [29], [30]: Diagnostic test	
	de Laet [23]: Mandatory positioning test for aspiring engineering students	
	Hussin et al. [22]: Test of mathematics knowledge and competency for students entering University Teknikal Malaysia Melaka (UTeM)	
	Nortvedt et al. [27]: Test of basic 'mathematical knowledge'	
Reviews		
	Lyon & Magana [24]: Systematic review of 27 journal articles on *mathematical modelling* in engineering education	
	Pepin et al. [4]: Literature review of 140 papers, book chapters, and proceedings to examine innovative teaching and learning practices in mathematics in engineering education	

4 DISCUSSION AND CONCLUSION

The objective of the review is to examine how mathematical competencies are being investigated in higher engineering education where mathematics is typically taught as a service subject. Addressing Research Question 1, this scoping review yielded 23 papers with studies conducted across 14 countries employing a diverse set of methodological approaches. The results are aligned with Niss et al.'s [32] finding on the conceptualization of competencies in mathematics education research. When naming mathematical mastery, the terminologies used are highly diverse. Without a deeper analysis, it is not clear whether the different terms refer to the same concept nor whether the same term was used but are referring to different constructs.

Despite the presence of terminological issues, the studies in this review suggest a shift towards symmetry in adopting the definitions provided by Niss [1]. A common definition would help to advance research and inform practice on mathematical competencies. Educators and researchers can build on each other's work by employing a similar definition and use the eight mathematical competencies from Niss as a starting point. Another way to move forward is to empower math educators in embracing and owning the notions of mathematical competencies [32]. By doing so, educators can better develop teaching materials and approaches to foster mathematical competencies.

For Research Question 2, this review found that research has focused on the investigation of two specific mathematical competencies, *modelling* and *problem solving*, either independently or combined in the same research context. An explanation could be that these two competencies play a central role in the education of future engineers [33]. However, this finding suggests the need for future research to examine how other mathematical competencies can be individually supported within service-mathematics courses for engineering students.

Furthermore, the analysis indicates that studies often investigate a combination of three or more individual mathematical competencies either as independent or interdependent concepts, e.g., [10]. This observation might be related to the fact that teaching methods and learning materials rarely address isolated mathematical competencies in authentic educational settings. In this case, Niss et al.'s [32] recommendation for more empirical research on the interconnectedness among individual competencies is highly relevant.

In relation to Research Question 3, the studies reviewed show an emerging interest in the abovementioned connection in the level of task analysis, e.g., [17]. Future research could investigate the relevance of different competency combinations at the level of various service-mathematics courses or engineering programmes, e.g., [15] and [16]. Moreover, Lakoma [18] and Pedersen et al. [34] suggest that there is a need to examine how development of mathematical competencies can be supported by various technologies given that digital technologies are becoming a commonplace at school and at work. An example of course design, using mathematical competencies linked to digital technologies and workplace contexts is the concept of Techno-mathematical Literacies by Van der Wal et al. [35].

The current scoping review had some limitations. First, only two major databases were used, so the search was not exhaustive. To gain a more in-depth understanding of mathematical competencies research in higher engineering education, a more systematic review of studies will be much needed. Nonetheless, the current scoping review acts as a precursor for future systematic review and raises potential questions and areas for research.

Secondly, the scoping review did not look at the dimensions for specifying and measuring progress in mathematical competencies. Future reviews could consider examining dimensions for a more thorough investigation of the literature on mathematical competencies. The goal of defining and researching mathematical competencies in SME is to support course and curriculum design based on competencies. This review shows that the field is not at that point yet with substantial research findings to guide the design of SME.

As an extension to the current scoping review, our future work will include investigating lecturers' perspectives on developing mathematical competencies in service mathematics courses. To conclude, the scoping review provides a contemporary understanding of the trend of mathematical competencies research in SME and adds to the emerging research field of competence-based course and curriculum design by identifying the gaps in research between the definition of competencies, their interconnectedness, and their assessment.

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Demonstrating Engineering Schools' commitment to the achievement of the SDGs: The ALCAEUS Evaluation Program / 2030 Agenda. A case study

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ABSTRACT

ALCAEUS is a voluntary evaluation scheme developed by the Spanish agency ACPUA, designed to provide visibility to institutions and centers that demonstrate commitment and contribute to the achievement of the UN Sustainable Development Goals (SDGs) / 2030 Agenda. It is a pioneering international external evaluation program within the European Higher Education Area, open to faculties and schools that have successfully undergone an IQAS certification review (institutional accreditation). The ALCAEUS pilot program was carried out last year and two Engineering Schools (Escuela de Ingeniería y Arquitectura and Escuela Politécnica Superior) of the University of Zaragoza (Spain) participated in it. The evaluation was based on a site visit conducted by an international review team. The two schools demonstrated a firm commitment to SDGs and were awarded a 2030 Agenda quality label valid for 6 years.

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1. INTRODUCTION

1.1 Origins of the ALCAEUS program: INQAAHE project

The program ALCAEUS arises from the participation of the Aragon Agency for Quality Assurance and Strategic Foresight in Higher Education (*Agencia de Calidad y Prospectiva Universitaria de Aragón*, ACPUA) –full member of ENQA and registered in EQAR– in the project 'Making connections between the Institutional Evaluation and the Sustainable Development Goals. Empowering stakeholders for quality enhancement'. This capacity-building project was awarded by the International Network for Quality Assurance Agencies in Higher Education (INQAAHE) and coordinated by the Higher Education Quality Agency of Andorra (*Agència de Qualitat de l´ensenyament superior d'Andorra* AQUA). It lasted one year (until May 2019) and involved the main stakeholders in higher education and sustainability in Andorra and Aragón.

The main objective of the project was to align quality assurance in higher education with the SDGs and to empower stakeholders in university systems. Through participatory processes of joint reflection and diagnostic analysis, a 'Proposal of indicators to embed the Sustainable Development Goals into Institutional Quality Assessment' was published in 2019 [1].

1.2 Aim of the ALCAEUS program

The main objective of the 2030 certification of centers and/or universities awarded through the ALCAEUS program is to give visibility to the efforts that institutions are making to meet the SDGs set out in the United Nations 2030 Agenda.

The ALCAEUS program contains an international assessment protocol that measures the degree of commitment to the SDGs, approved by ACPUA's Commission for Assessment, Certification, and Accreditation (CECA) on 17th July 2020. The process involves a verification and review process and awards points that correspond to four possible levels of certification [2].

2. METHODOLOGY

2.1 Program schedule

The ALCAEUS Programme was launched during the academic year 2020/2021 on a pilot basis. Those centers of the University System of Aragon that had obtained institutional accreditation during the academic year 2018/2019 voluntarily applied for this program. For this purpose, the announcement of 9th October 2020 was published by the Director of the ACPUA, which called upon the centers of the Aragon University System to participate in the pilot assessment for the certification of their degree of commitment to the SDGs.

After the deadline for submission of applications, no further 2030 certification processes of centers and universities under the ALCAEUS program were allowed to be launched until the pilot evaluation was completed and a meta-evaluation process of the pilot program was carried out, which included the results of the evaluation, as well as the opinion of the participants in the process (evaluated and evaluators).

Following the ALCAEUS evaluation protocol, at the proposal of the CECA, the Director of the ACPUA appointed on 14th December 2020 the expert evaluators of the visiting panel, who carried out online visits (due to the situation created by the COVID-19 pandemic) to both the Escuela Politécnica Superior (EPS) –on 17th and 18th December 2020– and the Escuela de Ingeniería y Arquitectura (EINA) –on 11th and 12th March 2021–. Both centers belong to the University of Zaragoza and base their strategy on the 2030 Agenda, taking as a starting point the recommendations of the UN Sustainable Development Solutions Network [3].

The panel of experts issued the relevant visit report which, together with the evaluation documentation, was submitted to ACPUA’s Subcommittee for Thematic Evaluations (SETE) and Subcommittee for the Evaluation of Centres (SEC). The latter committee issued the corresponding report proposal, which was sent to the centers so that they could make any allegations regarding the content of the report and any proposals for improvement of the program that they considered appropriate.

In their letters of allegations, the centers, properly understanding the characteristics and objectives of a pilot program such as this one, included and integrated reasoned contributions for the interpretation and improvement of the ALCAEUS program. For this reason, the aforementioned letters were sent to the ECSC (the technical committee responsible for ACPUA's evaluation methodologies and programs), which unanimously approved the final reports.

2.2 Evaluation protocol

The evaluation is based on several criteria, which are structured in six dimensions referred to aspects such as the strategy of the center, resources, transparency, Internal Quality Assurance System, teaching programs, and staff. Each dimension includes several criteria, which in turn, are broken down into several guidelines. For each guideline, criterion, and dimension a maximum score can be obtained, in such a way that the maximum total score adds up to 100. Table 1 shows all the dimensions and their criteria.

Table 1. Dimensions and evaluation criteria

Dimension	%	Criterion	%
1. Strategy, partnerships and recognition	20	1.1. Commitment and strategy of the centre	40
		1.2. Partnerships	40
		1.3. Internal and external recognition	20
2. Transparency and accountability	20	2.1. Public information	100
3. Internal Quality Assurance System	15	3.1. Processes and quality strategy	50
		3.2. Staff responsible for the Internal Quality Assurance System	50
4a. Programmes (for faculties, schools and	25	4.a.1. Development of policy frameworks	10
		4.a.2. Student-centered learning. Competencies	30

educational establishments)		4.a.3. Student-centered learning. Theoretical learning opportunities	30
		4.a.4. Student-centred learning. Practical learning opportunities	30
4b. Research projects	25	4.b.1. Objectives	40
		4.b.2. Planning of activities	30
		4.b.3. Outcomes	30
5. Staff	15	5.1. Heads of teaching provision/research activity	34
		5.2. Teaching and research staff	33
		5.3. Administrative and support staff	33
6. Founding and Resources	15	6.1. Administrative and support staff	60
		6.2. Resources	40

Before the visit of the external evaluation panel, each participant center prepares a self-assessment report about all of these dimensions/criteria and guidelines, providing evidence and setting a range of four levels for each criterion: A (fully implemented), B (sufficiently implemented), C (insufficiently implemented), and D (not implemented).

The final score obtained by each center leads to a final Certification level for teaching or research centers:

- Level 0 – No certificate. Score: 0-24 → Emerging commitment to 2030 Agenda.
- Level 1 – BRONZE. Score: 25-49 → On route to the 2030 Agenda
- Level 2 – SILVER. Score: 50-74 → Strong commitment to the 2030 Agenda
- Level 3 – GOLD. Score: 75-100 → Flagship and international reference center.

3. RESULTS

The ALCAEUS program is intended to enhance the motivation of university centers to implement the 2030 Agenda in all their activities. For this reason, at this stage of development of the program, the main results to be shown here are not so much those related to the level obtained by each center, but rather the strengths and weaknesses of the certification program concerning the aforementioned goal that have been identified in the pilot program.

The preparation of the self-report and the development of the visit of the external evaluation panel by the centers required them to develop a reflective and contextualization process about the multiple activities carried out, which in turn allowed them to identify points of improvement and to discover areas of untapped work. Both centers, when issuing their report on allegations and suggestions for the meta-evaluation, indicated that –although the certification mostly included dimensions, criteria, and guidelines appropriate for its purpose– some criteria and guidelines related to aspects on which centers lacked autonomy of action did not allow an adequate assessment of their true commitment to the SDGs.

Both centers also drew attention to the fact that a center's commitment to the SDGs does not reside solely in its teaching or quality areas, but rather that it must constitute an indispensable part of its own "metabolism", extending to its activity and the management of its infrastructures. This rationale implied that the actions of the centers aimed at reducing their environmental impact and activities aimed at a healthier campus, which directly affect several SDGs (viz. SDGs #3, #6, #7, #12, #13, #14, and #15), should also be taken into consideration. Hence, both centers suggested that the environmental management of the center/campus and the actions aimed at improving the quality of life on campus should be incorporated into the certificate as additional dimensions to be assessed.

After the contributions of the centers, the meta-analysis was carried out through different forums, among which the meeting conducted on 11th March 2022 may be highlighted. Various stakeholders, including the Director and technicians of ACPUA, Directors and Deputy Directors of Quality and Sustainability of the two centers involved (EINA and EPS), the external evaluation panel, as well as the Vice-Chancellors of Academic Policy and Infrastructures and Sustainability of the University of Zaragoza, in addition to various Secretarial Directors of those Vice-Chancellors, participated in the session.

Finally, it should be noted that both University of Zaragoza centers (EINA and EPS) obtained the ‘Level 2’ certificate, accrediting their “Strong commitment to the 2030 Agenda”.

Fig. 1. ALCAEUS seal

This ALCAEUS as an evaluation protocol of the Agenda 2030 is a pioneering programme in the field of quality assurance within the European Higher Education Area, as recognised by ENQA: “The planel commends ACPUA for developing ALCAEUS as a pioneering evaluation scheme focused on the UN Sustainable Development Goals, which aims to enhance the social dimension of higher education in Aragon” [4]

4. SUMMARY AND ACKNOWLEDGMENTS

The ALCAEUS pilot program proposed by ACPUA to certify and make visible the degree of commitment of university centers to the 2030 Agenda and the SDGs has been developed with the participation of two centers of the University of Zaragoza. The process, based on the contributions of both parties (evaluated centers –EINA and EPS– and the Agency –ACPUA–) has resulted in the final configuration of a certification that may be regarded as a powerful tool to encourage university centers to implement a strong and effective commitment to sustainability.

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DEVELOPING PROFESSIONAL INFLUENCING SKILLS OF YOUNG ACADEMIC ENGINEERS – CASE: YOUNG PROFESSIONALS' FORUM (YPF)

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ABSTRACT

Professional working life skills have become an essential part of the engineering skillset in recent years. However, it seems that basic engineering education does not sufficiently provide the students with these skills. The Finnish Association of Academic Engineers and Architects (TEK) established a new kind of peer forum to develop these skills of its younger members. The forum consists of workshops, assignments, and peer dialogues over a four-month time period The forum's approach leans on a dialogic, experiential and reflective way of learning enabling the participants to further build their personal influencing practices; investigate their professional relationships; experiment changes in their self-management practices; and share their experiences in peer groups. Since 2017, over 900 young TEK members have participated. The aim of this study in progress is to make an overview to the experienced impacts of the forum and scrutinize the forum's influence mechanisms in a more detailed way. The data was collected through an inquiry to all participants. The study indicates that the forum has been most influential in supporting the participants to become more aware of their professional influence, to build capabilities to change their personal and social practices, and to enhance their professional networks. The most significant impact element has been various peer discussions and dialogues. As a conclusion the study highlights the needs and interests of young professionals to develop the essential working life skills.

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1 INTRODUCTION

Professional working life skills have become an essential part of engineering skillset. The general change of working life to dynamically evolving VUCA (Volatility, Uncertainty, Complexity and Ambiquity) environment and the new forms of organizing require more advanced competences in communication, collaboration, personal and professional influencing as well as in change and development from all professionals including engineers [1,2]. However, it seems that basic engineering education provides the students insufficiently with these skills [3].

As a part of the service offering to its younger members TEK (Association of Academic Engineers and Architects in Finland) initiated a new peer forum to support the development of personal and professional influencing skills of freshly graduated academic engineers. The aim of this study is to make an overview of the experienced and perceived impacts of the forum, and highlight the influence mechanisms of the forum in more detailed way. The research questions are: *1) What have been the experienced impacts from the Young Professionals' Forum? 2) What have been the most essential elements of the forum on behalf of the impacts?*

2 YOUNG PROFESSIONALS' FORUM (YPF)

TEK (The Association of Academic Engineers and Architects in Finland) has some 77000 members of which 20000 are student members. TEK along with most of the professional associations in Finland has suffered a declining number of members during the past decade. After graduation, a growing number of student members has discontinued their memberships. To respond this negative trend TEK has renewed its strategy and started to develop services and activity models that would better serve the needs of its younger members. The new strategy has been successful and TEK has been able to turn the trend to positive. The Young Professionals' Forum (YPF) has been one of these responses. However, an even more fundamental motivation for the forum has been to support the young engineers to develop their essential working life skills in their early careers.

As leadership teachers we (the authors) were invited to develop the pilot version of the forum. The pilot version was arranged in 2017 with 50 participants. The positive feedback encouraged to continue the service. Since 2017 the forum has been arranged fifteen times for over 900 participants. In practice the forum is four-month long training process consisting of four three-hour workshops, three personal assignments, and three peer group meetings between the workshops. Next the pedagogical foundation and practical design of the YPF will be presented more in detail.

2.1 Pedagogical foundation

The pedagogical foundation of the forum is based on constructivist and experiential learning with dialogic, reflective, reflexive, and even critical undertones [4,5]. Improving personal influencing skills and practices in a sustainable way is a highly personal process as we all have a unique growth history, personalities, strengths and developmental needs, learning abilities, and professional contexts. Influencing skills are grounded on our views of social reality, our values, our past experiences, and our routinized habits and practices. Thus, improving personal influencing skills in a sustained way requires *1) willingness to scrutinize the prevalent personal beliefs, principles and values, influencing requirements within own professional context, and current personal and social practices, 2) getting experience of improvement steps in personal practices and reflecting on the experiences, and 3) to repeat the new practices long enough to routinize them.*

The additional elements of the learning process are processuality, contextuality, and a facilitative way of instructing. *Prcocessuality* refers to the duration and rhythm of the process as well as the integration, iteration and reciprocity of different program elements, themes, and concepts. *Contextuality* refers to the connection to each participants own professional and personal life context as well as to the temporary learning community formed in the forum. *A facilitative way of instructing* means that the role of the instructors is to engage the participants in an active conversational process and sharing right from the start; to enable allowing, trusting, and open atmosphere; to provide the participants with appropriate concepts and theories; and to maintain adequate structure of the process.

2.2 Practical application – forum design and delivery

The forum has been arranged mainly in the Helsinki area where the majority of TEK members live but few times also in other major Finnish cities. Due to COVID19 pandemia the forum was turned to online mode, which at first was worrying as the forum's concept leans heavily on living face-to-face conversations. Despite our worries the online forum seemed to serve its purpose relatively well. The online mode enabled participants to join more easily from distant locations. All in all the number of single forum participants has varied from 30 up to one hundred.

Basically the Young Professionals' Forum is a four-month long personal and social learning process consisting of four three-hour workshops, three individual assignments and three peer group meetings between the workshops. The aims of the forum are to *1) support newly graduated engineers to develop their personal professional influence and self-management, 2) strengthen participants' ability to build and develop their professional relationships and interaction, 3) build practices and commitment for continuous development as an interactor and influencer,* and *4) enable participants to build and strengthen their professional identities further*.

The forum is strongly participant-focused and is planned to create a holistic learning process, in which different elements build on each other. The participants are requested to investigate and scrutinize their current working practices, professional relationships, leadership thinking and preassumptions, interview their collaboration partners and ask personal feedback, and experience small step changes in their professional practices. These experiences are discussed and shared in the workshops, in which appropriate concepts and supportive tools are also introduced by the facilitators. Furthermore, in the beginning of the process the participants are divided into peer groups which aims to serve as support groups throughout the whole process. The peer groups meet between the workshops and share the assignment experiences as well as discuss the topics that are relevant for the group.

The participants are asked to document their assignments but they are allowed choose the level and accuracy of the documentation as the purpose is most of all to serve the personal learning. Documentation through writing allows the participants to reflect on the experiences in a profound way. The assignments build on each other forming a holistic review of the personal state of the art situation. The final report forms a reference point for assessement of personal development and thus, at its best serves as a reflective framework for further development.

3 METHODOLOGY

An online inquiry was sent to 740 former YPF participants. 123 responded to the questionnaire. The questionnaire contained five background questions, ten scale (quantitative) questions, and three open (qualitative) questions. The inquiry aimed at charting the initial participation motivation and expectations, the experienced and perceived impacts, the most influential elements of the forum, and the hidden potential of the forum. The qualitative data was analyzed following the guidelines of qualitative content analysis.

4 FINDINGS

The findings are divided into three sections. First the background of the respondents is summarized. Second the expressed impacts and usefulness of the forum are presented based on the questionnaire data. Finally, the impact factors of the YPF are presented based on the open questions of the inquiry.

4.1 Background of the respondents

The YPF has been arranged fifteen times from 2017 on. There were respondents quite evenly from all the years the forum has been arranged. The YPF participants represent in practice all possible industries and engineering fields as the TEK is an association for all academic engineers and architects. The YPF is directed to freshly graduated professionals (less than five years from the graduation) thus the vast majority of them fit to age range from 25 to 35. During the forum 90% of the respondents were in specialist roles and 10% in managerial roles.

To gain learning benefits from the forum based heavily on the participants’ own activity requiring to use of their free time to the workshops and assignments, and daring to share their personal thoughts and experiences with others. The respondents were asked how the overall way of working suited to them (“*The way the forum was organised was successful for me”).* 68% of the respondents expressed that the way of working suited to them well or very well. For 17% the way of working was ok, and for 15% less suitable. Furthemore, the respondents were also asked to evaluate how pleased they were on their personal way of working and participating (“*I am happy with how I got to participate and work during the forum”)*. 65% of the respondents expressed that they were pleased or very pleased how they managed to work and participate to the YPF process.

4.2 Learning experiences and outcomes

The learning outcomes and experienced impacts were scrutinized through scale questions, in which the respondents were asked to assess positive claims concerning the forum with a scale from one to five (1=not at all, 2=little, 3=somewhat, 4=significantly, 5=very significantly). The first claim was about the overall usefulness of the forum: "*The forum was useful to me".* Two thirds of the respondents expressed that the forum was significantly or very significantly useful for them. 23% felt that the it was somewhat useful, and 13% felt that the forum was just little useful for them. None felt that the participation was useless.

The Figure 1 illustrates how strongly the forum was experienced to contribute to the development of respondents' *self-management practices, professional influencing, continuous personal development, career advancement,* and *professional identity*. Improvement of practices both personal and social as well as the respective skills, and personal developmental practices were the core aims of the forum.

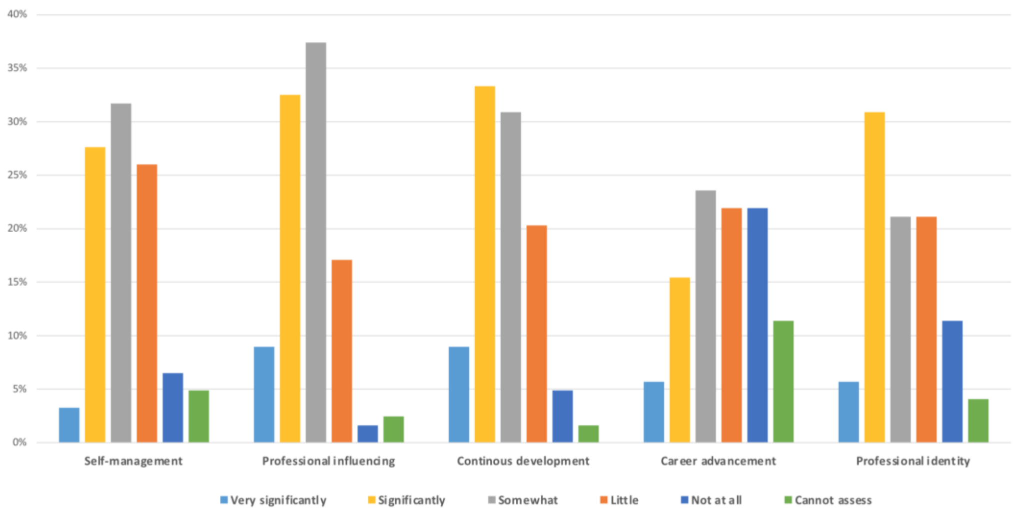

Figure 1. Expressed and experienced YPF impacts 2017-22

It seems that the forum has been successful in promoting the skills and practices which were the actual topics of the forum – *self-management, professional influencing, continuous development*. Based on the questionnaire data the strongest impact was indicated on the professional influencing skills and practices as almost 80% of the respondents experienced significant, very significant or at least some impacts on their professional influencing skills and practices ("*The forum supported me in developing my own professional interaction and influence")*. The mildest impact was experienced on the career advancement. However, the career advancement was not in the actual focus of the forum. An interesting result is that the participation was experienced to strengthen the professional identity quite clearly despite the fact that the focus of the discussions and the whole forum was in social aspects of the engineering profession and practice, not in actual professional content. Almost 60% of the respondents felt that there was a significant or very significant impact on professional identity ("*Participating in the forum has strengthened my professional identity").*

All in all, the forum seemed to be a meaningful experience to the majority of the participants both personally and professionally. In the end of the inquiry the respondents were asked to assess how strongly would they recommend the forum to their colleagues and friends. The scale was from one to ten in which one represented the absolute no and ten absolute yes. The average was 7,9 when 79% of the respondents gave 7 or higher.

5 IMPACT FACTORS

The second topic we investigated was what factors of the forum were experienced as the most essential from a personal learning point of view. The respondents were asked to assess the impact factors with an open question in the inquiry: "*The forum consisted of workshops, personal assignments and peer group meetings, which formed a process that lasted about four months. What elements and components of the forum did you find most important for your own learning and benefit? Why*?" There were 66 responses to the question.The responses were categorized by the mentioned impact factors. Four categories were formed: *peer discussions, workshops, assignments,* and *the process as a whole*.

5.1 Peer groups

The vast number (over 80%) of the responses mentioned the peer discussions and peer groups as the most essential impact element of the forum. The peer group meetings between the workshops were mentioned to enable deeper conversations in which personal questions and experiences were shared in a safe environment. An important realisation mentioned was that all others had the similar questions and worries and that sharing those with others is meaningful as one respondent described: "*Peer group discussions helped me to realize that all have work related challenges and worries, and sharing those with others is fruitful. Our group met on free time which supported to build open and trusting connection within the group"*.

The peer meetings and sharing were mentioned to be essential forums and sessions for personal reflection and meaning making. The interactive and social reflection helped the respondents to clarify and expand their own thinking – why do I think like this? What are other possible ways of interpreting and thinking? Social reflections were experienced to be much more fruitful than just thinking and reflecting alone as one respondent described: *"Through peer discussions you got many view points and perspectives and not just your own. In peer discusssions we generated a lot of new ideas and insights".*

The peer groups were formed randomly and people did not know each other beforehand. Nevertheless, there were multiple comments on how the peer group was experienced as a safe and trusting environment to share personal thoughts and experiences, and discuss even uncertainties and worries as one respondent commented: *"Peer meetings between the workshops were very fruitful. The group* *formed a safe and trusting place to talk and share personal experiences"*. For most the peer group seemed to form trustful and helping relationship context which supported sense making, reflection, and personal development in a meaningful way. There were groups that continued to meet also after the forum.

An important aspect was also to hear and get practical tips about the methods and practices, and also share your own experiences. The peer group sessions and sharing was mentioned to support to develop professional self-confidence further. All in all the realization that I am not alone with all these questions seemed to ease the personal pressures to perform excellently all the time.

5.2 Workshops

The second impact factor mentioned was the workshops. The most forums had four three-hour workshops in the evening time from 5 pm to 8 pm. The workshops were participatory, including sections of lecturing, group discussions and exercises in pairs. The workshops were mentioned to form important moments for personal thinking and reflection. The most comments concerning the workshops were about the group discussions but the theoretical and conceptual content and introduced practices were also mentioned as value adding elements: *"The best for me were the practices and concepts presented in the workshops as well as the sharing of ideas"*. Some also mentioned the coaching exercises in pairs as an impactful course element. For some the workshop discussions remained vague compared to the discussions in the peer group. Before the Covid, the workshops set-up was face-to-face which enabled the participant to network and continue their discussions also during the breaks. In online time this opportunity was cut off. The online workshops were experienced as beneficial, however, three-hour intensive sessions after online workday was considered rather tiring and demanding by many participants.

5.3 Assignments

The personal assignments that were done between the workshops formed the third impact factor category mentioned by the respondents. There were three assignments altogether, which were connected to each other in a way that formed an integrated whole. Fourteen respondents mentioned the assignments as an essential element from their personal learning point of view. The most connected the assignments and various reflection discussions together as an impact factor: *"Assignments and peer discussions were important. Through these it was possible the process, think, and develop the issues further".* The assignments enabled the participants to analyze and document their current situation, practices, thinking, relationships and work context, and later on in the workshops and peer discussions they were able to give deeper meanings and develop their thinking further. It was also mentioned that through the assignments, the participants produced a valuable documentation for themselves concerning their own development and practices.

5.4 The process as a whole

The fifth impact factor category mentioned by the respondents was the process as a whole. There were ten responses concerning the integrated and co-constituted impact of all the elements. One respondent described the impact very illustratively: *"I think that the most important from the learning point of view was the process as a whole. In the workshop the ideas and concepts were introduced and discussed which supported the accomplishment of the following assignment. Then the thoughts and insights from the assignment were shared with others in peer group meeting. The discussion continued in the following workshop and the ideas were shared cross the peer groups."* Most of those who mentioned the forum as a whole to be the essential impact factor highlighted the integration and collective influence of different forum elements. There was only one respondent who stated boldly that he "*experienced the whole forum more or less as a waste of time".*

6 DISCUSSION

This study is a work in progress. The YPF has been deemed a success by both the organizer TEK and the vast majority of the participants. Our data collection is still ongoing and this paper represents our first attempts to understand why and how the forum has been influential. According to our study, the participants in the YPF felt it enhanced their self-management practices, professional influencing, continuous personal development, and professional identity. It seems that the forum manages to produce impact on the essential working life and personal influencing skills in a sustained way.

The participants highlighted the peer discussions and opportunities to share their experiences, thoughts and insights as the most important part of the forum. Also the workshops and personal assignments got mentions as meaningful measures to support personal growth. Some participants saw that the process as a whole was what made it impactful. We argue that without the organized and facilitated process and individual analysis, and conceptual input the peer discussions would not have been so impactful. In our view, the experiences and impactfulness is most of all built through the confluence of different process elements.

The findings highlight strongly the social aspects of the learning process. One of our further directions in deepening our analysis is to look the forum as a "*temporary community of practice of learning*". This would allow us to tap into the processual, dynamic and relational aspects of the learning process. In building a better understanding of how and why the forum was experienced impactful, we strive to contribute on how to help engineers better their collaboration, influencing, and personal development skills. To be sure, there are multiple ways to achieve these goals. However, we hope our experience will shed light on what kinds of interventions might work, and thus, provide additional understanding and concepts to (engineering) educators what makes soft skills development impactful.

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SHORT PAPERS

SETTING-UP A RESEARCH CLUB FOR HIGH SCHOOL STUDENTS: AN ENGINEERING EDUCATIONAL CONCEPT BASED ON INCREASING BOTH INTEREST AND SELF-EFFICACY

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ABSTRACT

In the fall of 2019, the research club changING started as an outreach program in the Cluster of Excellence SE^{2}A. While the cluster deals with interdisciplinary research topics to explore technologies for sustainable and environmentally friendly aviation, the associated research club offers students from the 10th grade onwards the opportunity to gain insights into engineering. The target group here is primarily young women, who are heavily underrepresented in this career field. The research club is experience-oriented and offers high school students the opportunity to explore engineering, its systems, technologies, applications, and social and cultural significance by participating in different projects at various engineering institutes in the Cluster. During their four years of participation in the club, which is voluntary, students are challenged to discover, create, construct, and solve problems. In the process, students learn different engineering concepts and skills. Currently, three batches (75 highschool students) actively participate in the program, accompanied by engineering Bachelor students who serve as mentors. This paper presents the

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structure of the research club which is based primarily on theories of the emergence and development of individual interests and self-efficacy expectations. A well-known model depicting the development of individual interests is the four-phase model. This model is considered the basis for the structure of the research club program. In this paper, the most important factors in the set-up of the research club and the expected results as well as the many lessons learned are presented.

1 INTRODUCTION

In recent years, numerous initiatives have been developed to promote interest and understanding of technology. The everyday life and the social contacts of young people are increasingly characterized by technical devices. However, young people are usually not actively engaged with technology as such, as they are neither concerned with materials nor with the functionalities or the original use of the devices, as various interest studies show [1]. This discrepancy between a life in the midst of technology and simultaneous technology remoteness in terms of interest and understanding has various causes, which have been investigated in the studies on technology socialization [2]. Since October 2019, the research club has therefore been pursuing, among other things, the goal of promoting young people's interest in technology and science and providing insights into the professional field of engineers. In the next sections the conceptual framework is presented followed by the methodological approach and structure of the research club.

2 CONCEPTUAL FRAMEWORK

2.1 Emergence of Individual Interests

An overview of current theories of interest can be found in the review article by Renninger and Hidi [3]. In their review article, they define the characteristics of interest and emphasize that these are the characteristics that a majority of scientists in this field would agree with. Accordingly, interest is a motivational variable that meets five criteria points [3]. According to Krapp [4], interest occurs when the distinguished -cognitive, affective, and value-related components are experienced.

2.2 Development of Individual Interests

A well-known model that depicts the development of individual interests is the four-phase model by Hidi and Renninger [3]. It describes the first phase of interest development as triggered situational interest. The triggered situational interest can then move into the second phase, the maintained situational interest. The third phase can develop from the second phase and is characterized as emerging individual interest. The fourth phase is a well-developed individual interest. Each of these four phases is connected with certain affects, more or less pronounced knowledge of the subject and the value estimation of its content, i.e. the cognitive, affective and value-related components of interest. These components describe a form of cumulative interest development, provided that this process is externally supported and maintained. Without external support, any phase of interest development can break off prematurely, with interest regressing to the level of an earlier phase or disappearing altogether.

2.3 Self-Efficacy

Closely linked to the experience of competence, which is set as a basic need for interest development, is the self-efficacy expectation [6]. Self-efficacy expectations are defined as "beliefs in one's capabilities to organize and execute courses of action required to produce given attainments" [6]. The term self-efficacy beliefs refers to one's confidence in one's competence to initiate and complete even difficult actions. The belief that one is capable of organizing and executing certain behaviors or achieving certain goals influences one's choice of future activities, efforts, and perseverance.

2.4 Gender Roles and Career Choice

Studies show that the lack of personal contact with people in the engineering sciences and the lack of role models are among the most important reasons why so few female high school graduates choose to study engineering. In addition, many young women are afraid of confirming negative stereotypes [7].

From the point of view of developmental and learning psychology, career choice is not an isolated event, but a developmental process that is prepared by experiences during childhood. During this process, vocational interests, judgments about occupations, and expectations regarding the compatibility of an occupation with personal prerequisites and life plans are formed. Priorities are also formed, such as those expressed in Gottfredson's [8] postulated compatibility of an occupation with the criteria of "gender type", "social prestige" and "personal interest".

It is undisputed that career choice is significantly influenced by gender. Herzog et al [9] writes: "Professions have a face in which traits of social prestige and gender difference are drawn, which is why different professions are open to a girl than to a boy". According to Gottfredson [8], the public presentation of gender roles actually forms the most important occupational choice criterion. The choice of a gender-untypical profession therefore requires a great deal of self-confidence and a great willingness to compromise. Accordingly, Gottfredson emphasizes how important it is in today's society not to further reinforce the limitations in the self-perception of young people as well as in their perception of the professional world, but to keep the spectrum of acceptable professions open and to raise awareness of inappropriate processes of limitation.

3 SETTING UP THE RESEARCH CLUB STRUCTURE BASED ON THE CONCEPTUAL FRAMEOWRK

Evaluation studies [2] point out the importance of support programs in connection with situational interests, but at the same time show that such initiatives are not sufficient for the development of individual interests. For this, continuous offers are necessary from childhood until beyond the career decision. Our research clubchangING therefore offers regular meetings so that the development of individual interests can be ensured.

German as well as international studies [10] have shown that practical work and the production of a product with reference to the use in everyday life have an interest-promoting effect, whereby the latter is particularly motivating. For girls in particular, it is also important to deal with the social contexts of technology. Some studies [7] could prove a positive influence of technology lessons on the career choice.

The structure of the research club is based primarily on theories of the emergence and development of individual interests and self-efficacy expectations. The 4 phase model is considered as the basis for building the program of the research club. In Table 1, we show the most important factors in building the research club and the expected outcomes.

Table 1. Important Factors and the expected outcomes during the 4 years participation.

Factor/year	**1st year**	**2nd year**	**3rd and 4th year.**
Main goal and expected change.	**Generating initial interest**: According to [3], interest occurs when the different components - cognitive, emotional and value - are experienced.	**Increase interest and self-efficacy**. Interest development so-called Basic Needs that contribute to the stabilization of situational interests (cf. [3]): experience of competence, self-determination (or autonomy) and social inclusion.	**Development of own intrinsic interest** through individual projects PjBL. Impact of PjBL on **self-efficacy**. Competency expectations and the 4 sources of self-efficacy. [7]
Main Meeting type	Institute visits, basic skills, experiments, expert meetings	Same as 1st year. As well as working on self-directed projects in a MakerSpace.	Institute Projects: Students work on an authentic, real-world problem. Allows for different focus and processing methods.
Main parameters studied (measured impact)	Acceptance. Initial interest. Subgroup differences.	Change of attitude towards engineering. Increase in interest and self-efficacy.	Behavior change. Intrinsic interest and self-efficacy, study and career choice intention.

By participating in the research club, students in the 10th grade and above can experience the different facets of engineering. They can start in 10th or 11th grade and meet regularly once every two weeks. Mentoring and possible projects and workshops are offered through 13th grade. The groups are either all-girls groups or mixed groups.

In the research club, participants have the opportunity to interact socially with other technically interested young people while exploring the University and other facilities of the Cluster of Excellence SE^{2}A and experiencing research projects. Through the different meetings throughout the 4 years the participants gain background knowledge on the topics being researched in the participating institutes, including visiting the laboratories and assisting with experimentation. They thereby get an idea of what engineers do, get a chance to ask their own research questions and gain access to tools that facilitate their project work; they may visit areas of special interest and receive assistance from experts. Adding to that, the students are accompanied by experienced mentors and get to meet potential role models. The mentors are mechanical engineering students, preferably female, and accompany the groups during the 4-year program. Beforehand, the mentors are trained by an educational psychologist (training in mentoring tasks and gender-specific language use). This is a very important success factor, especially in the recruitment of female students [7].

3.1 Recruiting participants for changING – Lessons learned

One of the main goals of the research club is to attract talented and interested high school students. However, the marginalized minority, girls and students from low socioeconomic backgrounds should also be reached and supported.

As a strategy for attracting students, measures taken include the following: Physics teachers at schools are contacted to organize a visit so that mentors can introduce the research club directly to the youth in the classroom. Youth centers are also contacted and students form different socioeconomic backgrounds get the chance to join the club. Conventional means such as newspaper articles and social media are also used. The variety of channels ensures that a very large number of young people in the region learn about this research club and get the chance to join. The students are also offered to have their participation in the research club noted in their school reports in the form of an after school activity.

4 SUMMARY

The main objective of the changING research club is to support high school students to think seriously about engineering as a career and to increase the likelihood that talented youth will consider the possibility of pursuing a career in engineering.

Furthermore, it is important to support girls to think seriously about engineering as their career field, making it easier for them to consider engineering as a career option, since the social aspects of technology and engineering are explained and shown.

The participants are being interviewed at different points through their participation at the club and the participants' interests, self-efficacy expectations and career aspirations are surveyed, differences between subgroups are identified and presumed correlations between the variables are substantiated. In order to be able to derive factors that help to formulate measures for action, it will be investigated whether and to what extent participation in the research club influences the students' relationship to engineering and technology. Using the accompanying study to document the progression of the students' career decision-making over time as well as during their school years, it becomes possible to identify and map the influences that shaped their sense of purpose in the profession.

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PROJECT OF THE ACADEMIC PERFORMANCE IMPROVEMENT

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ABSTRACT

The transition of students from high school to university is a changing and complicated stage. It is during the initial phase when most drop-outs from engineering degrees occur. There are several reasons for this, however, the most highlighted ones are: i) the mismatch between the students knowledge level after finishing high school and the initial level required by the university degrees; and ii) the lack of a habit and constancy of study on the part of the students.

The proposed project aims to design specific tools to improve academic performance in the initial phase of the Degree in Industrial Technologies imparted at ESEIAAT by addressing the two problems mentioned before. In light of this, the measures adopted to solve these points will be tackled separately and properly explained in the following two blocks: block I) Initial level acces, block II) Monitoring of self-learning. Finally, an assessment of the strategies followed will be carried out in a final phase, block III) Integration project.

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1 INTRODUCTION

1.1 State of the art

The academic performance of students can be considered a key factor when analysing the quality of higher education [1]. The academic failure is on average 30% in the engineering degrees at ESEIAAT during the first years, with an accumulation of dropouts between the 1st and 2nd years. Once this phase is overcome, there is a certain stability in academic behaviour and also a notable improvement in academic performance. In addition, the dropout rate is significantly reduced to a value below 10%.

In [2], [3] and [4], there are several studies that try to determine the factors that affect the academic performance of students during these first years, in order to determine possible actions to prevent dropout, increase motivation and so, improving overall academic performance.

Of the many factors that trigger poor performance in engineering, the following points can be highlighted:

- Lack of understanding of basic concepts and even lack of preparation for the subjects taken in the initial phase, depending on the education received in secondary school.
- Difference between the learning methodology used in high school and the techniques used by university professors.
- Lack of study habits and therefore difficulties in planning autonomous learning.
- Memoristic learing habits that lead to difficulties in reasoning and extrapolating concepts when solving different problems.

Taking these factors as the basis for the deficiencies of the students, a series of tools have been desinged in order to improve these statements and therefore the academic performance of the students of ESEIAAT.

1.2 Objectives

The main aim of this project is to improve the academic performance in the initial phase of the degree in Engineering in Industrial Techonologies at ESEIAAT. To do so, the specific objectives are listed below:

- To ensure that students are able to detect their own lack of the necessary knowledge to start the engineering degree with a solid foundation. In addition, if necessary, to motivate them to carry out a series of actions in order to obtain the level required **before the start of the course**.
- Provide them with a weekly plan with all the tasks, both evaluative and autonomous learning, of the five subjects **during the first term of the initial phase**. In addition to accompanying them with a follow-up during this period.
- Assessment of the measures taken to prevent the student academic failure **during the second term of the initial phase** of the degree.
- To improve the horizontal coordination of subjects of the initial phase thereby providing a smoother change.

2 METHODOLOGY

The project has been definied by means of three main blocks which are divided into different tools integrated into the initial phase of the degree:

I. The development and implementation of tools designed to be used by future students just before access to the university degree.
II. A weekly tool for organisation, coordination and management of time as well as autonomous work during the first term of the initial phase of the degree.
III. An evaluative project within the subject called Industrial Technologies that encompasses the lectures taught during the first term of the initial phase of the degree. This project is carried out during the second term of the initial phase of the degree, thus assessing the competences aacquired.

The tools used in each block will be explained in more detail below.

2.1 Block I: Initial level access

The first block consists of a phase prior to the beginning of the course to ensure that students start the degree with a solid foundation from high school and with an adequate level to successfully overcome the initial phase.

In this block, two type of tools will be defined; one tool to assess the initial level of the students before starting the degree and another tool, for those students who require it, to acquire the necessary basic knowledge.

2.1.1 Initial level quizzes

Quizzes for each subject have been developed based on a selection of multiple-choice and true or false questions provided by each coordinator. These quizzes enable to check the level of the students before starting the course, both personally and on the part the teaching staff.

Each question have only one correct answer. In the case of a wrong answer, a feedback appears at the end of the test showing the correct answers as well as how the problem should be solved in some of the questions.

Once the student has completed the quiz, a global feedback appears (see Figure 1), so that the future student is aware of his/her level and be able to prepare for the beginning of the academic course.

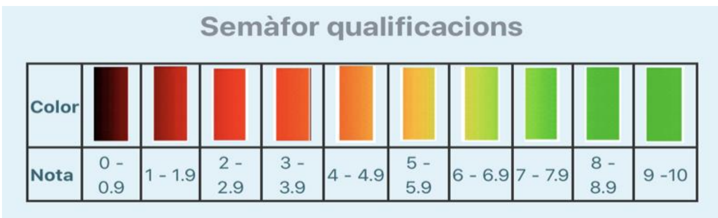

Fig. 1. Global feedback: traffic light of ratings

2.1.2 Entry level retraining support material

A web page has been designed for each of the subjects imparted during the first term of the initial phase of the degree in Industrial Technologies Engineering; Physics I, Chemistry I, Algebra, Calculus I and Graphic Expression. In which, with an agile, didactic and homogeneous format, support material of the lectures is presented to help students aquire the level required to successfully pass the initial phase. There is support material related to the content to consult during the academic period.

Below are listed the links to each of the support websites for the different subjects:

- **Algebra:** https://sites.google.com/upc.edu/greti-algebra
- **Calculus I:** https://sites.google.com/upc.edu/greti-calcul
- **Physics I**: https://sites.google.com/upc.edu/greti-fisica
- **Chemistry I:** https://sites.google.com/upc.edu/greti-quimica
- **Graphic expression I:** https://sites.google.com/upc.edu/greti-expressio-grafica

The support websites have been designed with a common structure to facilitate and speed up browsing. The structure consists of:

- Introduction and information about the current subject (see Figure 2). The contact details of the coordinators as well as the other professors.

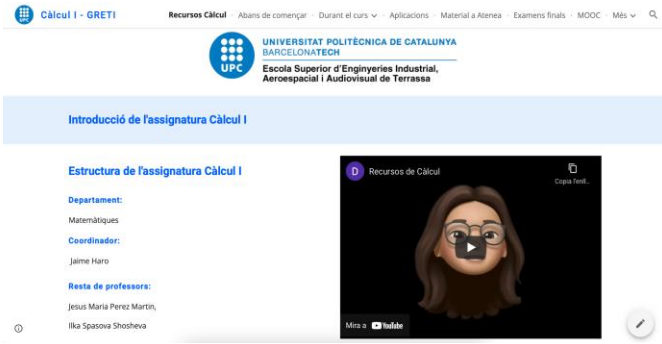

Fig. 2. Virtual assistant of the support website in Calculus I

- Support material to consolidate high school concepts prior to the beginning of the academic period separated in different sections. Within each thematic section, there are: short videos (5 – 10 minutes), teaching notes and many examples related to the lecture as well as practical applications.

- Thematic support modules for a better understanding of the content of the lectures imparted during the academic period (see Figure 3). Within each thematic module, there are: short videos (5 – 10 minutes) and some activities.

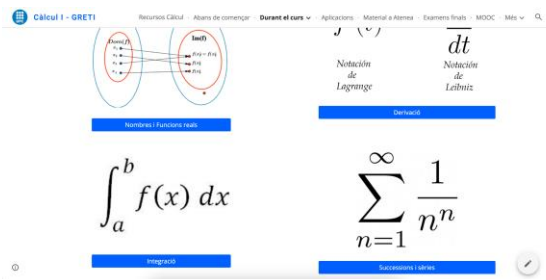

Fig. 3. Thematic modules of the content imparted during the academic period of the Calculus I support website

2.2 Block II: Monitoring of self-learning

The application of the second block takes place during the school period of the first quarter of the initial phase of the degree. This block seeks to consolidate the perseverance on the part of the students when it comes to autonomous learning.

Three types of tools will also be defined; a planning tool so that the student has the calendar of weekly tasks, exams, deliveries and number of hours of autonomous work or study scheduled for each of the subjects the first year of university career, another that will allow counting the number of weekly hours of dedication and finally a dossier that includes the proposed activities of autonomous learning by the teaching staff.

2.2.1 Weekly task planning template

A template has been developed and coordinated transversally (Figure 4), with the weekly tasks throughout the semester, of the 5 subjects that are part of the first engineering year. This template is made available to students on the first day of class to help them in the autonomous work of monitoring each subject.

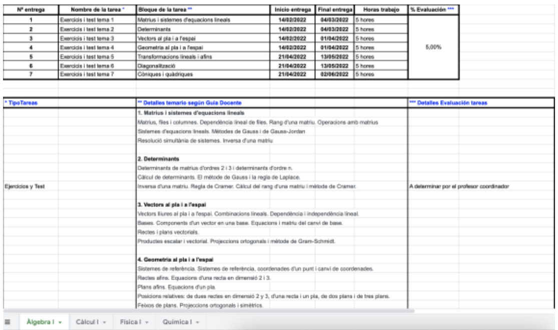

Fig. 4. Weekly task organization template

With this tool, the student can know in advance the dedication that each subject requires weekly in order to be able to keep a good study agenda that allows them to organize themselves and pass the subjects.Additionally, depending on the circumstances and availability of hours of the student, it can allow him to decide what magnitude of subjects he can tackle and correctly select his dedication.

2.2.2 Weekly autonomous learning hours log form

A link is sent to the student, at the end of each week and by means of a message through the forum that he receives with an SMS on his mobile, reminding him to fill out a form with the information corresponding to the hours of dedication (see Figure 5).

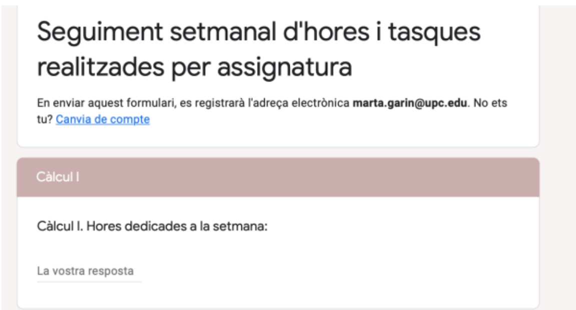

Fig. 5. Dedication hours registration form

Once the academic period of the first semester has finished, a graph has been made of the correlation between the average number of hours dedicated each week by the students based on the final grades obtained by them. It must be taken into account that factors other than the dedication in hours itself come into play, in such a way that it is not necessary to reach a firm conclusion. After a few generations, increasing the number of samples of the population, it will be possible to adjust to a more real scenario.

Below (see Figure 6) is the correlation between the average number of hours dedicated each week by a specific student and the final grade obtained by said student. From the linear regression equation, the future student could estimate the final grade for the subject based on the hours spent per week.

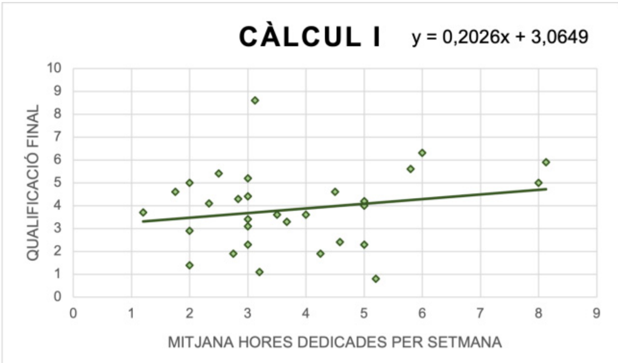

Fig. 6. Correlation between the time record and the final grades obtained

2.2.3 Autonomous learning dossier (Figure 7)

This tool consists of a compilation of the self-learning activities proposed by the professors during the academic period. In this way, students have in an ordered way a serie of activities which summarise the content of the lecutres. In addition, a transversal agreement has been reached with the coordinators of the subjects so that the delivery of these activities is worth 5% of the final mark.

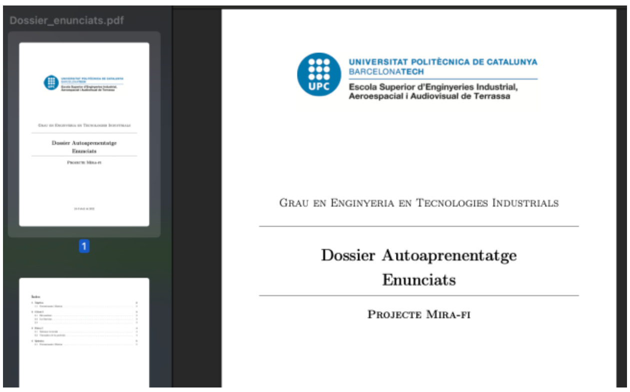

Fig. 7. Dossier of autonomous learning tasks

2.3 Block III: Integration project

This final block is the third phase of the project. It takes place during the second term of the initial phase in order to continue with the monitoring of the academic performance of the students. It consists of the **Integration Project**, carried out within the subject of Industrial Technologies.

The main objective is to evaluate the understanding of all subjects previously coursed through the creatin of a transversal project. The subjects that can not be assessed within the project itself have been integrated by means of a *Scape Room (Figure 8)*.

To carry out this project, students are divided into groups to encourage teamwork and motivate students with practical applications of engineering.

Fig. 8. Integration project website

3 RESULTS

The different tools designed for the implementation of the project are summarized below:

- **Database with personalized questions for each subject** of the first semester of the initial phase. From it, the questionnaires are generated that allow determining the level of access of the student.
- **Web page with support material** so that new students can acquire the necessary level to successfully follow the first semester of the initial phase.
- **Template for planning and managing autonomous work** that allows the student to have at the beginning of the course an organized and coordinated vision of the different tasks on a weekly basis for the block of subjects to be studied.
- **Registration form of the hours dedicated by the student to each subject weekly and real measurement of the work** required by the teaching staff to the students of the subjects of the first semester of the initial phase. Once the semester is over, it has been possible to graph a correlation between the average number of hours dedicated each week by the students based on the final grades obtained.
- **Autonomous learning dossier** that compiles a series of activities proposed by the teaching staff with the aim of consolidating a record in the self-learning of students.

- **Integration project made up of a series of enigmas** related to each of the subjects of the first semester of the initial phase for the evaluation of the skills taught in said subjects.
- **Homogenization of the teaching/learning methodologies** used in the different initial phase subjects.

4 CONCLUSIONS

The tools designed address the main problems detected in students who access an engineering course for the first time and their implementation gradually allows:

- Generate a study habit and encourage student involvement in their autonomous learning process.
- Improve student self-management and self-planning of their weekly study time.
- Improve overall academic performance.
- Increase student satisfaction/motivation.

5 SUMMARY AND ACKNOWLEDGMENTS

This project would not have been possible without the altruistic and rigorous collaboration of all the coordinators of the ESEIAAT's first-year Industrial Technology Engineering courses (Rafel Amer, Jose Antonio Diego, Jorge Macanás, Jaume Haro and Francisco Hernández) and of the fellows who have collaborated on it (Patricia Vela and Marta Sunyer), as well as the continuous support received from the Center through the sub-directorate of innovation (Marcel Macarulla).

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Promoting lab engagement in experimental compressible flow modelling

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ABSTRACT

The present work depicts the development of an experimental equipment that reveals compressible fluid dynamics, while collecting data from an incompressible flow like water in an open-channel. It consists of an extensive theoretical framework followed by a practical analysis, the aim of which was to trigger the hydraulic jump, both normal and oblique, in order to illustrate its hydro-gasdynamic analogy with a shock wave, occurring in supersonic compressible flows.

The assembly, called "water table", arises from the necessity of economical alternatives to expensive supersonic wind tunnels in the experimental study of compressible flows. Thus, a canal based on a Laval nozzle was constructed where water flow could experiment a hydraulic jump. Through its visual and experimental perception, fellow interested could more easily understand the physics and engineering behind this phenomenon.

Multiple design alternatives were evaluated considering environmental, economic, functional and aesthetic factors. A low-cost implementation was critical in the design process. The measurements revealed that the geometry of the nozzle and the wedges designed as obstacles to cause obliquity were the most influential elements in the formation of a hydraulic jump in the set-up. Regarding the experimental variables, the upstream and downstream

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heights had the highest relevance. Therefore, their manipulation and analysis could lead to further educational investigations.

This research is a step forward to support students in the understanding of compressible flow principles by providing an in-house experimental set-up. The equipment is an opportunity of carrying out lab measurements, which certainly guides to a major commitment in the field.

1 INTRODUCTION

1.1 Scope

The experimental study of compressible flow dynamics has been of growing interest since the 1940s, for both experts and students of fluid mechanics due to its learning difficulty, since this type of flow is not very common and easy to visually detect. Unfortunately, its experimental simulation presents the disadvantage of requiring expensive equipment such as a supersonic wind tunnel that not all universities can afford[1-5]. Therefore, the main goal of this paper is to describe the design, manufacture and experimentation of an equipment that illustrates the hydro-gasdynamic analogy between the shock wave, compressible flow characteristic, and the hydraulic jump. From the set-up students can collect data while experimenting with water easily and economically.

The purpose of this work is not only to show the evidence of theoretical formulas throughout an experimental modelling, but also to develop it by means of an inexpensive and easy-to-manufacture experimental assembly. Hence, it demonstates support for students' knowledge of compressible flow principles and, as a result, the physics and engineering education major engagement.

1.2 Theoretical context

The objective of the theoretical context is to elucidate the analogy between the dimensionless Mach (Ma) and Froude (Fr) numbers because they are both based in describing the fluid velocity, compressible and incompressible flow, respectively.

An extensive explanation of the theoretical development could be detailed and followed by fellow interested, but it is not the purpose of this short concept paper and it can be found in many fluid mechanics books[7]. In preference, the most relevant formulas are going to be presented.

On the basis of Bernoulli's equation applied between the stagnation state and a generic point of a reservoir open to the atmosphere of fluid depth connected to a hydraulic canal, the dimensionless Froude number (Fr) can be defined as:

$$Fr = \frac{v}{\sqrt{gH}} \tag{1}$$

Where v is the velocity, g gravity and H the height of the generic point. If an analogous analysis is carried out on a streamtube of compressible flow like air, where the steady-state conservation of energy equation is applied, and it is compared to the previous one according to an incompressible flow, a certain similarity between the ratios of velocities arises. At this point, the first analogy between Mach (Ma) and Froude numbers is revelead, if the hydraulic current is seen as a hypothetical gas flow of $\gamma = 2$. Consequently, both dimensionless numbers can be equally estimated[8].

$$Ma \cong Fr = \sqrt{2\left(\frac{H_0}{H} - 1\right)} \tag{2}$$

Additionally, Mach number is defined by using the sound speed (a) and the fluid velocity (u):

$$Ma = \frac{u}{a} \tag{3}$$

From the equations of perfect gas, isentropic flow and the continuity equation results the hydro-gasdynamic analogy for the ratio of the throat area and the local area in a diffuser of compressible flow. From the following formula, A denotes the surface and the superscript "$*$" represents sonic conditions[7].

$$\frac{A}{A^*} = \frac{1}{Ma}\left[\frac{2}{3}\left(1 + \frac{1}{2}Ma^2\right)\right]^{3/2} \tag{4}$$

Furthermore, the analogy between bidimensional supersonic compressible flow and supercritical incompressible flow can be studied. A shock wave can form an oblique angle when the oncoming flow collides with an obstacle, like a wede of angle 2θ. Under particular conditions for an incompressible flow, the analogous oblique hydraulic jump arises[2,3,6-8]. Thus, the following equation outlines the mathematical relation between their variables. It may be considered that β is the angle between the shock wave and the incident supersonic current, subindex 1 refers to supersonic flow and δ is the angle between the hydraulic jump and the oncoming flow.

$$\theta = \delta - tan^{-1}\left[\frac{2tan\delta}{-1 + \left(1 + 8{Fr_1}^2 sin^2\delta\right)^{\frac{1}{2}}}\right] \tag{5}$$

2 METHODOLOGY

To begin with the experimental set-up building process and analysis, a deep study and evaluation of design alternatives, materials and dimensions was carried out. The first 3D design incorporated two reservoirs (upstream and downstream) and the noteworthy water canal that followed a Laval's nozzle criteria.

The next step was the definition of different materials and configurations of the initial 3D designed model. The alternative called "A" consisted of two prefabricated plastic reservoirs and the water canal printed in 3D, made of polylactic acid (PLA). Whereas "B" was made up of methacrylate and "C" of stainless steel. All of them were evaluated following the weighted sum technique, marking each alternative according to the Saaty scale and a variety of criteria (see Table 1).

Criterion	**Weight (%)**	**Alternatives**		
		A	**B**	**C**
Environmental impact	20	8	5	6
Cost	35	9	4	4
Functionality	30	5	8	8
Aesthetic finish	15	7	9	8
Weighted score		**7.30**	6.15	6.20

Table 1. Weighted sum evaluation

As it is denoted in the resulting weighted scores, alternative “A” was the one developed for the experiment. In addition to the three main components aforementioned, three wedges were also printed in 3D and tacked on to cause obliquity.

According to Figure 1 Left), the hydraulic flow of the final experimental set-up starts in a water pump, from which it reaches the upstream reservoir through valves and pipes. Across the nozzle throat, the flow accelerates achieving first the critical state and finally the supercritical one. Then, the hydraulic jump makes the water return to its slow subcritical regime. From the mentioned figure also should be noticed the main variables of the work, which should be emphasized by students when recreating the experiment. There are two independent variables: e, the width of the throat, and b, the width of the nozzle’s diffusing part. The width of the throat was adjusted from 0.07 m to 0.03 m in steps of 0.01 m by means of two adjustable plates. Each of these widths generated a specific Froude number, which could be analytically obtained through the measured heights (dependent variables) H_0 and H, shown previously in equation (2). Finally, b was used to fix the point of the nozzle’s diffusing ending part, right after the hydraulic jump occurred.

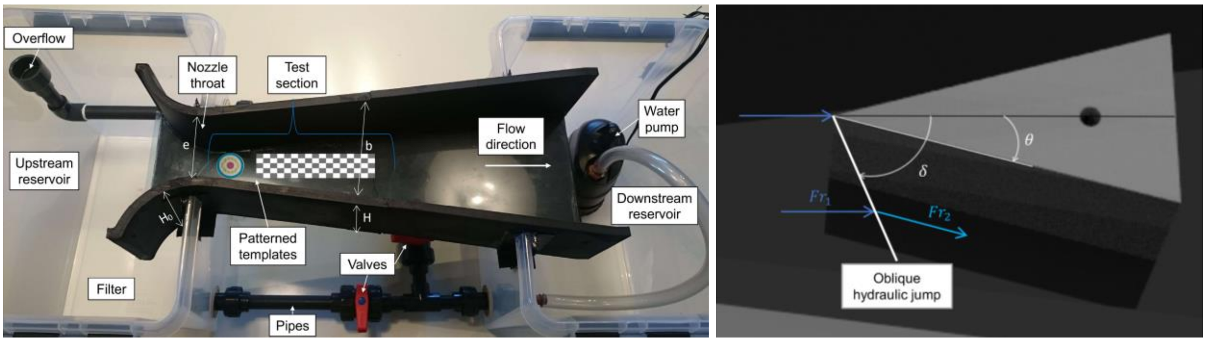

Figure 1. Left) Experimental set-up design and variables; Right) Wedges design and variables

Moreover, the wedges of angles 7.5°, 15° and 20° were of height 0.04m and length 0.08m. The independent variables of the second stage of the experiment are also the widths e and b, by adding the angle of the wedges θ. Hence, the angle of the oblique hydraulic jump δ caused in each case is the dependent variable (see Figure 1 Right)).

3 RESULTS

3.1 Normal hydraulic jump

For each of the fixed five widths of the nozzle’s throat, two Froude numbers were calculated from equations (1) and (2), respectively. In addition, theoretical and experimental values of A/A* were obtained through equation (4) (see Table 2).

e (m)	Ma=Fr (eq 2)	Fr (eq 1)	Relative error (%)	A/A* (eq 4)	A/A* (b/e)	Relative error (%)
0.07	1.593	1.482	6.96	1.168	1.214	3.84
0.06	1.558	1.242	20.27	1.151	1.417	18.78
0.05	1.420	1.035	27.12	1.091	1.700	35.82
0.04	1.183	0.763	35.47	1.020	2.125	52.02
0.03	1.085	0.528	51.38	1.005	2.833	64.56

Table 2. Mach and Froude numbers results

If the results are observed, it can be seen that Froude numbers from equation (1) are greater than one only for nozzle throat widths above 0.04 m, which indicates the experimental formation of a hydraulic jump for this range of width values. This result is consistent with the fact that the error between the results from both equations increases when the width decreases, from a 7% ($e = 0.07$ m) to a 51% ($e = 0.03$ m).

3.2 Oblique hydraulic jump

According to the fact that the best results were obtained from the throat widths of 0.07m, 0.06m and 0.05m, the second stage of the experiment was conducted to measure nine cases, and in five of them was possible to see experimentally an angle δ of the oblique hydraulic jump. Heights H_0 and H were also measured in order to obtain Froude numbers (through equation (2)) and consecutively theoretical δ values from equation (5), calculated by using MAPLE™ program[9]. Analogous to the behaviour of compressible flow, it occurs a detached shock wave (DS). This means that under these conditions, angle θ and Froude number, a δ value between 0 and 90° does not exist.

e (m)	θ (º)	Fr (eq 2)	δ (measured) (º)	δ (eq 5) (º)	Relative error (%)
0.07	7.5	1.573	63	51.07	23.36
0.06	7.5	1.536	50	52.93	5.54
	15	1.434	72	DS	-
0.05	7.5	1.408	58	63.81	9.11
	15	1.336	54	DS	-

Table 3. Angles δ results

3.3 Photo tracking

Photo tracking was utilised as means to physically capture the hydraulic jump. Figure 2 Left) shows an example of it when the width of the throat is 0.05 m and Figure 2 Right) depicts an oblique hydraulic jump, which corresponds to a throat width of 0.07 m and a wedge of 7.5°.

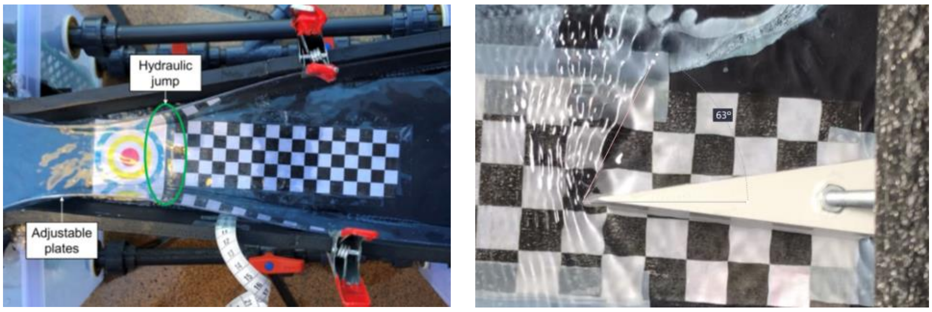

Figure 2. Left) Photographic capture of a hydraulic jump; Right) Photographic capture of obliquity

4 DISCUSSION AND CONCLUSION

From the theoretical study and experimental data obtained, it is concluded that under the suitable boundary and geometrical conditions, a compressible flow in a water table can be modelled by students on hydro-gasdynamic analogy.

The fact that an undular jump was visually detected and that the results were in agreement with the theoretical framework is outstanding. It adds even more value to this work the low cost of the constructed experimental set-up presented in this paper, being of 329 € (around 369 $), which is orders of magnitude less than a supersonic wind tunnel[6]. Thus, the set-up is easily reusable and inexpensive for fluid physics education.

Regarding the experiment itself, when the angle of the nozzle is higher, making its width smaller, the probability of what it could be called "stall" becomes higher, and this phenomenon can produce alterations in the flow path[10]. From the nozzle geometry designed in this experimental study, the theory confirms the presence of a “two-dimensional stall” for widths values lower than 0.05 m, which would justify the high error values. Hence, a plausible explanation is that hydraulic jump occurs for wide widths, whereas stall can appear as a restriction for narrow widths. Then, it is of interest for a future investigation to design a nozzle of higher experimental widths, to try to reduce this phenomenon and better visualise the hydraulic jump[11].

Finally, this study has found the cause-and-effect relationship between the results obtained and their meaning, which brings a sense of fulfilment. One of the major lessons learned is that despite the difficulties encountered and low budget invested, the presented work proves valuable. From the point of view of a fluid mechanics student, who has carried out the experiment, I believe that it is more illustrative and formative to physically see results with theoretical background rather than memorising random formulas. Therefore, it could be included in physics and engineering bachelors as a laboratory practice so that more students could gain the same enriching learning and engagement, and carry on with the proposals for future research in the field[12].

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Unite! European University: Main difficulties regarding Flexible Study Pathways identified by Partners with Impact on Joint Programmes – Results of a survey across Europe

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ABSTRACT

The European Universities Initiative (EUI) promotes European values and identity and aims to revolutionise the quality and competitiveness of European Higher Education. As part of this effort, the University Network for Innovation, Technology and Engineering (Unite!) is working on developing a Joint Program (JP) offer with embedded mobility and flexibility. To achieve this goal, we present in this paper the major challenges in implementing Flexible Study Pathways (FSP) at a transnational level identified in a survey conducted at the seven partner Universities of Unite!.

The most desirable forms of flexibility regarding content of course/program were Elective Courses outside the domain and inside the degree of specialisation. Main difficulties identified by partners are related to academic calendars, time cost to organise FSP, legal matters, program agendas and ensuring the achievement of learning outcomes.

The results of this analysis show possible directions for the development of a European degree, which will require effective communication and stakeholder coordination and engagement.

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1. INTRODUCTION

European Universities are key players in the establishment of a more resilient, progressive and thriving European Higher Education and Research, particularly by facilitating the implementation of Joint Programmes, pooling capacity and resources, and ultimately, to work together towards a joint European Degree.

The University Network for Innovation, Technology and Engineering (Unite!) [1] was one of the first 17 transnational alliances funded in the context of the European Universities Initiative [2] by the EU in 2019. Within this context, Unite! is working on developing Joint Programmes with embedded mobility and flexibility, allowing for students to develop individualised professional profiles, co-creating their learning. As part of this effort, and together with other European University Alliances, Unite! has published a Joint Position paper on the European Degree [3], collectively signalling the possible implementation bottlenecks, as well as pointing out some measures to ensure its success. These ideas are aligned with the step-by-step approach towards the Joint European Degree, as suggested by the European Commission [4]: exploring the scope, benefit and feasibility of a joint European degree as well as mapping obstacles and key enablers to foster joint study programmes and establishing European criteria for creating a joint European Degree.

Accordingly, this work aims to identify most desirable types of flexibility and major difficulties in achieving higher degrees of flexibility at a transnational level, discussing them as possible obstacles in implementing Joint Programmes.

2. METHODOLOGY

Information was collected through a survey [5] designed to cover four major topics: (i) the FSP forms, already present in Unite! Universities, as perceived by respondents; (ii) the most desirable forms of flexibility; (iii) the perceived difficulties to achieve higher levels of flexibility; (iv) the factors that can facilitate the implementation of greater flexibility. Accordingly, and considering this publication's objective, this work focuses mainly in sections (ii) and (iii). The survey included closed and open questions, which allowed for both quantitative and qualitative data analysis, thus increasing the questionnaire's robustness and completeness.

The targeted sample of respondents for the survey included informed directors, coordinators, student representatives, administrators and the like (target A); professors, students and administrators randomly selected (target B). About 20 to 30 surveys were sent per target (A and B) and per partner. The aim was to collect at least 15 answers from each partner university. Data were collected from October 2020 to January 2021. The collected answers were sorted by (i) Type of Participant and by (ii) University. Regarding the distribution by type of participant, respondents were classified into four major categories departing from a previous set of options (see parenthesis): Study Programme's Responsibles (Mobility Office Staff; Study Programme Scientific/Academic Coordinator/Manager), Students (Student at decision level/Student representative/Student delegate), Professors (Joint programme Faculty/Teacher/Lecturer) and Others (Quality Assurance of Study Programmes Faculty or Staff; Other).

3. RESULTS

A total of 112 answers from all partners were received. Figure 1 shows the distribution of respondents according to (a) Type of Participant and (b) University:

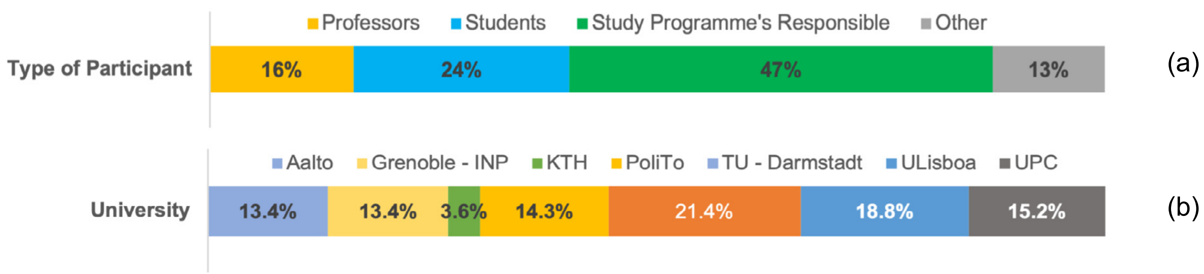

Fig. 1. Distribution of respondents (%) by (a) Type of Participant (b) University

The survey required respondents to choose the most desirable forms of flexibility from a closed list, with a possibility of indicating other options not included in the short list. The distribution of answers given on the most desirable forms of flexibility regarding content of course/program (%) is shown below in Fig. 2 by (a) Type of Participant (b) University:

	Type of Participants				Universities						
	Professors	Students	Study Programme's Responsible	Other	Aalto University	Grenoble - INP	KTH	Politecnico di Torino	TU - Darmstadt	ULisboa	UPC
a) Elective courses outside the domain	83.3%	77.8%	64.2%	85.7%	86.7%	80.0%	75.0%	68.8%	62.5%	85.7%	58.8%
b) Elective courses inside the domain	72.2%	63.0%	83.0%	85.7%	86.7%	46.7%	75.0%	87.5%	83.3%	76.2%	76.5%
c) Minors	38.9%	40.7%	43.4%	64.3%	86.7%	46.7%	50.0%	12.5%	29.2%	61.9%	35.3%
d) Alternative courses (same topic)	44.4%	51.9%	49.1%	28.6%	40.0%	40.0%	0.0%	56.3%	54.2%	66.7%	23.5%
e) Assignments and subject choices	66.7%	48.1%	37.7%	14.3%	46.7%	53.3%	50.0%	37.5%	33.3%	47.6%	35.3%
f) Supplemental courses	50.0%	44.4%	62.3%	42.9%	40.0%	80.0%	25.0%	31.3%	62.5%	71.4%	35.3%
Total of Participants	18	27	53	14	15	15	4	16	24	21	17

(a) (b)

Fig. 2. Distribution of answers given on the most desirable forms of flexibility regarding content of course/program (%) by (a) Type of Participant (b) University

The desirable forms of flexibility regarding content of course/program were flagged if reported by around 60% or more of the respondents. Elective Courses both inside and outside the domain (options *a)* and *b)*) are predominant and evenly distributed (around half the type of participants and Universities prefer outside the domain flexibility, whereas the other half favours having options inside the specialisation).

Considering these desirable forms of flexibility, the partners were asked what were the major obstacles to the implementation of FSP, and were given a series of possible reasons. The answers are synthesised below in Fig. 3:

	Type of Participants				Universities						
	Professors	Students	Study Programme's Responsible	Other	Aalto University	Grenoble - INP	KTH	Politecnico di Torino	TU - Darmstadt	ULisboa	UPC
a) University policy	38.9%	59.3%	41.5%	14.3%	46.7%	46.7%	50.0%	43.8%	29.2%	42.9%	47.1%
b) Legal matters (e.g, quality assurance in higher education)	38.9%	33.3%	60.4%	50.0%	40.0%	33.3%	50.0%	62.5%	41.7%	52.4%	64.7%
c) Programs agendas	44.4%	40.7%	49.1%	35.7%	53.3%	66.7%	100.0%	37.5%	33.3%	19.0%	58.8%
d) Academic calendars	66.7%	55.6%	64.2%	42.9%	53.3%	60.0%	50.0%	75.0%	58.3%	42.9%	76.5%
e) Lack of digital tools	16.7%	40.7%	15.1%	14.3%	13.3%	13.3%	0.0%	12.5%	37.5%	33.3%	11.8%
f) Time cost to organize flexible study pathways	55.6%	51.9%	49.1%	42.9%	60.0%	53.3%	50.0%	62.5%	50.0%	38.1%	41.2%
g) Autonomy in designing programs	16.7%	44.4%	32.1%	14.3%	26.7%	33.3%	25.0%	25.0%	25.0%	38.1%	35.3%
h) Lack of interest from university management	22.2%	40.7%	20.8%	14.3%	13.3%	46.7%	25.0%	31.3%	16.7%	14.3%	35.3%
i) Lack of interest from faculty	27.8%	48.1%	18.9%	28.6%	26.7%	26.7%	50.0%	25.0%	50.0%	14.3%	17.6%
j) Lack of interest from students	5.6%	14.8%	7.5%	14.3%	6.7%	20.0%	0.0%	6.3%	16.7%	4.8%	5.9%
k) You don't think it is a priority	0.0%	7.4%	3.8%	7.1%	0.0%	0.0%	0.0%	0.0%	12.5%	9.5%	0.0%
l) Cost of such programs	33.3%	40.7%	22.6%	28.6%	20.0%	20.0%	25.0%	12.5%	41.7%	38.1%	35.3%
m) Ensuring the achievement of learning outcomes	38.9%	40.7%	32.1%	50.0%	60.0%	6.7%	50.0%	43.8%	20.8%	52.4%	41.2%
n) Avoiding duplication of content	16.7%	25.9%	24.5%	28.6%	20.0%	13.3%	50.0%	25.0%	12.5%	33.3%	35.3%
o) Workload on counselling individual students	33.3%	18.5%	49.1%	50.0%	40.0%	40.0%	50.0%	31.3%	50.0%	42.9%	23.5%
p) Multidisciplinary assessment of multidisciplinary study paths	16.7%	29.6%	24.5%	21.4%	13.3%	6.7%	50.0%	31.3%	12.5%	28.6%	47.1%
Total of Participants	18	27	53	14	15	15	4	16	24	21	17

(a) (b)

Fig. 3. Distribution of answers given on the main difficulties in implementing the Flexible Study Pathways (%) by (a) Type of Participant (b) University

The obstacles were flagged if referred by around 60% of the respondents. They are mostly associated with two types of difficulties: practical issues (academic calendars, legal matters, time cost to implement higher levels of flexibility) and content of courses/programmes (program agendas and ensuring the achievement of learning outcomes). Regarding practical issues, it might be worth putting the effort into harmonising academic calendars in order to allow timely adjustments between partners. Regarding legal constraints, collected data indicate that further research needs to be done to identify the restrictions at the local and national level. For instance, in the case of ULisboa, these issues are often connected with the existence of a national accreditation agency and requirements imposed by professional orders.

The present study shows that the path towards FSP will demand effective communication and stakeholder coordination to overcome the practical and administrative issues, as well as the development of a common European Higher Education framework that ensures strong and coherent scientific and pedagogical offerings. Strong and consistent engagement from decision makers to provide flexible options that better prepare students for existing and future challenges will have to address policy-relevant issues such as coordination, articulation and transfer policies, as well as legislative and regulatory matters.

The development of innovative approaches to teaching and learning specifically targets the creation of Unite! Joint Programmes with integrated flexible study pathways and embedded mobility [5], expanding beyond the traditional dual and double-degree ideology. It is clear that it will be necessary to deepen the present analysis of data in order to properly design specific measures, eventually bycross-checking the most desirable forms of flexibility with the expected difficulties, thus establishing a potential correlation between them, in order to draw more accurate conclusions regarding both anticipated difficulties and possible solutions for identified roadblocks, paving the way towards a European Degree.

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CURRICULUM AGILITY
AT FACULTY, DEPARTMENT, PROGRAM AND COURSE LEVEL

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ABSTRACT

This short paper describes the first prototyping of a self-evaluation process of Curriculum Agility at a Faculty of Technology in Sweden. The process comprises guided, semi-structured, individual interviews at different organisational levels within the faculty, a joint narrative based on those interviews, prioritizing development strategies per level, and jointly mapping them on importance and implementation time. The self-evaluation is part of and based on the research on the principles of Curriculum Agility. The results show the interplay in timely curriculum change for futureproof engineering education between the teaching staff, the systems and the people who control the systems. The self-evaluation brings together the different perspectives and perceptions within the faculty and gives insight in how those affect

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the willingness towards and occurrence of curriculum development. This work in progress indicates how doing such a qualitative self-evaluation paves the road for transparent strategic dialogues on a holistic level about what to give attention and organize differently.

1 INTRODUCTION

1.1 Transforming the engineering curriculum in a timely manner

For a higher education institution (HEI), having Curriculum Agility means "*to be responsive to changes in societal, industrial, and student characteristics and needs, by proactively adapting relevant organisational structures, learning outcomes, learning activities, and assessments in a timely manner*" [1][2]. The pandemic in the past two years has shown how much flexibility and responsiveness can be required of all educational organizational structures within a short amount of time. But Curriculum Agility is particularly important to engineering education, which for a few decades now is said to need to adopt to the fast changes in technology and society [3]. Certain engineering disciplines indicate that part of what they teach their students will have already become obsolete only a few years after graduation [4]. That means that the body of knowledge and skills that is taught in the curriculum needs to be adjusted accordingly and timely.

Another reason why Curriculum Agility is important is the increasingly diverse student population at the HEIs [5] as a result of globalisation, inclusivity, and accessibility. It makes personalisation of the learning ever more important for students to be able to go successfully, and at a desirable pace, through their program of choice. And those adjustment lie both on pedagogic principles of flexible education in pace, place, and time, as well as a flexibility in learning content. Furthermore, it prompts revisions of the traditional ways of teaching. For example, the perceived usefulness and willingness to co-create the education with students themselves is growing [6].

A fourth reason for Curriculum Agility is that engineering education is changing due to changing ethical perspectives [7], which change the intentions and approaches of the engineering profession. There is a growing understanding that engineers of the future work from within a social context and carry responsibility towards sustainability [8]. That inserts an added complexity to their work and asks for a shift in competencies that engineering students need to learn [9].

All these reasons together make the actually needed curriculum changes to be of an innovative or even transformative kind [10]. The engineering curriculum needs agility, to be able to grow with and towards what is happening in the outside world. But changing a curriculum has become a wicked problem, as it is nested within the contemporary organisational structures, policies, and legislation of HEIs. Many different stakeholders are involved who all have their own needs, constraints, politics and traditions.

2 METHODOLOGY

2.1 The Principles of Curriculum Agility

This research is part of an ongoing research project that started in 2018. What it takes to be able to work towards Curriculum Agility has been captured in nine principles by a diverse group of engineering educators from all over the world, in a series of so far eight, focus-group type, co-creative workshops during different conferences and seminars on engineering education [1] [2]. The widespread input of the participants has so far resulted in a more inclusive and less normative approach to what timely curriculum transformations are envisioned and desirable. The principles were sought to be in that line of thinking, and applicable in international settings under different circumstances. The set of principles as used is listed in the first column in table 1. The principles were divided in three areas. The principles on Curriculum Vision and Strategy looked at the proactive adaptability vision and which stakeholders involved in order to make that vision come true. Secondly, the principles on Curriculum Quality and Provision looked for the space for innovation within the existing structures while safeguarding the quality and conserving that which remains valuable in the transformations. Thirdly, the principles on Curriculum Design and Research deal with the changed design of the more agile curriculum and the pedagogical and didactic competency needed to make it successful.

2.2 The role of this sub-research in the whole process

The currently ongoing step in the workshop series is to provide universities with a self-evaluation method on the 9 principles of Curriculum Agility. Both the principles and the self-evaluation tool are developed through continuous prototyping. This sub-research was the first prototyping activity for the self-evaluation and served as input and inspiration for an upcoming co-creative workshop day in June 2022 on the self-evaluation. The main questions to answer in the Curriculum Agility narrative were: How are we doing at this moment? What enablers and barriers are present in our situation? And what do we want to grow towards? The richness and practicality of the resulting data of this trial was of interest for the ongoing research.

2.3 Method (describe briefly what reviewer 1 wants to see)

A choice was made for a qualitative, narrative approach to scanning the engineering Faculty of a Northern Swedish university on their Curriculum Agility. Because the concept is still relatively unknown and covers different aspects of the curriculum from organisation and management to course content, a guided process was picked, in which the interviewer informed the respondents as well as questioned them. Multiple levels within the organisation were included, i.e. Faculty, department, program, and course level. Respondents were first interviewed alone, and then invited for dialogue and strategizing together with the other respondents. This way the resulting narrative would be a multi-perspective mapping of their Curriculum Agility, and one they all agreed on.

The interviews were semi-structured, 60-120 minutes each, with 4 respondents from different levels within the university (faculty management, departmental director of education, head of program, and the latter two also functioning as senior lecturers). For each principle, respondents talked about the perceived strategic importance at their own and other levels, how much it was happening already, including examples, and which enablers and barriers were present. Short narratives were written based on the interviews. In a separate session, the respondents were asked to map desirable priorities that came out of the interviews on scales of must-have to would-be-nice-to-have, and (very) short-term to (very) long-term implementation. Next, their input was grouped and labelled in one visual overview, showing the different and similar viewpoints at the different levels. That was the basis for the final joint strategic session, in which the respondents were asked to discuss, group, prioritize and (re)position the strategic development points for increasing the curriculum agility of their faculty, and tweak on the narratives.

3 RESULTS

3.1 Summarizing the narrative

The set-up of first individual and later group discussions resulted in honest, modest, and insightful narratives which increased transparency throughout the organisational layers. It extends beyond the scope of this paper to show the depth of the acquired Curriculum Agility narratives. In table 1, brief summaries of each principle's narrative can be found.

Table 1. Narrative summaries for each of the Principles of Curriculum Agility (based on the principles as described in [1] and [2]).

Curriculum Vision & Strategy		
1	Educational Innovation: Towards Agility	Although for the faculty there is no literal vision of being agile towards changes in society and technology, at each level the respondents do feel it is an aspiration of their faculty. At this point, a more generic quality system for change and improvement is the focus. The willingness to change is different at the different levels, time is the biggest barrier.
2	Management Approach: Change Culture	Ensuring and maintaining a culture rather than a "one-person engagement" for change is deemed very difficult by all respondents. Teaming up over different departments, collaborating, and supporting initiatives are mentioned as facilitators. Barriers are the big cultural differences between departments, especially in collaboration with other faculties.
3	Stakeholder Involvement: Co-creation	Involving external stakeholders has suffered greatly during the pandemic, but interaction with industry and students is still happening at certain places. Internal stakeholders are not usually co-created with but are part of a quality system based on feedback, adaptation, and approval processes. It doesn't always result in the desired engagement.
Curriculum Quality & Provision		
4	Legislation and Policy: Reframing the Rules	Finding the space for innovation in between the rules is most feasible for the program director who is also involved in teaching. That double role creates opportunities for agile curriculum changes. Faculty managers also report some room for manoeuvring. Apart from that, the rules are indicated by all respondents to rather have a perceived change-inhibiting effect on teaching staff in general, particularly at department level.
5	Organization and Governance: Responsive Administration	The people working at the faculty can empower the systems that are used, up to a certain level. Finances are both a facilitator and a barrier, because of the faculty-budgets structure. Responsiveness often depends on the (pedagogic or contextual) understanding of what, how and why change needs to happen, and that can be a barrier.

6	Decision Making Process: Accommodating Implementation	Curriculum and course approval procedures have been directed at quality control, which sometimes collides with the aspired trust-culture. Informal leadership and delegated decision-making make more direct decisions possible, with some co-creation happening there. Timeframes are perceived long, 1.5year for bigger changes, half a year for smaller changes, and problematized mostly to the level of detail required at those deadlines.
Curriculum Design & Research		
7	Programme and Course Design: Dynamic Content and Flexible Education	Holistic learning goals bear the challenge of translating them into examination. There are wishes for more variable examination formats. Courses are mainly made flexible on content by using project education. Programs differ in level of flexibility for the students and internationalisation. In new courses or programs, difficulty is perceived in students choosing them, needed to break even and in maintaining progression through the years.
8	Pedagogy and Didactics: Scholarship of Teaching and Learning	There is a lot of facilitation of SoTL possible, with funds for visiting courses, conferences, and a meriting system in place at the university. Teaching is put on equal terms with research by the faculty. In the departments the enthusiasm for pedagogic development varies highly. Pedagogic development is facilitated for those who are willing and open. There is quite a bit of traditional teaching going on, despite efforts on incorporating inclusivity, sustainability, and active + project-based learning.
9	Learning Spaces: Flexible Solutions	Blended and hybrid social, physical, and digital learning environments are used, especially since the pandemic, and funds are available for more development. The pedagogic side of using these resources is still in its children's shoes. GDPR hinders.

The strategic mapping of Curriculum Agility priorities within the faculty resulted in increased insights in and agreement on issues within the faculty, which need attention. Outcomes varied from on short notice letting teaching staff know it is not that hard to change course or program plans (related to principle 4), and to provide (more structural) support for them (principle 1 and 7), to long-term building of a more unfluctuating positive teaching culture (part of principle 8). Also long-term was the wish for involvement of students and administration in curricular development work as co-creators instead of evaluators (coming from principle 6 and 3).

4 CONCLUSION

The chosen self-evaluation method proved to result in a multi-level understanding of the Curriculum Agility of the Faculty of Technology, as was intended. The dialogue provided by the method was highly appreciated by the respondents. In a follow-up, it would be interesting to include student level as well as higher management (at university level) in the process. Selecting respondents should of course be done in a way that gives the broadest information possible. To that avail, multiple same-level respondents could be considered as well, as much as resources permit.

Importantly, during the mapping process, the principles were all confirmed in their importance by the respondents, who had not been involved in formulating them. There was a natural flow from one principle to the other in the interviews and group discussions, but the grouping of the principles can be reconsidered. However, this first prototype of a self-evaluation of Curriculum Agility gave practical indicators per principle and forms a solid basis for a Curriculum Agility mapping method to increase the understanding of how capable engineering education is to adopt to the fast-changing future, and what is necessary and desirable to work on.

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EXPLORING ENGINEERING SKILLS DEVELOPMENT THROUGH A COMPARISON OF INSTITUTIONAL PRACTICES IN MEXICO AND SCOTLAND

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ABSTRACT

The future of engineering education does not depend only on the curricula designed by universities, but increasingly on the needs of society and the complex requirements of Industry 4.0. Now there is an urgent need to work on an educational approach based on the close collaboration of three stakeholders: the university, which facilitates authentic learning opportunities for students and professionals and ensures the quality of learning outcomes; the industry, which establishes the skill sets and competencies it requires of its workforce; and finally, governments and professional associations, which can influence, provide global collaboration frameworks to support transformation and funding for reskilling, upskilling, as well as institutional responses. This study presents an analysis and comparison of the engineering skills "eco-system" that considers not only the technical education in

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response to the Fourth Industrial Revolution, but also the problem-solving needs of society and the human factors that shape the transition to the labour market in global contexts.

1 INTRODUCTION

According to the recommendations of international educational organisations in their recent reports, the new curricular programs for engineering education should arise from a collaborative dialogue between academia and industry, based on a multicultural, sustainable, and socially oriented perspective. Examples are the reports of the World Economic Forum (WEF) [1] for general skills, and the Sky 4.0 Project [2] for specific skills. The review of the international literature shows how higher education institutions are beginning to incorporate the lessons learned during the COVID-19 crisis and to implement the most successful strategies, to end the state of educational contingency and move towards achieving the objectives education planned for 2030 [3]. From this review it became evident a gap has formed between Higher Education Institutions (HEI) from different regions of the world, related to the economies of the institutions, the level of digital transformation, and their technological infrastructures [4]. In this communication, we present the preliminary findings of the ongoing project in which Glasgow Caledonian University and Tecnologico de Monterrey collaborate on their institutional practices, programs, and initiatives in engineering, for the promotion and development of the new skill sets required by Industry 4.0. A desktop-based analysis and comparison of the policies and practices in the two countries/universities that have shaped current approaches to such skills development -the eco-system- and the impact that these are having on teaching, learning, and assessment approaches are presented.

2 ENGINEERING SKILLS “ECO-SYSTEMS”

2.1 The case of Scotland

Glasgow Caledonian University (GCU) is a modern university with a long history of providing education for professionals from Scotland, the rest of the UK and internationally. Its new strategy (Strategy 2030) clearly responds to these future demands through a key priority area around employability and skills, and also through its graduate attributes that influence all programme design and delivery with the updated attributes introducing ‘Systems Thinking’ as a new attribute, and centring learner agency. This new strategy is underpinned by the UN SDGs and is a continuation of previous educational practices to create globally competent graduates. The skills agenda eco-system for Scotland is reflected in Figure 1, where a combination of UK, Scotland-specific and industry influences the future skills requirements. To give examples of educational approaches that develop transversal skills and positive outcomes in engineering, the students are offered international mobility experiences, including Collaborative Online International Learning (COIL). Whilst international mobility dropped during the pandemic, it has recovered strongly for this academic year 2021-2022, with a similar pattern being seen for year-in-industry placements. Additionally, in another module shared across many programmes, students in teams self-define a future-driven community-focused problem aligned to UN SDGs and design an appropriate solution to this. Such student-centred learning is a growing feature of programmes. Also, GCU is the largest provider of Graduate Apprenticeships (GAs) in Scotland – these are degree-level apprentices in which students gain the required professional competences through university studies and workplace experience to a standard co-designed with industry [5]. Positively, GAs provides opportunities for those who want to up-skill themselves as much as for those starting their careers and produce industry-ready graduates. Importantly, 90% of graduates from all Engineering programmes are in employment or further study after 15 months, with 80% of those in employment in high-skilled graduate jobs.

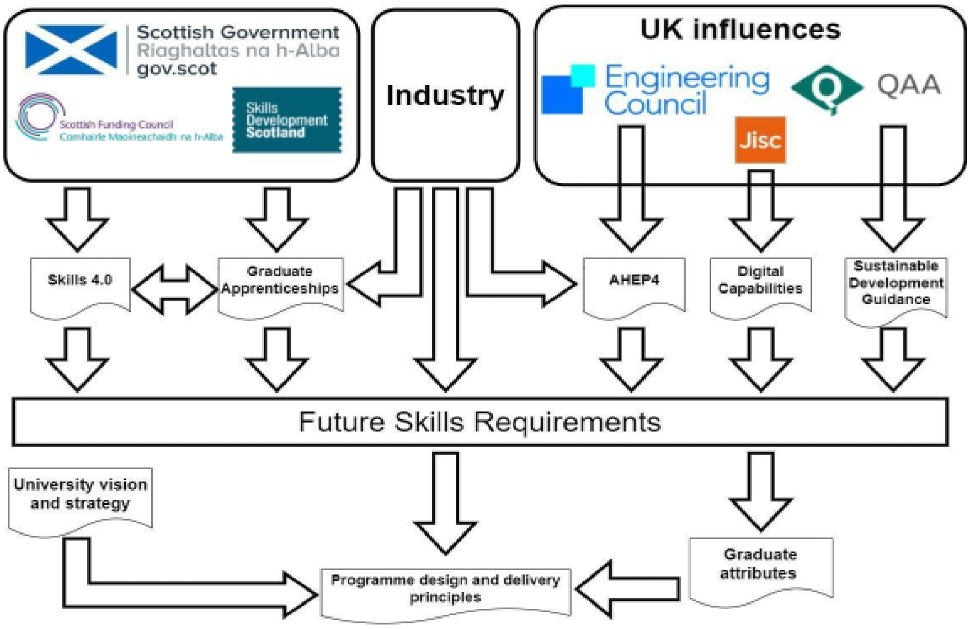

Figure 1: Skills eco-system influence engineering programmes in Scotland [Skills 4.0 defines the set of meta-skills for Industry 4.0; AHEP4: Accreditation of Higher Education Programmes 4th edition]

The strategic drive to enhance employability and meta-skills across the faculty is reflected in a Royal Academy of Engineering funded Visiting Professorship focused on preparing students for work in innovation-driven workplaces of the future. Considering technical skills, existing programmes emphasised digital and computer-based design and modelling, as well as systems approaches. Future curriculum transformation is underway with new modules with a focus on digital twins, predictive maintenance, and robotics, as well as new postgraduate programmes recognising the role of data science in engineering. Additionally, defining and implementing an Industry 4.0 Skills Taxonomy would better structure future enhancements in skills development.

2.2 The Case of Mexico

Tecnologico de Monterrey (TEC) is within the first 26 positions in the 2022 QS World Employability Ranking and the Top #1 university in Latin America [6], hence the interest to study the strategies that TEC has designed to be successful in terms of employability. The fundamental mission of the TEC is to train professionals and postgraduates with levels of excellence in the different areas of knowledge through specific educational programs and policies, to promote in students the development of an entrepreneurial and innovative spirit, responsible leadership, honesty, respect for the dignity of the human person, the preservation of the ecology and the appreciation of the historical-cultural values of the community and the country. TEC governs its programs by the Accreditation Board for Engineering and Technology (ABET). Currently, the process of globalisation of the world economy has had an impact on engineering education in four events: rapid technological change; the emergence of a new techno-industrial paradigm (Industry 4.0); the emergence of information technologies; and the worldwide institutionalisation of academic and professional accreditation systems. Faced with these demands, TEC decided in 2015 to progressively begin the implementation of a new educational model with four fundamental pillars: 1) Inspiring teachers, with great preparation; 2) Flexibility with hybrid or fully distance courses to enable learning anywhere; 3) Memorable Experience, with comprehensive physical, cultural, mental and sports development programs; and 4) Challenge Based Learning (CBL) where all courses are designed through a challenge resolution scheme, not problems or projects. These challenges are driven by real-world situations and for this approach to succeed, then the educational model in the design of the challenges involves not only the faculty but also training partners (Companies, industries, civil associations, non-governmental, municipal, or federal authorities, etc). The new paradigm must then be characterised by active learning, centred on the student that solves real challenges [7]. Active learning with the educational model with the CBL didactic technique is the fundamental basis of Socially Oriented Education, that is, developing skills based on the current need, whether labour or social problems [8].

3 METHODOLOGY

The study was designed considering the 2021 report in which the WEF brought together the ideas of ministers of education and labour, chief executive officers, chief human resource officers, chief learning officers, online learning providers and key industry skills experts, to propose a new framework for a global skills taxonomy based on ESCO (European Skills, Competences and Occupations) studies and aligned with the Occupational Information Network (O*NET) framework [1]. The report identifies that the successful adoption of this taxonomy is dependent on both institutional policy and practice. A comparative study focused on the strategies followed by the two universities -TEC and GCU- is being carried out during 2022. Strategies around fostering contemporary and lifelong skills in engineering are being compared: the description of skills frameworks, the how and by whom they were shaped, as well as how institutional policies supported these skills. The taxonomy used in this work integrates additional new skills and emerging attitudes related to the Fourth Industrial Revolution:

- Global Citizenship
- Socially Oriented and Multicultural Perspective
- Challenge-Based Learning

4 DISCUSSION AND FUTURE WORK

Similarities between the two universities include partnership with industry; approaches being influenced by the main industry sectors in the economy; responding to societal challenges (alignment to UN SDGs); and the desire to develop relevant meta- and technical Industry 4.0 skills.

Moreover, at both institutions, the partnership between university, employers and Professional Engineering Institutes nurtures professional engineers through work-based assignments that link module content and the workplace, as well as ongoing reflection.

Additionally, COIL opportunities at both GCU and TEC develop intercultural competencies, international perspectives, and ethical sensitivities, which are essential to develop as responsible global citizens. Companies value these skills as graduates have a more holistic understanding of synergy between engineering and business.

Furthermore, the inclusion of challenges and experiences that are socially oriented and focused on the UN SDGs allow for the robust development of skills (socially conscience and empathy; openness and resilience; creativity and sense-making) which are essential for obtaining jobs that meet the expectations of future engineers.

Some differences in approaches to skills development emerged: particularly the CBL approach present throughout the TEC curriculum allows for dynamic and ongoing engagement with industry, while at GCU it is generally a hybrid approach of project-based and more traditional technical modules. Another difference detected is that the national/government policy in Mexico does not have as much influence in defining the political agenda, so TEC had to develop its own framework, while GCU is being strongly influenced by educational policies at the national level.

The analysis also determined that the Skills Taxonomy, as outlined in [1], at both institutions was being defined. Future work includes the final stages of the study to analyse strategies that respond to the current concern of companies: what are the reasons for the difficulties in finding competent talent within each country? The analysis will focus on the circumstances that relate the difficulty of companies to find talent and the following shortcomings of engineering graduates: soft skills, digital skills, knowledge, and mastery of languages other than their native one, work experience and interpersonal skills.

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IT'S YOUR DAY! TAKE ACTION AND CLICK ON THE VIDEO ZONE: UNDERSTANDING, IMAGINING, DOING AND REVIEWING.

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***Conference Key Areas**:* Mathematics at the heart of Engineering, Virtual and Remote Labs
Keywords: *Videos, Self-learning, Lab sessions, Testing progress.*

ABSTRACT

This paper summarizes the results obtained in a project conceived to improve remote and face-to-face teaching of Calculus in the fields of industrial and biomedical engineering. The project consists of developing teaching videos that treat key topics of Calculus subject through some engineering problems at a first level university course. We focus on achieving the goal of learning by setting it in the approach and solution of a subject, making it more experiential. This type of practice should be the central focus of activities inside and outside the classroom. In this way we will be able to consolidate the students' mathematical skills, but at the same time acquire other skills that will be vital for their professional and personal development. The evaluation process must be formative, as the assessment should provide teacher-student

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feedback in order to adjust teaching or learning based on the information received. We propose two main types of activities: Production of audiovisual material for the improvement of teaching and completion of Wiris questionnaires for self-assessment. The didactic video is very useful in class and has a motivating intention because rather than transmitting exhaustive and systematized information on the subject, it aims to open questions, raise problems, arise the interest of students, disturb and generate a participatory dynamic. With the elaboration of these videos, we promote that students be able to understand through specific problems and with the help of graphic material, a specific problem and then move on to the abstraction of more general situations.

1 INTRODUCTION

The health events of recent years, together with the growth of social networks and video platforms, have represented a revolution in the educational system. The world has evolved from the traditional education system to the online classroom system. Video conference rooms and platforms that offer live streaming for education have acquired the relevant role that the market was requiring. A clear example can be found in the Spanish platform Edpuzzle, which has revolutionized the world of education through video. Educational videos currently represent a very important part of higher education, providing an important tool to capture the attention of students. The effective use of video as an educational tool is enhanced when teachers consider different elements as how to maximize student engagement with video and how to promote active learning from video, see [1] and the references therein for an in-depth discussion of the topic.

In the present paper we present the material developed under a project that has been carried out in the Barcelona East School of Engineering by a group of professors teaching in the initial level courses. When the pandemic interrupted our lives, teachers had to make a 180º turn in their way of teaching. Most of the members of the group offered virtual classes through GoogleMeet using Ipads for transmission, others recorded their classes on videos and we created a YouTube channel to communicate with the students (Canal Càlcul). The generated material is open access in the ZonaVideo UPC. A subsequent analysis made us see that one-hour class through a screen or videos of more than 20 minutes may not be as effective as initially thought, which is consistent with the results presented in [2]. Our interest in capturing the attention of students and creating materials that can be used in any situation led us to consider creating videos of no more than 5' that introduce a topic through a problem of interest to them. This material has been complemented with brief scripts, videos of problems in Cristal Board and online tests to monitor if the objectives have been achieved. The materials produced will be available in open format at UPC Video Zone.

2 METHODOLOGY

The objective we want to achieve is attract the attention of student and raise their interest in studying and expanding their knowledge in each of the topics that make up the Calculus course. It is a standard first year course in any of the engineering careers.

The topics to be developed are function representation, continuity, derivability, Taylor polynomials and Riemann integration. Our approach has been to think of an object or concept that could be present in each of the videos and that would serve as a common thread for the presentation of the problem. Once the concept was chosen, we scripted the video and, with the collaboration of the Caminstech center, we produced the material. On the other hand, we use the support provided by CristalBoard to solve problems associated with each of the videos, as well as a small pdf of about 4 pages each that expands on the topic and includes some historical notes. Finally, self-assessment tests have been developed using the WIRIS software on the ATENEA platform of the UPC. The developed materials have been produced in Catalan and English, since part of our students take the subject in that last language. To give agility to the presentation of the videos we thought of animations with music and not in videos in which some teacher gives the explanation. Our goal is to give lightness to the presentation and get closer to the way of doing the students.

The object chosen as the initial thread was the Heaviside function. This function is an unknown element for students that comes from high school or cycles, so it can rise the curiosity of students. In addition, the Heaviside feature is largely present in the themes that we wanted to develop and that could be introduced as a real problem.

3 RESULTS

The results of the developed Project are classified into 3 typologies.

3.1 Videos

We have designed, scripted and produced 5 videos of no more than 5 minutes in which one of the topics of the Calculus subject is introduced through a problem of technological interest as explained in the Methodology section. In the following table we summarize the characteristics of the videos.

Table 1. Video futures

Video Name	Theme	Problem	Media
Turn on and off with mathematics!	Continuity	Turn on a light	Heaviside function
Displacement, intensity and velocity with mathematics!	Function representation and changes	Signals changes	Translation and dilation of functions
Turn on and off immediately with mathematics!	Derivability	Instantaneous changes	Delta function
Approximating functions with mathematics!	Taylor Polynomials	How a calculator works	Polynomials

Discharge of a capacitor with mathematics!	Riemann integration	Discharge of a capacitor	Antiderivatives

3.2 Complementary short text

To complement the information of the videos we have developed an explanatory text associated with each of the videos of no more than 4 pages in which the information contained in the videos is expanded and a small historical note of a character related to the topic in question is added, if it exists.

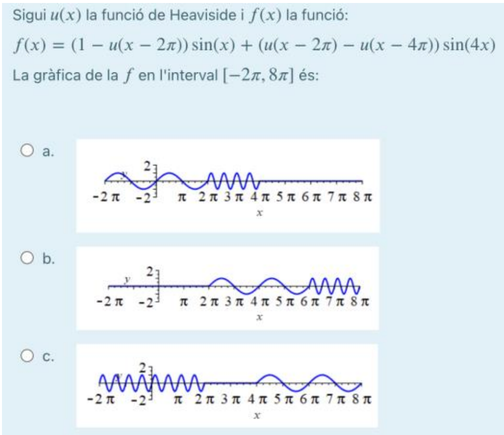
Table 2. Complementary material futures

Title	**Historic note**
Heaviside function	Oliver Heaviside
Functions transformations	Generic on functions
Delta Dirac function	Paul Adrien Maurice Dirac
Taylor Polynomials	Brook Taylor
Riemann integration	Georg Friedrich Bernhard Riemann

3.3 Test evaluation

The evaluation process must be transparent and formative. Transparency refers to the fact that the evaluation criteria must be public and known to the students from the first day of the course. And they must also be formative, since the assessment must provide teacher-student feedback, to be able to adjust teaching or learning based on the information received.

Figure 1. Example of a question



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DEVELOPING ENGAGING ENGINEERING EDUCATION RESOURCES BASED ON STUDENTS LEARNING AND EDUCATORS' TEACHING STYLES

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Conference Key Areas: Curriculum Development, Teaching methods

Keywords: teaching resources, engineering education, learning styles, teaching styles, project-based learning

ABSTRACT

The learning styles of engineering students have evolved over the years with the advent of technology-enhanced education. Educators have also changed their teaching styles to incorporate student-centric pedagogy and educational technology. While the COVID-19 pandemic proliferated online teaching worldwide, often forcing educators to conceptualize and convert face-to-face teaching materials to online learning modules, Ansys academic endeavours have also pivoted to support educators and digital learning. This paper highlights the Ansys Education Resources, aimed at helping undergraduate materials and simulation-based design educators teach and inspire students. These are also perfect for students and self-learners who are looking to complement classroom content. Moreover, these help professors in assigning supplemental homework or capstone projects.

The resources, of which 80% are openly accessed, are categorized as lectures, case studies, micro-projects, exercises, etc., and make the educators' job easier in inspiring and engaging the students' digital learning process throughout the undergraduate curricula. Solutions to exercises and projects are restricted to educators with current Granta EduPack product licenses. In developing these resources, the content developers consider different teaching and learning styles with special emphasis on project-based learning and incorporating questions that inspire students to consider societal impact and ethical choices. Some resources are purposely prepared for discussions and debates.

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The impact of these resources is measured through qualitative questions-answers in user group meetings, periodical surveys, and quantitative performance (such as download numbers) of the website repositories.

1 INTRODUCTION

1.1 Learning Styles of Students and Teaching Styles of Professors in Engineering

Students learn in diverse ways, depending on their own learning styles, but also depending on the discipline of study. The teachers should be adapting to such learning styles by designing appropriate teaching resources and picking up the appropriate style to instruct a specific group of students. The learning styles of engineering students have often been described as visual [1, 2, 3]; however, with the advent of digital communication systems, students lean on receiving information via digital media, with the ability of interacting with such material in different ways. In undergraduate engineering education, however, little has changed in classroom teaching to inspire students with these evolving learning preferences until the Coronavirus pandemic in 2020. Within a couple of weeks, sometimes even shorter, universities and colleges worldwide had to transfer in-person classes to remote teaching, often to live online classes or video-based asynchronous learning. Online flipped classrooms where students studied on their own and then joined live online discussions proliferated. However, the effort was more of a reactive response than a thoughtful, pro-active approach.

1.2. Teaching Resources for Visual, Interactive and Digital Learning

Preparing visually attractive, interactive, engaging teaching resources in digital format is not easy. For more than 10 years, the Education Division of Granta Design in the UK has been preparing such resources to help the teachers that will inspire materials education. Since 2019, after its acquisition by Ansys, this team expanded and are also engaged in preparing resources for simulation-based design and other engineering disciplines. This paper presents a few of those examples with relationships to how students can learn and how professors can teach in digital mode, using such resources, without losing interactivity or engagement in a virtual or an in-person classroom.

2 METHODOLOGY

2.1 First, Make it Visual

It is no secret that a picture speaks a thousand words. When Dr. Mike Ashby, a professor at the University of Cambridge and co-founder of Granta Design, Ltd. started working on such resources, visual appeal to engineering students, through appropriate animated slides, was one of the primary concerns. Resources were made where an educator would simply use one slide to describe a complex phenomenon, a concept, or seed a debate in the classroom.

2.2 Second, Make it Interactive

Sets of interactive learning resources were prepared for students in Adobe Flash, which have recently been changed into interactive PowerPoint slideshows that students could easily play with and learn from, and thus be inspired to learn more.

2.3 Third, Make it Thought-Provoking and Engaging

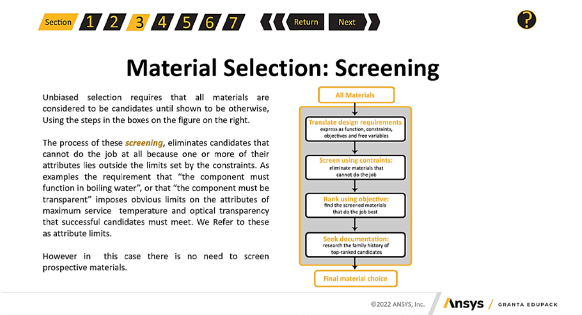
Today's students are well informed and genuinely want to contribute to the sustainability of earth and consequently to the 17 Sustainable Development Goals that the United Nations has set forth in Agenda 2030. The resources have embedded examples that provoke such conversations and engage the students.

2.4 Fourth, Make it a Package to Help in Teaching

We know from analytics that professors extensively use lecture notes, quizzes, exercises, micro-projects, case study-based projects, etc., to help students learn. So, the team has prepared teaching packages exclusively for professors, providing solutions to the exercises, quizzes and microprojects that the students cannot access. This helps new teachers and experienced professors alike to spend less time in creating examples and frees up more time to prepare for teaching.

3 RESULTS

3.1 Visually Engaging and Interactive Resources: An Example



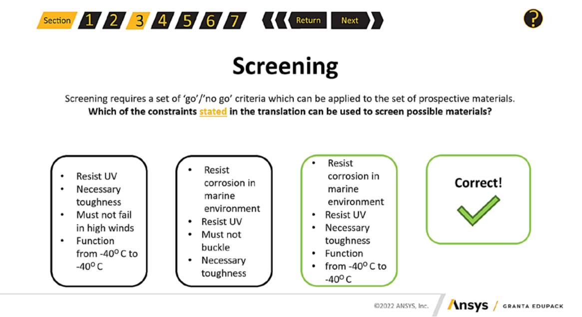


Fig.1 Students can click a box to assess knowledge *Fig. 2 The test takes to right or wrong answer*

3.2 Complete Teaching Packages

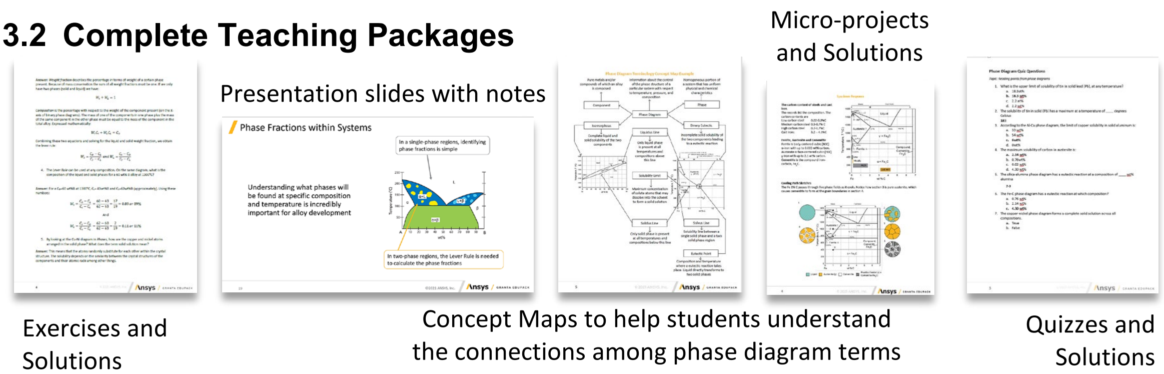


Fig. 3 A complete introductory teaching resource package contains lecture notes, micro-projects, concept maps and exercises besides other components.

3.3 Measure of Success: Quantitative

The team measured the likability and usage of every resource on the website [4]. Among the unrestricted access resources, visually appealing, active learning-inducing infographics had highest download of 11957 in the 2-year period examined, followed by booklets, such as Material Property Data for Engineering Materials, with 10460 downloads. All interactive examples and advanced industrial case studies (often used for final or capstone projects) had high download numbers, around 7000-8000, with the Industrial Case Study on Automotive Door Panel having the highest amongst those (8289).

3.4 Measure of Success: Qualitative

The team held a number of Users Group Meetings (UGMs) and surveys to know the usage of the resources and ways to make those better. From these UGMs, it was clear that professors were keen on using the, so called, advanced case studies, whereas the students preferred engaging, interactive, colourful documents. In recent years, there is an increase in requests for sustainability related resources that also include societal impacts from materials sourcing, product manufacturing, design, supply chain management and reuse of products.

4 SUMMARY AND ACKNOWLEDGMENTS

Addressing students' learning styles during teaching, thus adapting to a teaching style that engages students is essential. Today's students, especially those who study engineering, are digitally savvy and environmentally and socially conscious. A variety of teaching resources show that addressing all of these is possible through thoughtfully crafted, visually and interactively engaging and scientifically accurate resources that, based on the content, can be used for teaching and learning.

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The UPV Design Factory. What is it good for?

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ABSTRACT

Universities have the challenge and responsibility to society to train good professionals. Moreover, they must adapt to current demands. They must do so not only by improving the contents of the different degree programs but also by incorporating new programs and activities that help students develop soft skills, teamwork, connections between the university and real life, making them the best professionals and excellent citizens.

To this end, in 2014, the UPV launched a program called Design Factory to channel and frame initiatives carried out by students to develop their prototypes and participate in student competitions.

The program facilitates the creation of interdisciplinary learning communities in which students are committed to their goals, their teams, and the university. The program's spirit is to encourage learning in an eminently practical way. Students have to lead the projects, attract and select candidates, manage a budget, carry out their activities and try to achieve their goals, which involves many soft skills.

For the program's operation, the university provides a team including management, technical and administrative staff, facilities, and economic endowment to the teams to carry out their activities. Funds are distributed in terms of the quality proposal, impact on the university, and results from the previous edition.

More than 2,000 students participate in more than 60 engaged teams whose coordinators show high satisfaction with their roles in the current academic year.

1 INTRODUCTION

1.1. UPV Design Factory

Since 2014, the Universitat Politècnica de València (UPV) has been promoting projects managed by students with the tutoring and support of professors.

The students motivated the creation of this program, asking for support to participate in specific championships such as Formula Student, in which students are responsible for designing and building an F1 prototype for a students competition.

Later in 2018, the UPV the Design Factory Program was officially approved, describing it as a training program that aims to support the extracurricular activities carried out by the university's students. These activities are characterized by contributing to the student's comprehensive development and facilitating the acquisition of transversal skills, self-learning, and new teaching-learning methodologies that promote training based on practice and integration of students in the university community from a broad perspective.

In 2020, with previous years' experience, the UPV approved the Rules for the Design Factory Program, which includes the operating guidelines. The regulations include the functioning of the groups to focus on the objective, that is, students learning by doing.

1.2. Design Factory promotes student learning

Aalto University (Finland) was the pioneer in promoting design factory groups in higher education.

The origin was creating an ideal working environment for students to develop their projects autonomously, with the collaboration of researchers and professionals.

This model of work teams has been exported to other universities, and after several years of experience, it can be affirmed that they contribute to improving students' learning and provide them with skills that often have no place in the curricula of the bachelor's degrees [1].

These skills developed are often called cross-curricular learning outcomes and undoubtedly have great importance in graduates' employability at the end of their studies [2]; we can highlight the development of skills related to teamwork and leadership, among others. On the other hand, belonging to these teams forces students to work in interdisciplinary, competitive, and complex environments, which leads to the development of skills that employers demand and are necessary for entrepreneurship [3,4,5].

For all these reasons, belonging to a Design Factory team will significantly impact the graduates' professional life development.

2. OPERATION OF THE PROGRAMM

The program's direction promotes that the students decide the topic, the project, and, if case, the competition they wish to participate in. The regulations require interdisciplinary teams, with a minimum number of members and a professor tutor who can supervise and help in the work they develop. The fact is that projects are complex and often require the help of multiple professors, which makes learning more valuable.

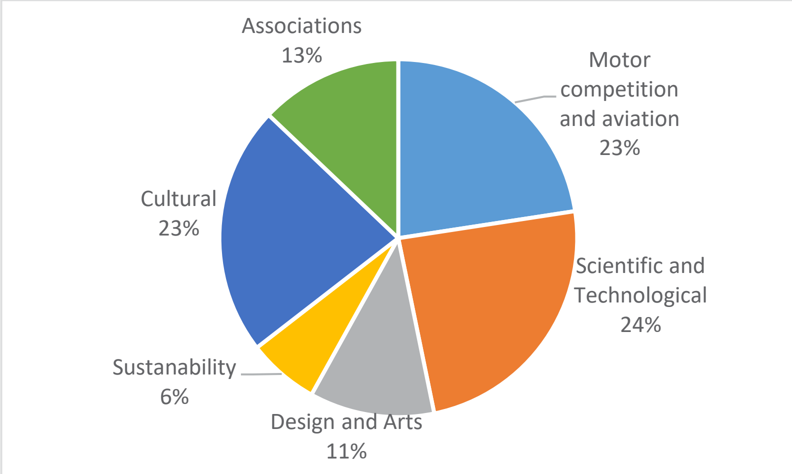
Two calls for funding are made per year, coinciding with the beginning of the course and the year. However, every year, projects are becoming more and more complex, consequently needing more budget, so teams need to seek sponsors to help cover the expenses of their projects, getting good partners. Collaborations can be both economic and in kind. These sponsors can also become partners of the university in different ways.

Each team has a lead captain who is the interlocutor with the program's direction. However, most complex teams usually have several coordinators who assume the direction of communication, management, design, and construction tasks.

3. RESULTS

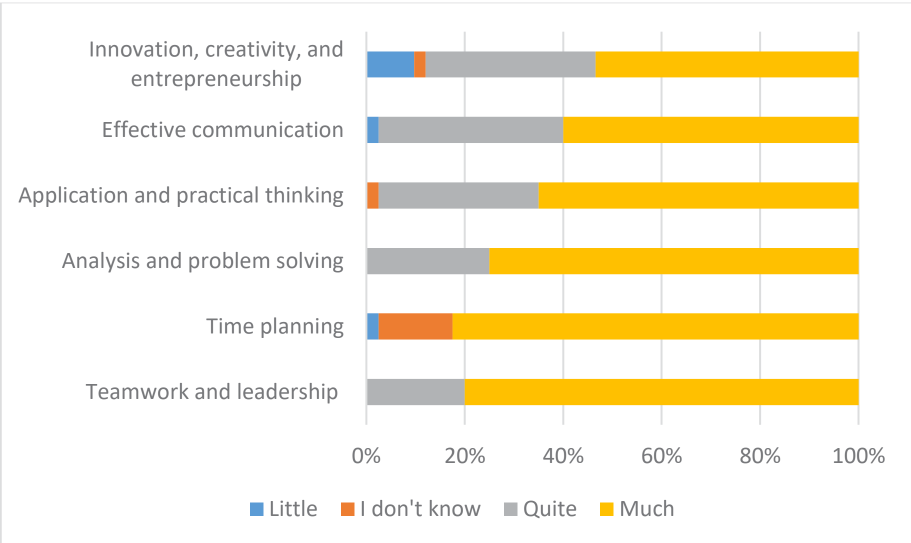
The most immediate successful result is the number of teams enrolled in the program and that has increased from 18 in the 2017-2018 academic year to 62 in the 2021-2022 academic year, distributed in the following categories:

Fig. 1. Design Factory Teams in the 2021-22 academic year by category



In addition, in a recent survey sent to students about their experience leading the team, they answered regarding the soft skills that they considered had developed more, the following:

Fig. 2. Soft skills developed by students' perception



Furthermore, 87.5% of team coordinators believe that being part of a team improves their readiness to enter the job market, and 72.5% of the coordinators consider their expectations met.

Lastly, the answer to whether they would recommend students join a Design Factory Team was 100 % positive.

4. CONCLUSION

There are many benefits to belonging to a Design Factory team, despite the challenge of making it compatible with formal learning. Students can put their knowledge into practice, improve their soft skills, interact with peers from other disciplines, and participate in events and competitions with other students, providing them with a well-rounded education.

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THE INCREASING NECESSITY OF SKILLS DIVERSITY IN TEAM TEACHING

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ABSTRACT

The advantages of including technological tools, for example dynamic graphing software, into the teaching and learning of technical subjects have long been recognised. Using such tools effectively in the classroom is at least partially constrained by the teacher's knowledge and skills. Any teaching team benefits from skills diversity and always has, however, in recent years the skills needed for effective use of the tools available are becoming more numerous and more varied. Using a range of tools for assessment, rather than for in-class teaching and learning, demands an extra burden of care. Using an example from our own recent experience we illustrate the need for skills diversity in teams teaching and raise questions related to traditional assessment in mathematics.

1 INTRODUCTION

The value of technological tools for the learning and teaching of mathematics has long been recognised, from early computer algebra systems to today's powerful visualisation and computational packages. Over the past two decades such tools have gone from fringe elements of the classroom to being core features. GeoGebra, for example, is an excellent package to use in vector calculus as it requires no coding experience on the part of students or teacher and contributes valuable 3-dimensional visualisation. In specifically engineering contexts another example is LTspice simulating software, which lets the user model the behaviour of simple and

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complex (analog) circuits. Programming languages specific to engineering, such as MATLAB, are also widely used.

Many examples can be found in practice and in the academic literature on using these tools in the classroom for active teaching and learning purposes, yet far fewer examples can be found of them being used in assessment. Mathematics exams continue overwhelmingly to be closed book, written individually in a secure environment, without access to electronic devices. The reasons for not including digital tools in an exam are many and varied. For example, do we wish to assess whether our students can solve integrals by hand, or visualise and draw surfaces and curves without technological help? Additionally, tools that require access to the internet have inherent security concerns.

So why did we choose to carry out a technology mediated exam? The pandemic experience, forcing us to shift into uncomfortable spaces and to accept hitherto unacceptable options, also forced us to look at how we assessed in a new light. In the case of vector calculus we came to recognise that access to graphing software, powerful calculators and many reference materials could be seen as a boon.

This short paper forms part of documenting a larger project of exploring the design journey of shifting from traditional assessment to technology-mediated assessment in vector calculus. Elsewhere [1,2,7] we have discussed design principles, consequences for pedagogy and comparison of student results.This paper contributes to the conversation on team teaching in mathematics, highlighting the need for explicit roles to be filled by the team members. We provide context of the technology-mediated assessment project, discuss certain aspects of team teaching with special emphasis on roles, then analyse our practice in terms of roles and team teaching practice.

2 CONTEXT

Our vector calculus course runs February-April. In March/April 2020 and again in 2021 we were forced to have our vector calculus exams written remotely, at home, necessarily open book. Despite the challenges we experienced we recognised the value of allowing students to use the many powerful tools available to them. We were forced into a position of setting questions that assessed for higher order skills and conceptual understanding instead of falling back on questions that were more procedural or relied on memory. We have written about this elsewhere [1,2].

There are distinct disadvantages to the mode we were forced to accept in 2020 and 2021, primarily security. Now, in 2022, we are returning to writing the exams under secure circumstances but aim to retain the best aspects of the previous two years. Before the pandemic students wrote the exam without a calculator or notes. Now we allow a formula sheet, a graphical calculator and use of a Chromebook virtual environment including access to GeoGebra, Symbolab and course slides. GeoGebra is 2d and 3d graphing software and Symbolab is a powerful online calculator.

3 TEAM TEACHING

3.1 Team teaching roles and phases

[3] observe that the complexities of higher education are increasingly making team teaching a necessity rather than a choice. For example blended learning (in which learning activities are a blend of online and face to face) requires a teaching team with a variety of roles and skills [4] and interdisciplinary and multidisciplinary programmes require teachers to work in teams [5] to “collaboratively design courses that allow for the integration of various disciplines” [5: p. 198].

Clear roles for the members of the team are important [4,5]. [4] warn that failing to clarify roles incurs a “risk of assuming a perceived understanding around expectations” [4: p. 869] which can impact teaching practices. The role of leader within the team is of particular importance [4,5] although that role can rotate within the team [6]. Members of the team assume roles appropriate to their knowledge and skills and to the needs of the pedagogic environment. Beyond the roles of the teaching team, [4] observe that the students themselves adopt roles, such as active contributor, observer and evolving expert.

[5] outline three phases of collaborative course design, which are “preparation (phase 1: planning), teaching (phase 2: enactment) and evaluation (phase 3: reflection).” (p. 198) They advise that in phase 1 pedagogic needs must be prioritised over practical decisions and in phase 2 adaptation to the needs of the students must be possible. Our short paper contributes to the reflection phase of our design project.

3.2 Our team roles and practice

Our team was made up of the first author, a co-teacher and a member of the university’s e-assessment group. The first author assumed the leadership role. She was responsible for setting the exam, facilitating communication within the team and ensuring that the students were well informed about the assessment with opportunity to practise the skills required. The second member of the team co-taught on the course and advised on exam design. The third member of the team was an e-assessment specialist. He managed the Chromebook environment and liaised with the technical team and exam venue management.

Our team teaching practice [4] began a year before the exam with the formation of the team, planning, and booking use of the university Chromebooks. During the enactment phase the two teachers on the team incorporated use of the digital tools into the teaching and learning resources. They designed the exam questions, aiming for assessment of conceptual understanding and higher order thinking skills, and “stress tested” them using the digital tools. On several occasions the whole team met to consider the design of the virtual environment. The first author and the e-assessment specialist communicated with technical staff and venue management.

The three key activities were exam design, technical set up and communication. These three activities were performed competently, thoughtfully and timeously. Nothing should have gone wrong and yet something almost did.

3.3 A flaw in the system

The second author was a student taking the vector calculus course. Through active engagement with the digital tools he took on the impromptu role of evolving expert [4] and became aware of characteristics of the tools which had implications for the security aspect of the exam. He familiarised himself with the full extent of the weaknesses in the system and devised a plan for closing the security holes. He informed the first author of the situation and thereafter the virtual environment was redesigned to make it more secure.

Both Symbolab and Geogebra allow users to work remotely in groups with one another, which would jeopardise the security of the exam. GeoGebra furthermore has the option of uploading documents into one's profile, thereby creating inequitable open book environments. We must be clear about calling certain features of the tools we had chosen to use “weaknesses”. These are not weaknesses of the packages overall, they are rather an impediment to secure, individually-written exams.

The exam proceeded without a hitch. After the exam the second author remained in the exam venue, testing the security of the virtual environment in a variety of ways.

We are now in phase 3 (reflection) of the design process, which includes reflecting on what went wrong and how we could have avoided it. We are reminded of [4]'s warning that roles should be clarified to avoid perceived expectations. The teachers implicitly assumed all technical considerations to be in the purview of the e-assessment specialist, yet he (quite accurately) did not consider testing for security flaws in the digital tools to be part of his mandate. The exam itself was “stress tested” for use in the planned virtual environment, yet the environment itself was merely approved for looking as the team expected it to look; it was not stress tested for flaws or weaknesses.

In hindsight we recognise that what was missing from the team was someone with the role of stress testing the virtual environment, having both the technical skills to do so and close familiarity with the digital tools themselves. How this gap in the team might have been avoided would have been to explicitly identify the roles needing to be filled and to ensure that the team could fill those roles. A scenario planning brainstorming session early in the project would have been valuable.

4 CONCLUSION

Many higher education environments require the skills of more than simply one lecturer with a whiteboard, such as blended learning [4], interdisciplinary modules [5] and technology mediated assessment. Team teaching (or team working) [3] is called for in such cases. With the ubiquity of digital teaching and learning resources and tools, the recent increase in remote learning and a diverse student body, all embedded in a world facing local and global challenges, we suggest that not only is team teaching of vital importance, but the team should be carefully constructed to embody the diversity of skills required.

We have found the framing of "roles" useful for analysing our practice and how it (almost) failed. We suggest that, upon embarking on a team taught project, an explicit effort is made to identify all necessary roles and to ensure the needs of those roles can be met by the team. This could perhaps be achieved by a scenario-planning brainstorming session. Everyone on the team needs to be aware of their roles to avoid perceived understanding of expectations.

5 SUMMARY AND ACKNOWLEDGMENTS

Better informed on how to proceed with team teaching we are left with some fundamental questions. Should we even be shifting towards technology-mediated assessment given inherent security concerns? Should we only use software designed for assessment purposes in that case? Should we be assessing "securely" at all, that is, should we rather assess mathematical proficiency using groupwork or take home assignments? These are all questions informing our work as we aim to problematize and improve assessment in vector calculus.

In closing we observe that our contribution answers the call of [4] to include students as co-authors and co-researchers in the scholarship of teaching and learning. We gratefully acknowledge Tugce Akkaya and Amanuel Gecer for their invaluable contributions to this project. For further information on this project, including comparison of results, we direct the reader to [1], [2] and [7].

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An argument for incorporating sociological approaches into phenomenological analyses in engineering education research

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ABSTRACT

Despite numerous research studies that have examined why women are underrepresented in engineering education programmes, the phenomenon is still not fully understood, and no effective general solutions have been found. In this context, analysing women's experiences in engineering education can provide insights regarding the evolution of the students' learning strategies and socialization processes as well as contextual factors that influence their choice to persist in or leave their courses. This paper explores the pertinence of enhancing phenomenological analyses conducted in engineering education research by incorporating sociological perspectives, drawing on sociological studies that explore the relationship between gender, STEM education and persistence in STEM courses. The aim is to contribute to building a conceptual framework that, on the one hand, captures lived experience in engineering education and, on the other hand, analyses the social settings around engineering itself, i.e., the objectively significant circumstances, that condition female students' attitudes, behaviours, and expectations towards persisting or not in engineering courses. Conclusions suggest the conceptual framework around *subjectively meaningful experiences,* proposed by Alfred Schutz, who followed the phenomenological school of thought initiated by Edmund Husserl, might be useful in understanding not only (a) the representations

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of the subjective social world for women in engineering education (that induces feelings of identification, security, symbolic values, and ultimately social actions), but also (b) the intersubjective social system that structures daily life, legitimizes behavioural patterns, assigns roles, and defines group membership along education in engineering. Expanding engineering education researchers' conceptions of phenomenology, to consider more of the structural issues that influence women's experiences and choices, can help generate increasingly meaningful research findings.

1 INTRODUCTION

Researchers have identified the social cultural masculinization construct in Science Technology, Engineering and Mathematics (STEM) fields as a prominent barrier, discouraging women from choosing any of these career paths [1, 2]. Although a variety of theoretical and methodological frameworks have been used to explore those factors and, of course, to elucidate how to reduce them [3, 4], enrolment data in STEM courses continue to reflect an unbalanced representation of women, particularly in engineering fields of study, where men represented 74% of new entrants in engineering, manufacturing and construction on average across OECD countries in 2019 [5][2].

Investigation about the underrepresentation of women in STEM fields has grown, to focus not only on factors or influences related to context and historical research of gender inequity in education (e.g., sexist institutional environments, gender imbalance in the profession, cultural barriers and lack of support), but also to study women's lived experiences throughout STEM education programmes [1, 6, 7].

In this context, the objective of this paper is to contribute toward eventually building a conceptual framework in engineering education research (EER) by now introducing the phenomenological sociology approach developed by Alfred Schutz. The Schultz approach can be helpful in the development of an analytical framework that captures the subjective interpretation of the students who elaborate a body of beliefs, values, and norms from their daily life experience in engineering education, as well as the social structural constraints reflected in such experiences. This means that together, they create and continually re-create a system of social values, and that structure, in turn, curtails their choices.

2 METHODOLOGY

Several researchers [2, 6, 8, 9] have encouraged increased use of theoretical frameworks in engineering education scholarship to foster a professional field that is more inclusive and diverse. In this sense, it is relevant to develop conceptual

[2] Also retrieved from the publication's website with additional information https://www.compareyourcountry.org/education-at-a-glance-2021/en/3//default/all/OAVG

approaches that address women's lived experiences in the male-dominated world of engineering [1,7–11].

Understanding how students experience their introduction to the world of engineering makes it necessary to build a conceptual framework that allows returning to the people who elaborate (enact and create) their social environment from daily life, attributing subjective meanings to it. In that sense, phenomenology as a research method explores the essence of a phenomenon by focusing on the perspective from those who have experienced it [12]. This approach is helpful to gain a deeper understanding of the meaning of everyday experiences of women in engineering education.

This paper uses a 'scholarship of integration' approach as defined by Boyer [17] to identify methodologies and prior research that can inform our upcoming study regarding the underrepresentation of women in STEM, a topic that has been researched from a broad variety of fields of knowledge, particularly psychology and education. Drawing on sociological studies that explore the relationship between gender, STEM education, and persistence in STEM courses, the aim is to explore the pertinence of enhancing phenomenological analyses in engineering education research by incorporating a sociological approach. Below, we review recent phenomenological studies conducted within EER; later we provide background on Alfred Schutz's sociological approach of phenomenology to, finally, explore some research performed with other methodologies, where Schutz's conceptual framework happens to be also helpful to interpret their findings and results.

3 DISCUSSION

Dryburgh [1] was a pioneer in conducting research on women's experiences in engineering who used a vast variety of qualitative methods. Based on Erving Goffman's theory of symbolic interactionism and the concepts of the presentation of self, Dryburgh's conclusions stated that women engineers must show competency in the field, in addition to enacting masculine norms of attitudes and interactions. Furthermore, the educational phase constitutes a learning path, through socialization processes to manage the masculine culture into which they are entering, a competence that requires extra effort beyond what is asked to men. Dryburgh concluded that women's adaptation to masculine culture includes denial of sexism, a condition that keep hiding obstacles for women may face in engineering.

Later, in 2012, Charity-Leeke [7] conducted research on women in engineering using phenomenological analysis to find meanings of the sociocultural systems that help women succeed or that challenge them as engineers. With a sample of nine participants, her analyses generated 5 categories: gender roles and sociocultural influences; context-based learning; gender relationships; work and family; essence of women as engineer. Her main findings, similar to Dryburgh's [1], show that women in engineering seek to prove their knowledge and improve their self-confidence as part of their socialization process.

More recently, Rodriguez et al. [10] conducted phenomenological research, with a sample of 17 undergraduate students, exploring the role of religious beliefs in shaping STEM identity in Latina college students. Results show that both elements reinforce each other, but also that intersectionality of multiple “marginalized” identities may be essential to sustaining students’ interest in STEM context as ways to examine and redefine their cultural values. Likewise, Morton and Parsons [9] explored the influence of a racial and gendered identity in STEM, using the Phenomenological Variant Ecological Systems Theory to better understand 10 undergraduate black women’s perception of race and gender in STEM. Conclusions indicate that the identity as ‘black women’ is in fact a positive and protective factor for their STEM engagement and persistence.

Phenomenological research approaches have become more popular in EER, and methodological toolkits have been published to increase understanding and applied knowledge of the phenomenology. An example in 2022 has been provided by Tomko et al. [11] who developed a methodological roadmap for phenomenologically based interviewing in engineering education.

However, some of the main criticisms of phenomenology are that it tends to ignore the structural context where the phenomena happen (leading, erroneously, to an overestimation of individuals’ agency) and that commonly results are based on small samples of participants (typically fewer than 30 people). To address such problems, we propose using the theoretical and methodological frameworks based on Schutz’s postulates of an intersubjective social world. These frameworks are intend to help distil the subjective interpretation of social action, to better understand the meaning that individuals attribute to objectively significant circumstances and use to guide their behaviour and ‘projects’ [13,14].

With regard the sample size, it is worth mentioning that this paper is framed as part of a broader project, initiated at Technological University Dublin in 2014, by Professor Shannon Chance with the support of Professor Brian Bowe [8], which currently has a longitudinal data set, comprised of 72 interviews, that represents a valuable resource for phenomenological analysis helpful to generate an understanding of the lived experiences of women who chose to study engineering.

Main concepts of the social phenomenology of Alfred Schutz

In the mid 1940s the sociologist Alfred Schutz [13] revived the phenomenological tradition of Edmund Husserl [15] in an effort to incorporate social characteristics in the understanding of the meaning structure in the world of daily life. This daily reality is presented to individuals and groups as a shared world. Schutz’s phenomenological sociology made possible the transition from Husserl’s theory of a ‘conscious individual’ to a new theory about the subject acting in society [16]. Schutz provided new conceptual tools to define the social structure of the world of daily life where we, as subjects, share a language, i.e., a series of signs, that help us understand others and be understood, emphasising the concept of the intersubjective world.

Using the concept of *subjectively meaningful experiences,* Schutz [13] argued that people elaborate a body of beliefs, values, and norms to help themselves understand their reality; these form a representation of their world and work together as a system of meanings that structure daily life, legitimize social relations, and help people assign roles. The system also induces feelings of identification, security, norms, and symbolic values within individuals, ultimately influencing their social actions. This postulate is helpful for understanding socialization processes that define the sign systems used by engineering students, conditioning their behavioural patterns and how they create membership groups.

In line with Schutz's concept, Eisenhart and Allen [19] reported that the socio-cultural system in STEM education, mainly in engineering and computing, constantly plays out in various types of exclusions that adversely affect many young women of colour. These include unequal opportunity structures, negative discourses and stereotypes, and interactions that marginalise certain groups of people. As a result, although a woman might have interest, ambitions, or the ability to pursue STEM fields, her socio-cultural system might carry expectancies that hinder her sustained engagement. Moreover, according to Dancy et al. [20], often members of privileged group of students in STEM education (white men) are unaware of how race and gender affect students' experiences as STEM majors. Exclusionary factors are frequently invisible to those not affected by them.

Increasing diversity in STEM education requires not only understanding how students experience membership but, also subjectively, how the group to which they belong plays a role in the formation of the sense of self held by individuals. This sense of self informs the adoption of behaviours of the group, demands certain norms to be respected and expectations to be fulfilled.

Schutz's system of meanings also explains how individuals make sense of and understand, organise, or order their experiences of time. Schutz [13] argues that 'memories' are established and shared by members of a group because the intersubjective world of everyday life was there before them, and it will continue to exist after they leave. The 'future' provides a common frame of reference for the projection of individual actions. Thus, the system of meanings links individuals to both the past and the future – linking them to their predecessors' and successors' sense of belonging to the group. In this way, the community transcends the finitude of its individual members.

That aspect surfaced in research by Smith et al. [18] who, referencing the concept of social capital (i.e., resources obtained from relationships), found that students' social networks are key factors influencing their persistence in engineering through the provision of support and information. Smith's team therefore suggested that women and underrepresented and minoritized students should be encouraged to participate in sectorial organizations at very early stages of their majors. Likewise, Turnbull et al. [2] identified factors explaining why female students are underrepresented in physics (while in the life sciences women are more equally represented). They stated that "individuals who begin their life with more capital, be that through inheritance or immediate exposure to the dominant culture, will be more able to gain personal and social advantages" (p5).

4 CONCLUSIONS

A group's culture, represented as symbolic systems, can be characterised as a set of objectified values. These objectified values are continually defined and redefined by the group, as members work to make sense of their lives, so that they can apprehend and transmit ideas. The symbolic system does not represent a permanent and intact code, but rather a constantly changing construction reinterpreted by individuals who adjust concepts to reflect new daily life experiences. In this sense, Schutz's conceptual frame might be appropriate in the exploration that retrieves the voice of women who, during their time at university, have also experienced the metamorphosis of engineering education.

Although engineering education is the result of a cultural elaboration, it has a subjective meaning for those who experience it, and therefore phenomenology is a pertinent method to analyse and interpretate qualitative data about the everyday experiences of women. Explanation of the social world demands understanding what the social world means to the people within it, and what meaning people assign to their actions within it. In that frame, phenomenology contributes with a useful methodology, but the approach used in EER can be further enhanced by incorporating more sociological perspectives in the lineage of Schutz [14] and Husserl [15]. Using sociological perspectives can expand the research produced within EER to consider structural aspects of the shared experience that using phenomenology alone has tended to overlook.

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SCALING-UP PRACTICAL TEACHING: THE ONE-THOUSAND STUDENT WEEK

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ABSTRACT

Multidisciplinary Engineering Education (MEE) is a specialist department at the University of Sheffield, dedicated to the practical teaching of all the University's engineering students. To deliver this, MEE has a unique building comprising workshops, study spaces, and most importantly 16 laboratories offering a spectrum of lab activities to a population of approximately 4000 students.

Effectively managing our resources (staff, equipment, lab space) is challenging due to the heavy demand of student numbers, but an effective approach allows at-scale teaching while ensuring the institutional vision of teaching excellence.

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This paper presents the approaches used to optimise the "Cantilever Truss" activity, taking place in the MEE Structures Lab. Over the last 5 years, several key stakeholders helped develop this activity's efficiency and scalability which include academics, technicians, MEE's timetabling manager and teaching assistants.

The key factors in developing the activity were; tuning the learning outcomes for transferability across 3 major courses, optimising the activity tasks for constructive alignment, cross-departmental timetable management, and specialised training for the teaching assistants.

The improvements are measured by several teaching design parameters (teaching hours, student numbers, lab "up-time", cross-disciplinarity), and considered alongside information gathered from teacher reflection forms as well as informal student feedback. This paper discusses how the approaches used have yielded value in optimisation and improvement, before suggesting general elements that could be useful 'take-aways' for different contexts and institutions.

1 INTRODUCTION

The Faculty of Engineering at the University of Sheffield attracts hundreds of new students every year. With an increasing student population, large lecture theatres hosting up to 400 students make at-scale lecturing possible. However, it is not economically viable to have sufficiently large laboratories to support at-scale *practical* teaching. For example, one of the larger teaching labs for engineering at Sheffield (Structures Lab) has an actual capacity of 40 students. The labs (16 in total) are all housed in a state-of-the-art specialist department, Multidisciplinary Engineering Education (MEE) which is dedicated to practical teaching [1]. The limitation on lab capacity is overcome by repetition so that lab activities get delivered repeatedly until all the students in a given cohort have worked through them. For example, with a 200-student cohort, it would take 5 sessions for the cohort to complete one activity. To scale up this process, it is essential to optimise the use of resources (i.e., increase student numbers, minimise staff hours, maximise lab space and equipment usage) [2] while introducing appropriate quality control measures to ensure teaching excellence [3]. In particular, this study presents the gradual actions taken over 5 years to scale up the "Cantilever Truss" lab, focusing on three areas of intervention: the lab activity, timetable/resource management, and quality control.

2 METHODOLOGY

2.1 Teaching Activity

The "Cantilever Truss" lab teaches students (first year, first semester) the basics of load paths and load distribution within a simple truss structure. The optimisation process of this lab was guided by the constructive alignment philosophy [4] thus ensuring that all intended learning outcomes (ILOs) were catered for in the teaching/learning activities (TLAs). With this in mind, ILOs and TLAs were finely tuned, and the redundant or ineffective elements were removed. "To demonstrate the Principle of Superposition, as applied to forces and deflections of linear systems" was one of the original ILOs in 2017. However, a review of the programme material showed that students would not cover “deflection of elastic members” in lectures before the time the lab was scheduled. Dropping the “deflection” component of this ILO ensured better alignment between lab and lecturing material. This also meant students would not need to take deflection measurements, resulting in a significant reduction in the session time. To further reduce session time and to support student engagement, highly repetitive elements of the TLA were dropped. For example, the number of times students applied a load and took internal force readings was halved (from 10 to 5 repetitions) while still gathering a sufficient dataset to draw analogue conclusions. The optimised session time was pursued over the years via trial and reflection. ILOs deemed as low value (“Use a spreadsheet to collect data”) were also removed to focus on the core theoretical ILOs (“Qualitatively determine the distribution of internal forces in a truss structure”). In addition, online digital learning (pre-lab activities including a mandatory quiz) was employed to ensure that students arrived well prepared for more efficient working.

Once the TLA was sufficiently streamlined for Civil and Structural Engineers, it was advertised cross-departmentally. Due to the large overlap of basic concepts across several disciplines, the Mechanical, Aerospace, and General Engineering Departments each decided to include this TLA within their programmes.

2.2 Management

Since MEE opened in 2015 it has served across departments and disciplines in the engineering faculty. Initially, individual departments would dictate MEE weekly lab slots (a slot is “Monday p.m.” or “Thursday a.m.” for example) which often resulted in clashes or having to run the same activity over consecutive weeks, inefficiently. This, in turn, meant that lab time was largely spent being idle or setting up/taking down rather than teaching. To make labs more efficient, in 2021 MEE started timetabling the weekly lab slots for all departments, based on which of the MEE labs each department would primarily use. This averted potential clashes and allowed all departments to use the same lab within a *single* week, greatly minimising downtime.

2.3 Quality Control

The delivery of at-scale teaching in MEE hinges upon Graduate Teaching Assistants (GTAs), which make teaching high numbers of students possible with limited academic staff. To ensure excellence in teaching is retained despite the cyclical turnover of the employed GTAs, a new GTA training system was introduced in 2018 [5]. This training method supports GTAs ongoing pedagogical development and provides lab-relevant technical training.

3 RESULTS

Table 1 shows key data regarding the delivery of the Cantilever Truss lab over the last 5 years and their projection for the future.

Table 1. Teaching Delivery Data for the Cantilever Truss Lab

Year	Number of Modules	Teaching		Sessions		Teaching time (hr)	Lab usage (%)	Timetabled number of students	Students taught per-hour
		weeks	days	Number of	duration (hr:mm)				
2017	1	2	2	3	3:00	9	56	180	20
2018	1	2	3	5	2:00	10	42	120	12
2019	3	2	5	16	1:30	24	60	640	26
2020*	4	2	8	44	1:15	55	86	880	16
2021	5	1	5	23	1:30	34.5	86	920	26
Future	≥5	1	5	28	1:15	35	88	1120	32

* In 2020, due to the COVID-19 pandemic, the lab capacity was reduced to 20 students.

The optimisation of the TLA allowed for more than halving the session duration. Observing students suggested that this intervention was pedagogically effective as shorter sessions promoted students' focus and engagement. On the other hand, overly-short sessions (2020/21) caused the slower groups to struggle to complete all TLAs, potentially impacting students' achievement of the ILOs.

The centralised timetabling management was instrumental to the broader incorporation of the activity in different programmes (5 modules) as well as to the improved utilisation of the lab space. In 2021, 23 Cantilever Truss lab sessions were taught in just 5 days of a single week, maximising the teaching time (86% of the total weekly slot time was used) and minimising set-up and downtime.

In addition, the number of students taught increased more than fivefold (180 to 920) while the number of students per academic hour increased by 30% (20 to 26). This suggests that the implemented strategies were highly effective at scaling up teaching, with a secondary benefit to the usage efficiency of staff time. The drawback of having more students is the increased teaching load on staff. This was mitigated by employing more GTAs per session (up to 4). The introduction of a professionalising GTA training allowed staff to delegate teaching delivery without impacting its quality.

In the future, to accommodate a growing student population, this lab activity could be further streamlined and potentially delivered to over 1100 students in a week.

4 CONCLUSIONS

The Cantilever truss lab represents a 5-year process to scale up practical engineering teaching using lab activities. Some elements herein implemented for the Structures Lab will be employed by other MEE labs in the future.

- Teaching activity: minimising redundancy and promoting engagement.
- Management: streamline timetabling to maximise lab usage.
- Quality control: increase skilled teaching capacity by employing and training GTAs.

The philosophy underpinning such elements could be transposed to different contexts and used as a guideline also by other institutions aiming to develop their lab teaching.

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A Case Study of Engineering Instructor Adaptability Through Evidence of Course Complexity Changes

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ABSTRACT

Use of a wide array of teaching practices and strategies has been shown to improve students' conceptual understanding, appeal to a diverse set of students, and preparation for engineering work. Adaptability theory provides a lens for understanding changes instructors make and can be useful for conceptualizing faculty development going forward. How an instructor's adaptability plays out in the face of new demands lies in the complexity of the courses they teach. Course complexity refers to both the extent of the array of teaching practices/strategies used in a course and the challenge to implement those practices/strategies. The purpose of this paper is to begin to examine what information is embedded in syllabi that may be used to quantify complexity via a Course Complexity Typology. This work is a case study of a single instructor-course pairing and their course syllabi from multiple semesters.

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1 INTRODUCTION

The use of a wide array of teaching practices and strategies (WATPS) has long been promoted as a means of improving student learning, including diverse learners, and preparing the next generation workforce [1-3]. Meantime, the COVID-19 pandemic shutdowns and long-term response forced instructors to adapt to the crisis as instruction moved from in-person to remote to modified-in-person delivery. This work is part of a larger project to investigate the long-term impact of events, such as the pandemic, on engineering instructors' employment of a WATPS through the development of a typology for course complexity. The purpose of this short paper is to begin to examine how syllabi may be used to reveal changes in and the extent to which a WATPS are employed by engineering instructors prior to and during the COVID-19 pandemic.

Adaptability is the theoretical framing of this study. It is novel in its focus on external motivators and therefore differs from traditional change models utilized in engineering education. Adaptability is defined as "the effectiveness of an individual's response to new demands resulting from the novel and often ill-defined problems created by uncertainty, complexity, and rapid changes in the work situation" [4, p. 3]. In this study, the external motivator for change was the COVID-19 pandemic.

Course (class) complexity accounts for the extent to which a WATPS are used in a course. The course complexity typology also considers the level of challenge for an instructor to implement each teaching practice or strategy. Practices are a focus as teaching quality is dependent on the teacher's beliefs, knowledge, and practices [5]. Practices can be directly accounted for via artifact measures such as syllabi and learning management software.

One assessment of college teaching is the Teaching Practices Inventory (TPI) [6]. The TPI provided insight into practices that might be captured from syllabi including course information (learning goals), supporting materials (e.g., notes, videos, readings), assignments (nature and frequency), other (student choice, reflection, diagnostics).

2 METHOD

Case Study Methodology

A case study approach was utilized in this research as it allowed for a deep dive into a single participant's experience [7]. The unit of analysis for the case was an instructor-class pairing, meaning one instructor and one class they taught.

Participants & Setting

The setting for this study is a College of Engineering at a research intensive university in the United States. The instructor-class case was selected based on the instructor teaching the same class over a period of time including pre-COVID, initial COVID-shutdown, and sustained COVID impact on instruction.

Data Collection & Analysis

Class syllabi were collected for all undergraduate engineering classes taught in the period of Fall 2019 (pre-COVID) through Spring 2022. Fall (Fa) typically occurs mid-

August to mid-December and Spring (Sp) occurs mid-January to mid-May. Analysis of the syllabi was conducted by two researchers. The TPI [6] inspired coding scheme consisted of five categories: (1) Class Descriptors; (2) Student Collaboration; (3) Communication of Student Performance; (4) Opportunities to Learn; and (5) Learning Supports for Students. Within each category, at least three codes were utilized to try to capture aspects of complexity change.

3 RESULTS

Course Descriptors

For the case selected, the instructor taught a lower division required engineering class each semester from Fall 2019 through Spring 2021. A total of five syllabi were collected; these included two from Spring 2021 (original and revised for the COVID shutdown). The class was a lecture/lab class. The addition of a second section (offering) in Fall 2020 expanded the enrolment and teaching assistant support for the instructor. The delivery mode for this class was in-person (Fall 2019 and Spring 2020 prior to COVID shutdown), asynchronous (Spring 2020 COVID shutdown), in-person (Fall 2020), and online synchronous (Spring 2021).

The learning objectives were reworded in Spring 2020; however, these changes did not imply a change in learning expectations. The number of Accrediation Board for Engineering and Technology (ABET) 1-7 outcomes addressed by the course dropped from four Fall 2019 (Fa19) to three Fall 2020 (Fa20) to two Spring 2021 (Sp21), retaining problem formulation (STEM content) and experimentation and losing teaming and learning strategies use. The only integration of the learning objectives through the class activities was related to the technical content.

Student Collaboration

Student Collaboration are activities that require students to work with each other including in teams and/or groups and in and out of class. Across all syllabi, there was no indication of teamwork activities and no out of class group assignments. In-class group assignments that pertained to the labs were present on the Fa19 and Spring 2020 (Sp20) syllabi but were absent as of the Spring 2020 Covid-revision (Sp20rev) syllabi and never re-appeared.

Communication of Student Performance

Communication of Student Performance includes the transparency of student expectations and grading criteria, student access to their performance in the course, and provision of feedback. Across all time periods, there was no change in the articulation of a grading scheme, how the course grade letter was assigned, or in how academic integrity was described (standard language with course specific consequences for violations). The number of grading penalties and leniencies (typical grade deductions on assignments) increased across the data collection period. In Fall 2019, there were three instances of grading penalties which increased to six on the Sp20 and Sp20rev syllabi. Grading penalties reached a total of seven on the Fa20 and Sp21 syllabi. Leniencies followed a similar pattern increasing from one on the Fa19 syllabus to two on the Sp20 and Sp20rev syllabi to four on the Fa20 and Sp21 syllabi. Prior to Fall 2020, there was no indication that feedback would be shared with students. Starting in Fall 2020 and into Spring 2021, an indicator of feedback (posting of exam averages) was present.

Opportunities to Learn

Opportunities to learn are indicated by both the frequency and variety of assignments and the contribution these opportunities made to the class grade. The frequency of assignments (weekly), variety of assignments (homework, lab work), and the graded components (homework, quizzes, lab work, class participation) remained the same across all syllabi. Homework became a larger contributor to the class grade (reflecting a reduced number of quizzes) during the COVID shutdown (Sp20rev). The change in the homework and quiz contribution to the class grade remained thereafter.

Learning Supports for Students

Learning Supports for Students are focused on the ways that an instructor provided guidance to students for learning and includes items such as class schedule, available personal supports (e.g., for mental health) and learning supports (e.g., for writing), technology that supports learning, and means of communication (Table 1).

Table 1. Summary of Learning Supports for Students

Coded Dimension	**Summary of Indicators**
Class Schedule	• Topic-list (Fa19–Sp20) • Meeting time based (Fa20)
Personal Supports	• Mental Health resources added (Fa20–Sp21)
Learning Supports	None
Assignment Descriptions	Format and submission logistics
Expectations	• Note on effort (Sp20–Spr21) • Note on classroom culture (Sp21)
Justifications	Links required presentation of work to professional practice (Sp20-Sp20rev)
Office Hours	• Location change: in-person (Fa19–Sp20) to web-conferencing (Sp20rev-Sp21) • Hours increased: 5 (Fa19) to 15 (Sp21)
Student Communication	Email (all semesters); discouraging email through the learning management system (LMS) (Sp21)
Instructor Communication	• Quiz topic announcements (Sp20rev) • Delivery mode updates (Sp21)
Technology	• LMS (Fa19-Sp21) • Web-conferencing (Sp20rev–Sp21) • Clickers and Plagiarism detection added (Fa20-Sp21)

4 SUMMARY

Course descriptors overall appeared to indicate a reduction in course complexity as links to teaming (ABET 5) and learning strategy use (ABET 7) are removed from the syllabus. But in fact, their removal was a better reflection of what was actually being taught in the class. Development of students' teaming skills and learning strategies were not found within any of the syllabi. Student collaboration was reduced due to the elimination of group assignments; however, this reflects the impact of having to teach remotely.

Communication of Student Performance in terms of penalties and leniencies adds complexity to assignment grading but detracts from students' learning as it focuses students' attention less on learning and more on points. There is a tension here in the provision of leniencies which promote a feeling of fairness in the class and penalties which force compliance and assimilation that some students might not understand and promotes a feel that grading is arbitrary.

Opportunities to learn were consistent from week to week (e.g., homework, labs) but perhaps limited in variety which limits the kind of learning objectives that can be integrated.

There are several artifacts related to COVID seen within the Learning Supports for Students that may indicate an increase in course complexity. Technology use increased overall and appeared to have a ripple effect on the number of office hours which were conducted via web-conferencing starting in Fall 2020. This increase in hours allowed students more access to the instructional team. The level of transparency of course expectations and justifications were found to be unstable as they were only sometimes present. Justifications disappeared in Fall 2020 while at the same time leniencies and penalties further increased. The removal of justifications may indicate that the instructor became increasingly focused on managing student behaviours during COVID versus connecting course practices to the overall bigger picture of engineering practice.

Overall, the current work outlined was helpful in identifying indicators of a WATPS that could be gleamed from a syllabus. The challenge ahead is to connect the highly nuanced class changes that can be gleaned from a series of syllabi to the literature on effective teaching practices and strategies. Mapping these changes will lead to a robust course complexity typology.

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TEACHING ADVANCED QUANTITATIVE TECHNIQUES THROUGH A COMPETITIVE PROJECT

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ABSTRACT

Heuristics, metaheuristics and matheuristics are quantitative techniques that can be used to solve complex combinatorial optimisation problems for many engineering applications (industry, logistics, supply chain, scheduling, services, etc.). The course Quantitative Methods of Industrial Process Management II from the Master's Degree in Industrial Engineering of the Technical University of Catalonia addresses such topic. The course is organised into 3 session typologies: (1) master classes, where lecturers provide students the theoretical concepts; (2) practical classes, where students solve small-size problems based on real cases; and (3) competitive project, which is the core of the evaluation. On this regard, a real-based combinatorial optimisation problem is provided and, in 3-member groups, students have to develop an ad hoc (meta/math/hiper)heuristic, based on the theory concepts, and code it with standard language (Python, Java, C++, etc.). For the evaluation, each group solves 10 exam-instances of the problem. The qualification is based on the result achieved by each group for each instance in comparison with a minimum quality threshold, defined by the lecturers, and the results of the other groups. In this manner, students learn very complex concepts in a friendly but competitive environment, which invites them to work hard on the application of theory concepts into a problem close to those they will find in their professional career. Students' assessments show an increase in their performance and interest regarding the course.

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1 INTRODUCTION

In last years, university education is using innovative methodologies to improve students' understanding, reasoning capacity or skills for problem-solving [1]. In particular, future engineers are expected to deal with multidisciplinary problems, requiring cross-curricular capacities [2]. Project Based Learning (PBL) is gaining attention [3]. Students adopt an active role, while addressing real-based motivating projects [4]. PBL has been adopted in many courses [5]; often using a gaming environment to ease integration [6]. However, implementing PBL in Spain is not straightforward, mainly due to administrative and curriculum barriers [7].

This paper presents an application of PBL into the course Quantitative Methods of Industrial Process Management II (MQ2), taught at the Master's Degree in Industrial Engineering (MUEI) of the Technical University of Catalonia (UPC). It is a 4.5 ECTS course, compulsory for the Industrial Organisation branch students of MUEI and optional for the other branches. Every semester, around 40 students are enrolled.

1.1 Learning objectives and competencies

In MQ2, students learn to model and solve industrial organisation and management problems with exact and heuristic procedures. The learning objectives are:

- To model and solve classical combinatorial optimisation problems using exact and heuristic procedures.
- To develop ad hoc solving procedures for non-standard problems.

In addition, the competencies worked in the course include:

- Transversal. Group working.
- Basic. To develop ideas, in a research context.
- Basic. To apply concepts learnt into new and multidisciplinary contexts.
- Specific. To develop and apply analytic methods for decision making.

1.2 Teaching methodology

This course is based on PBL to favour learning of objectives and competencies [3]. There are 3 session typologies:

- In <u>master classes</u>, lecturers introduce the theoretical concepts of the course, using illustrative examples to ease understanding.
- In <u>practical classes</u>, lecturers guide students in applying theory concepts to solve small-size problems, encouraging critical reasoning.
- In <u>competitive project</u>, students develop an ad hoc heuristic to solve a real-based industrial organisation problem in 3-member groups (Section 2).

MQ2 has 7 modules: (1) mathematical programming, (2) combinatorial optimization, (3) heuristics, (4) enumerative searching procedures, (5) neighbourhood exploration algorithms, (6) matheuristics and hiperheuristics, and (7) real-based applications.

The final mark is calculated according to the competitive project (80%), as detailed in Section 2, deliveries during the practical classes (10%) and an exam to evaluate whether students have understood the practices or not (10%).

2 METHODOLOGY

The core of MQ2 is the competitive project. At the beginning of the semester, a real-based combinatorial optimization problem is proposed to students. The problem is enough complex to lead to a very high amount of feasible solutions, although only one (or a reduced set) is optimal. Over the course, students develop an ad hoc (meta/math/hiper)heuristic, based on the class concepts, and code it with standard language (Python, Java, C++, etc.). Examples of problems are: (a) assignment of boats to quays and containers to port locations or (b) path in a warehouse to pick up products for pallets to be sent to supermarkets.

Together with the problem statement, a set of test-instances is provided to students, each one representing a different combination of parameters of the problem, that can be used for testing purposes. The format of the instances and the results returned by the heuristics is defined beforehand and students adapt their codes accordingly. In addition, the results of the objective function obtained by a simple heuristic, developed by the lecturers, is also provided for the test-instances. This value represents the minimum quality threshold that will be considered acceptable for the evaluation. Finally, a testing programme is also provided to ensure the objective function is properly calculated, the results format is correct and avoid unnecessary mistakes during the evaluation.

The day of the evaluation, a set of 10 new exam-instances is provided to students (with the standard format). Using identical school computers, students launch their codes and solve the 10 instances in a maximum time of 5 minutes per instance. After 50 minutes, the results together with the code and a report, explaining the heuristic developed, must be delivered.

The evaluation of the competitive project is calculated based on the report (20%) and the average mark for the 10 exam-instances (80%), where each instance mark is:

- If the solution is better than the minimum quality threshold, the mark is 10 for the group getting the best solution and 7 for the worst (overcoming the threshold). A linear progression is considered for intermediate groups.
- If the solution is worse than the minimum quality threshold, the mark is 0.

The competitive environment forces students not to share their findings (ex.: strategies for developing heuristics), while being in a friendly-gaming environment.

In order to evaluate the perception of this activity by students, the students' satisfaction surveys carried out by the university are reviewed. At the end of each semester students can optionally give their opinion about the courses through an online university platform, logically anonymously and without the intervention of lecturers. These surveys are answered at the end of the lecturing period and before the exams period, to avoid the final marks influence the answers. The survey includes a quantitative assessment where students evaluate, on a 1-5 scale, lecturers and courses; and a quantitative assessment where they can express their opinion in a short text.

3 RESULTS

The evaluation of this activity is complex, since it was implemented during a Masters curriculum modification (September 2015), without the possibility of considering control and experimental groups. In addition, some sources of information are not available for all the semesters. Despite these limitations, Table 1 summarises the performance for some indicators before and after the competitive project, gathered from students' satisfaction surveys. Since surveys are optional, a variable number of answers is obtained each semester. However, approximately 30-40% of students answer the survey, i.e. around 12-16 students each semester. Before the competitive project here assessed, the course contents were the same and the teaching methodology was also based on master and practical classes, but the evaluation was done through traditional exams.

Table 1. Course performance before and after the competitive project

Indicator	Before	After	Variation
I1. Students' interest on the course (1-5 scale)	3.59	3.85	+7.2%
I2. Students' satisfaction on the course (1-5 scale)	3.52	3.44	-2.4%
I3. Students' average final mark (0-10 scale)	6.14	7.51	+22.3%
I4. Students abandoning the course (%)	9.9%	1.5%	-84.4%

The indicators I1 and I2 are compiled from students' surveys, carried out at the end of each semester. As observed, the interest on the course has significantly increased (+7.2%), although the satisfaction has slightly diminished (-2.4%). Examining the comments section in students' surveys, the main reason for not being more satisfied is that the competitive project requires from programming skills that many students do not have. Efforts are currently being made to address this issue. On the other hand, indicators I3 and I4 are calculated from the results of students after the course evaluation. As observed, the average mark has notably improved (+22.3%). This indicator is not robust since it compares two different evaluation methods, but assuming the course responsible has remained the same person, the rigorousness can be considered similar. Under this assumption, a notable increase in students' performance has been accomplished. Indeed, indicator I4 shows a very relevant diminution of abandonments and, through the comments section of students' surveys, a much higher dedication can be deduced.

4 CONCLUSION

This paper shows an example of PBL to teach complex engineering concepts, such as advanced quantitative methods to solve combinatorial optimisation problems (course MQ2). In general terms, the evaluation of PBL implementation is positive. Students invest more time to understand and apply the course contents and they show a higher interest. However, some limitations in the requisites to accomplish the competitive project still need to be addressed.

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STUDENTS DESIGNING FOR STUDENTS: A PEER MENTORSHIP TOOLKIT FOR A CROSS- CAMPUS, EDI, ENGINEERING TRANSITION SCHEME (SHORT)

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Keywords: *peer mentorship, transition, EDI, students-as-partners, mentor training*

ABSTRACT

The smooth transition of students from secondary education to university study is seen as a factor of student retention and achievement. This is especially important in the case of students from non-traditional backgrounds who may lack the social capital that could help ease their transition. Peer transition mentoring is one of the

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tools universities use to enhance the experience of new students. This study examines how the transition mentoring scheme of a highly selective institution (UCL) could be modified to cater for the students of a new EQF level 3 engineering preparatory programme (Foundation Engineering) which is aimed exclusively at students from under-represented groups. The transition mentoring scheme needs to address two practical obstacles: the lack of peer mentors with knowledge of the needs of the non-traditional student demographic and the physical distance between the main campus, where the peer mentors are located, and the off-campus location of the preparatory programme. A Students as Partners approach is implemented to examine the transition mentors' perceptions of their role. Semi- structured interviews with 16 current and former transition mentors were conducted to investigate the experiences of peer mentors and to establish their training needs. The paper concludes with practical guidance on best practice for organising and managing training for students mentoring peers from non-traditional backgrounds.

1 INTRODUCTION

1.1 Background

Peer mentoring transition schemes are used in higher education to help new students transition from secondary education to university life. It has been shown [1] that transition support is beneficial to students from underrepresented groups in STEM education, such as first-generation students, women and ethnic minorities, who would otherwise find it difficult to adapt to university life due to disengagement or the lack of social capital that would enable them to navigate successfully the early steps into higher education.

The authors' institution, a research-intensive, highly selective, large, multidisciplinary university, has in place a peer mentoring transition scheme. Paid "transition buddies" are assigned to every new student. The features of the scheme are given in Fig. 1. In recent years the scheme has been delivered online only, due to COVID-19.

Training	Structure	Resources
• One day training • Awareness of the role • Emphasis on boundaries and how to avoid problems	• 10 mentees per mentor • The scheme runs for the first term • Weekly meetings with the group at a time and place arranged by the university • Schedule of topics to be covered at the meetings	• Moodle page where all mentoring materials are stored • Booklet with addresses etc. • Q&A with Senior Mentors hafway through the scheme.

Figure 1: Features of the current transition mentoring scheme

UCL will offer an Engineering Foundation Year Programme (EFY) from the 2023-24 academic year. This is a one-year preparatory programme at level 3 of the European Qualifications Framework for students from underrepresented groups who have not achieved the normal entry requirements for an engineering degree. Its aim is to prepare students for study by improving their academic skills and subject knowledge. Although Foundation programmes are offered by many universities in the UK, this is the first time UCL is offering it in any discipline. Admission is based on socio-economic criteria such as family income, personal circumstances etc. The current peer mentorship programme does not consider the needs of the specific cohort nor does it reflect the way the EFY will be realised: There is an opportunity to redesign the peer mentoring scheme to better serve EFY students.

In existing literature the emphasis is on the mentees and the benefits of transition mentorship. There is less discussion of the experience of the peer mentors, raising the question of how peer mentors experience their role and how this could inform the redesign of the mentorship scheme.

2 METHODOLOGY

A students-as-partners (SaP) approach was employed [2]. Student and staff partnership for co-inquiry, co-creation and co-design is a pedagogical approach that has gained traction in recent years. It was chosen because it can give voice to the concerns and needs of student mentors and can lead to the design of processes that will address those concerns and needs [3]. The team comprised three undergraduate students who had previously worked as peer mentors and one postgraduate student carrying out research in engineering education. Two academic staff members acted as coordinators and advisors. Administrative and support staff were also consulted as necessary.

A case study approach was used for data collection. Sixteen semi- structured interviews with current peer mentors were carried out by the student-partners. This helped narrow the gap between interviewer and interviewed and enabled the participants to be open and critical of their experience. The aim of the interviews was to understand the participants' experience of peer mentoring, their thoughts on the training they received and their awareness of the EFY demographic. A thematic analysis helped identify areas for improvement.

3 RESULTS

The results of the study are somewhat limited due to the relatively small number of participants and the fact that the mentor experiences relate to a different demographic than the one expected at the EFY. Despite these limitations there are some strong themes emerging:

- *Participation*: Mentee participation was low, exacerbated by the online format. *"A lot of the mentees [are] so caught up with their university experience, they don't actually like to come to sessions". "The good thing about online meetings was it was so flexible". "Because it's online they don't open the camera and microphone. It's just like I am talking with my computer".*
- *Topics discussed:* Mentees were possibly discouraged by the group setting to discuss personal issues. *"Most commonly the sort of stuff I would hear would be very admin related not so much about their background […] but sometimes we would have one on one conversations and that's where I really got to hear […] their story".*
- *Format and content relevance:* Most mentors believed that the format was too rigid *"UCL had prepared all those leaflets for us but they didn't match my mentees' needs, for instance, I had to talk about London in so many meetings […] and all the mentees I had were from London.[…] I could go a bit faster, but still the mentees lost interest.". " It would have been really nice if we had discussed more about the actual course more things about that". "I didn't like that plan that much because I don't think it would be a good way to [address] mentees needs, like, it's quite kind of a one way instruction".*
- *What content should be like*: *"I prefer listening to previous transition mentor's experiences, I would like to look into personal experiences, rather than*

general instructions". "[I would prefer] instructions for us to develop our approach ourselves rather than telling us".

- *Support:* More input from experienced mentors and from each other was expected. *"I think maybe we could [talk] with past mentors every week". "I didn't have a senior mentor myself, to be honest, I didn't have someone to go to, one person. I knew there were some senior mentors in general, but not a specific person". "It would be nice to have some activities with other mentors regularly, to get to know each other and exchange ideas".*
- *Boundaries*: There were mixed feelings although friendship was seen as a positive benefit of mentoring. *"The boundary between mentors and friends is hard to control". "It's a quite good experience 'cause we can make friends with [the mentees]".*
- *Knowledge of non-traditional students:* There was no awareness of DEI issues in higher education. Only one mentor considered mentee background: *"I wish I had more demographic information about my mentees".*

Based on these themes, the recommendations for the scheme are given in (Fig. 2). The main features are:

- *Attendance*: Personal or one-to-two mentors. Embed mentoring activities to the teaching timetable. Start with face to face and let participants make their own further arrangements.
- *Match mentors to mentees*: The literature [5] indicates that mentoring schemes are more effective when mentors and mentees have similar backgrounds. This may not always be the case, so dditional training needs to be offered to mentors.
- *Flexible content:* Guide mentors to adapt the mentorship content to the needs of their mentees.
- *Support and community building*: Ensure staff/ senior mentors are available for ongoing support. Organise events where mentors can meet other mentors informally and exchange ideas.

Training	**Structure**	**Resources**
• Two or more days training • Awareness of underrepresented demographics • Being non-judgemental • How to nurture friendships • Setting boundaries and avoiding problems • Social events with other mentors	• One- two mentees per mentor • Run scheme for the whole year • Weekly meetings scheduled in teaching timetable on first term • Guidelines on topics to be covered, but flexibility to adapt • Social events for mentors and mentees • Allocated senior mentor	• Moodle page where all mentoring materials are stored • Booklet with addresses etc. • Training handbook • Staff check-ins with mentees to ensure support and smooth running

Figure 2: Features of the proposed transition mentoring scheme

4 CONCLUSIONS

Student-partners helped shape the future peer mentorship programme of the Faculty. The outcomes of the research will be implemented in the new Foundation programme and will help train new peer mentors, helping them better understand the importance of their role and supporting in the formation of long-term partnerships with the mentees, that could go beyond the mandated mentorship activities [4].

By implementing a students-as-partners approach the academic team were able to understand the student experience better. The approach also helped foster commitment, a sense of belonging and shared responsibility of the future of the scheme. At the same time, the practitioners underwent a personal journey of acceptance of the partnership as a power-sharing process with uncertain outcomes as opposed to a guided experience with known outcomes [5].

Further work needs to be carried out to assess the effectiveness of the peer mentorhips once the scheme is implemented in the EFY cohort. The experiences of peer mentors and mentees of the old and new programme will also need to be compared to those from other universities with peer mentoring schemes, with a view to further refining the scheme.

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REFLECTION IN TECHNICAL HIGHER EDUCATION: STUDENT PERCEPTIONS (SHORT CONCEPT PAPER)

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ABSTRACT

The project 'Strengthening reflection in technical higher education programs' is a response to the need for well-trained reflective science and engineering professionals and the subsequent question of teachers about how reflection can be designed and embedded in a meaningful way, especially in technical study programs. Within this project, eight technical education teams from two Dutch universities of applied sciences are working on improving the use of reflection in their

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curriculum. Among other things, teachers are professionalized in their guidance skills, to improve the guidance of reflective activities of their students. One of the research activities within the project involved a questionnaire to gain insight into: 1) the extent to which engineering students have an inclination and need for self-reflection, 2) the reflection level that engineering students reach according to their own judgement, and 3) how engineering students value (guidance of) current reflection activities in their study program.

In the short (concept) paper we will address some main findings of this questionnaire based on data of 843 first- to fourth-year students from eight technical study programs. Amongst others, results indicate - contrary to some other research findings - that engineering students acknowledge the importance of being able to reflect as a future professional. However, they seem relatively less satisfied with currently provided guidance regarding reflection in their study programs. Also, most often employed reflection activities (i.e., reflection reports) are generally perceived least useful. Results give further direction to optimize activities and teacher guidance regarding reflection within higher (technical) education programs.

1 INTRODUCTION

1.1 Background

Within the current labor market there is a growing need for technically trained professionals. To function well within this labor market, young professionals should be able to critically react to often fast changing (knowledge) developments [1]. More specifically, there is an ongoing demand for technically trained students who are capable of reflective thinking in addition to their domain-specific specialism.

Though reflection as a means to foster students' personal and professional development and the importance of incorporating it as essential part of the curriculum is generally acknowledged [2], schools and teachers also experience difficulties regarding effective implementation of reflection in their programs [3]. Also, related research has shown that especially engineering students not always recognize the added value of reflection and the written format that is often used to incorporate reflection does not fit this technical target group [4].

The project 'Strengthening reflection in technical higher education programs' addresses these issues; eight technical programs from two Dutch institutes for higher education are working together with a project team for the duration of two school years on an improved vision and curriculum regarding the incorporation of reflection in their programs. In addition, efforts are made to improve reflection activities for students and professionalize teachers regarding the necessary guidance skills in order to help their students develop essential reflection skills.

1.2 Current study

As part of the project, a questionnaire was administered to gain insight into 1) the extent to which engineering students have an inclination and need for self-reflection, 2) the reflection level that engineering students reach according to their own judgement, and 3) how engineering students value (guidance of) current reflection activities in their study program. The first two parts are beyond the scope of this article; this paper focuses on the third part of the questionnaire.

2 METHODOLOGY

2.1 Participants

Participants came from two universities of applied sciences in the Netherlands. They were first- to fourth-year students divided over eight different technical study programmes. Initially, a total of 944 students participated in this study. Students who gave no permission for using their data or who did not finish the questionnaire were not included in analyses. This resulted in a final sample of 843 students (M_{age} = 19.9 years; 545 males, 298 females).

2.2 Materials

The part of the questionnaire that aimed to gain insight into the current situation regarding (guidance of) reflection activities consisted of different question types. A first set of items displayed various predefined reflection activities, aiming to provide insight into how often particular reflection activities are currently employed and to what extent those are considered meaningful by the students. These items were complemented with two open ended questions to determine examples of reflection activities that are perceived meaningful and less meaningful and reasons why they are considered to be meaningful or less meaningful. These questions were followed by seven statements focussing on perceived guidance related to reflection. A final set of five statements addressed the added value of reflection (activities).

2.3 Procedure

Prior to the distribution of the questionnaire, the questionnaire was pilot tested among engineering students who did not participate in the study to determine whether questions and items were clearly formulated. The final questionnaire was administered during a regular class whenever possible. When this turned out not to be feasible, the questionnaire was distributed by a teacher (known by the students) via email or another communication channel with a reminder being sent after a week. At the start of the questionnaire, students had to sign an informed consent, containing information regarding the goal of the research, their voluntary participation, and processing of their data.

3 RESULTS

3.1 (Perceived usefulnes of) currently employed reflection activities

Table 1 provides an overview of the extent to which predefined reflection activities are currently employed within the technical study programmes.

Table 1. Mean scores and standard deviations for currently employed reflection activities (1 = never; 5 = very often)

Reflection activity	M	SD
Reflection reports	3.34	.92
Reflection assignments	3.10	.95
Reflection conversations	-	-
Classroom	2.63	.97
With study career coaches	3.01	.84
With teachers	2.48	.91
With (group of) fellow student(s)	2.96	1.02
Pitches / presentations	2.36	1.05
Other	1.60	1.07

Table 2 presents an overview of the top 5 reflection activities that were most often indicated by engineering students as least meaningful.

Table 2. Frequencies of least meaningful reflection activities

Reflection activity	Frequency
Reflection reports	19.2%
Specific reflection assignments (e.g. games)	12.6%
Pitches/presentations	12.3%
Group conversations (in-class)	11.2%
Specific reflection assignments (personality/talents tests)	8.4%

Reasons why *reflection reports* are perceived least meaningful can be categorized as *only providing socially desirable responses / "fill-in-the-blank assignments"*, *waist of time / taking too much time*, and *no new learning involved / repetitive activities*.

Table 3 presents an overview of the top 5 reflection activities that were most often indicated by engineering students as most meaningful.

Table 3. Frequencies of most meaningful reflection activities

Reflection activity	Frequency
(1-to-1) conversation (with study coach)	19.5%
Specific assignment (other/track specific)	11.8%
Group conversation (project)	10.2%
Group conversation (unspecified/other)	7.2%
Reflection reports	6.5%

Reasons why *(1-to-1) conversations (with study coach)* are perceived most meaningful can be categorized as *gaining more insight from others or being/others held up a mirror, provides opportunities for improvement, provides insight in functioning, tailored towards the person himself/herself.*

3.2 Currently provided guidance

Table 4 presents an overview of statements related to received guidance regarding reflection and provides insight into the extent to which students agree with these statements.

Table 4. Means and standard deviations related to guidance (1 = fully disagree; 5 = fully agree).

Statement	M	SD
I receive clear instruction on what reflection entails	3.33	.89
I receive clear instruction on *how* to reflect	3.11	.94

I receive guidance from my teachers during my reflection proces	2.97	.97
I receive guidance from my teachers that helps me a step forward during my reflection process	2.99	.93
My teachers serve as a role model when it comes to how I should reflect	2.52	.99
I receive feedback from my teachers on my reflection	3.21	1.11
I receive feedback from my fellow students on my reflection	2.69	1.10
I receive clear instruction on what reflection entails	3.33	.89

3.3 Perceived added value of reflection

Table 5 presents an overview of statements related to perceived added value of reflection in general and provides insight into the extent to which students agree with these statements.

Table 5. Means and standard deviations related to guidance (1 = fully disagree; 5 = fully agree).

Statement	M	SD
I think it is important to be able to reflect as a future professional/worker	4.16	.63
I think reflection is an important skill to learn during my program	3.79	.82
When I'm given the task to reflect, it's about things that are important to me	3.46	.87
When I'm given the task to reflect, a connection is made to meaningful (practical) experiences	3.28	.90
When I'm given the task to reflect, I can see the added value of it	3.35	.91

3.4 Concluding considerations

Results indicate that engineering students do acknowledge the importance of being able to reflect as a future professional, apparent from a relatively high score on its corresponding statement. However, when considering the educational context, most often employed reflection activities (i.e., reflection reports) are generally perceived least meaningful. Also, mean scores regarding guidance can be interpreted as relatively low; students seem relatively less satisfied with currently provided guidance regarding reflection in their study programs. On the other hand, reflective conversations with study coaches are most often indicated as most meaningful. This emphasizes the importance of the teacher role in guiding students' reflections, but also indicates that there is room to further improve that guidance. Among other things, these improvements can be about being a role model and providing appropriate feedback as a teacher.

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MINDING THE GAP BETWEEN SECONDARY SCHOOL AND UNIVERSITY

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ABSTRACT

The renewal of engineering education requires an education that is more affected by students' circumstances which, if known, will help to guide them into the future. It is about channelling the students towards learning, taking into account the factors related to the acquisition of knowledge and how they can share this knowledge with the teachers. The specific aim of the current study was to examine what it means for students to transition from secondary school to university and introduce changes to reduce the failures it generates.

The causes of low grades in the initial phase of university are analysed; subsequently some remedies are included. First, to gather information, student surveys and interview activities, led by an expert, were conducted. Subsequently, compensatory actions were organized by experts, for students and teachers.

The surveys were designed to provide a self-assessment of new students regarding dedication and performance, and were given to those who failed the first important exam, capturing how they experienced university entrance and their first failure. They point to some personal causes of low performance: time organization deficiencies, impediments to devoting themselves to continuous study, and difficulties to adapt. Half believe their dedication merits better learnings and marks, and stress the difficulties associated with an insufficient level of secondary education and with the types of exams.

This study, encompassed within the framework of the activities dedicated to educational improvement at UPC, highlights the need to implement guidance and accompaniment actions devoted to first-year students.

1. INTRODUCTION

We address a widespread phenomenon among engineering students in the first year of university, although with differences depending on the competences, degrees and higher education systems concerned. Many students who begin engineering studies do not pass some subjects, others pass hardly any of them, and some leave, at the end of the academic year, or before. The abandonment of university studies wastes tens of millions of euros of public and/or private spending in universities and also frustrates the personal expectations of more than a third of Spanish university students. Spanish universities record high gross rates of global abandonment ranging from 37% to 50% [1]. Only a small percentage of students easily complete the initial phase during the academic year of their admission. The current project analyses this problem and tries to improve the situation. Failed subjects can negatively affect students in relation to their initial perception of university [2] and also their motivation to learn.

2 METHODOLOGY

Many teachers in many universities have thought about solutions to the problem. They have offered all students, free of charge, ways of achieving greater "inclusion": tutorial plans, seminars, adaptations of curricular workloads, recordings, multimedia materials or environments with virtual reinforcements to facilitate comprehension, online self-assessment tests, flexible consultation schedules. But the problem remains.

At the Barcelona School of Agri-Food and Biosystems Engineering (EEABB) at UPC-Barcelona Tech, actions such as those described in the previous paragraph did not work for mathematics and chemistry, or did not work sufficiently. Due to the failure of so many initiatives of this nature, our group of teachers have now considered some forms more closely related to the accompaniment of students [3] and/or to specific features of the motivation of first-year students [4]. This is the "Mind the Gap" project. In particular, we have adopted a change in perspective and in the investigation of students suffering from the problem (or who at least appear to be candidates), what they think of themselves, the causes of the problem most attributable to themselves and, on the other hand, how they feel. In mathematics, the project is linked to one topic of the Special Interest Group in Mathematics (MSIG - SEFI): the activation of the students to ensure that they participate more in the learning process.

To this end, after the first major exams, and once the results were known, we addressed the students who had not passed them. In the 2019/20, 2020/21 and 2021/22 academic years, a survey was conducted with defined themes and closed and open questions. The response rate was sufficiently satisfactory, between 35% and 70% in different circumstances, for populations of between 80 and 100 students. The students were interviewed, looking for answers to questions concerning the issues described in the paragraph above: how they perceive their first academic failure, what level of demand they had in their way of working, and so on.

Students were asked the following questions, on qualitative more than quantitative aspects.

1. Do you think you have followed the subject?
2. What do you think about the knowledge you had when you got to university?
3. And about your learning capacity?
4. What dedication do you think you gave to the subject?
5. What was your weekly assignment of hours to the subject, in absolute terms?
6. And in relation to the other subjects?
7. What do you think about the relationship between dedication and results?
8.How do you value the virtual materials, based on their utility for study?
9.How do you value the interest of the different classes?
10. Have you used personal aid or external material resources such as private classes or classes in a training school outside the university?
11.Could you point to two topics that proved particularly difficult?
12. What was your mark in the exam?
13. What do you think your final mark will be?
14. With the experience you now have of the subject, what do you think you should improve?
15. Have you had personal situations making it difficult for you to follow the subject?

The desire to change the students’ vision led teachers to ask for psychological and pedagogical information, about students’ human traits, social forms and their attitudes, to help them discover the basics of the problem. The support was structured as a six-hour training activity conducted by an expert. Issues such as motivation, time management, adaptability, commitment, involvement and awareness emerged, focusing on specific points. The assessment was positive. Reflection and debate on the role of the teacher arose, taking into account how current students arrive. The key role of the initial phase was emphasized, as it is the time when the student needs to form a link with the studies, and the importance of using tools to strengthen the student’s commitment.

3 RESULTS AND IMPROVEMENT ACTIONS

In question 5, on weekly dedication to the subject, almost all the respondents answered two hours, one third of what ECTS credits require. In question 14, "With the experience you now have of the subject, what do you think you should improve?", the most common answers were: regularity in dedication (58%), organization of time (57%), motivation (45%), study technique (40%), prior knowledge (31%). According to surveys, the features that students see as low-performance causes are mostly personal: lack of organization of their time (non-continuous dedication) and problems in adapting to the university (their dedication does not correspond to enough learning or high enough marks). There are also more academic causes, notably the types of assessment and a deficient level of secondary education. This last response could encourage action to be taken in secondary education, but that has not been considered in this project as it is internal to the university.

First, actions were elaborated that would allow direct action on the roots of the problem, helping student persistence. This was done, above all, not in classical training fields (adhering to an academic aspect of training on the specific topics involved), but in more closely accompanying elements linked to positions, characteristics, customs and practices rooted in the students themselves.

The affected students took sessions in the field of psychological and pedagogical skills with the aim of altering their way of working and guiding them towards successful behaviours, with advice for a good first year at university, especially offering learning techniques to overcome organizational shortcomings. This was done with a free eight-hour workshop entitled “How to Improve My Academic and Personal Performance,” which was well received by the attendees and found to be helpful. From this area, also follow-up, attention and help sessions were opened, with a view to welcoming new students, and extended throughout the first semester. Learning assistants (more experienced students) were also integrated, as these can help to overcome some limitations that are commonly experienced when integrating far-reaching actions into long courses [5].

By way of conclusion, the project has led to greater awareness of the problem among the entire group. It has been seen that there are important extra-academic factors for failure, that students need support actions to overcome this type of difficulty and that it is important that the university transmits this support.

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Challenge-based learning as a tool for creativity and talent expression

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Keywords: *challenge-based learning; hackathon; creativity; participatory learning; digital education*

ABSTRACT

After the stop caused by the pandemic, the University of Trento and its newly born FabLab reopened the doors to DigiEduHack (https://digieduhack.com/en/), the decentralized hackathon dedicated to the most pressing challenges of digital and innovative education. More than 30 multidisciplinary students have ventured into the design of innovative learning tools to meet the challenge thrown at them: prototyping educational board games; multimedia artefacts and installations at the intersection of big data, art and technology; co-designing festivals in a combination of art, science and fun; laboratory images to be presented in the classroom. In this short paper, as a case study one, we will outline the DigiEduHack initiative, focusing on the potential of a challenge-based approach in stimulating and strengthening introspection, creative thinking and talent's expression. Supported by a set of qualitative data collected before and after the event, this work reports an education case study and shows the progress and preliminary reflections of the students and educators involved.

1 INTRODUCTION

1.1 Challenge-based learning

The Challenged Based Learning approach (CBL) found fruitful context at the University of Trento that is open to innovating teaching and learning, is embedded in a dynamic innovation ecosystem and is pushed to spread out stakeholders' networks. The pedagogy of CBL can be inscribed in the constructivism perspective

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where students are the main characters of their learning process: they identify, analyse, and design a solution that solves a real-world issue (Tecnologico de Monterrey, 2015). Due to the fact that students approach complex problems, the learning experience is multidisciplinary, it includes stakeholders' perspectives, and it aims to collaboratively find a sustainable solution (Kohn Rådberg et al. 2018). Professors are facilitators and help teams in the process of building guiding questions, gathering the right information, processing data, presenting solutions, and eventually executing the outcomes. Improving soft skills, self-reflection, and stimulating talent expression are another important asset of the CBL approach.

1.2 Hackathon

In the context of CBL, hackathons are one of the most widely used formats. They are highly engaging, limited-time competitions in which participants, divided into groups, design and develop a solution in the form of an idea or artefact to a proposed challenge. Rosell, Kumar and Shepherd (2014) identify four constitutive attributes of hackathons: (i) focus on activity caused by the limited nature of time and space, (ii) novelty in both *doing* (creating something that did not exist before) and *knowing* (learning something new) dimensions, (iii) collaboration stimulated by time constraint, and (iv) reward that can act as an incentive for participation and productivity. Given their attributes, they represent a subclass of the so-called Innovation Contests: competition of innovators who use their skills, experiences and creativity to provide a solution for a particular contest challenge defined by an organizer (Bullinger and Moeslein, 2010).

2 CASE STUDY

2.1 DigiEduHAck at the University of Trento

The UniTrento Fablab joined DigiEduhack, the international initiative of the European Institute of Innovation and Technology (EIT), for the third consecutive year, as part of the European Union Digital Education Action Plan that takes place worldwide on the same dates. As stated by their website, "DigiEduHack is a global movement dedicated to solving the toughest digital education challenges organisations face today, which is manifested in a 24-hour hackathon taking place simultaneously in major cities around the world." (DigiEduHack, n.d.).

After the virtual edition of last year, the third edition of the local DigiEduHack challenge, organized by the Department of Information Engineering and Computer Science - DISI in collaboration with SOI (School of Innovation) and HIT (Hub Innovazione Trentino), in the framework of the Boogie-U project (Boosting Innovation and Entrepreneurship through European Universities) returned again on 9th and 10th November 2021 at the University of Trento. Students applied in order to participate in this optional initiative.

More than 30 students with different backgrounds have tried their hand at designing innovative learning tools to meet the challenge launched by the organizers: prototyping educational board games; multimedia artefacts, installations at the intersection of big data, art, and technology; festivals able to combine art, science, and fun; laboratory activities to be conducted in the classroom.

The five competing teams co-designed tools and activities, with the support of mentors from the SOI, HIT and the two FabLabs of the University of Trento and the University of Bolzano.

For the second, consecutive, year the winning team from the Trento edition also won in the global competition, this time with the project Hachi (https://digieduhack.com/en/solutions/hachi), an application for smartphones and tablets that can facilitate the understanding of abstract concepts thanks to augmented reality (AR).

2.2 DigiEduHack survey methodology

CBL, as a new model of learning, requires new assessment tools that monitor the self-reflection capabilities and soft skills acquisition process. Specifically, reflective learning tools can support this assessment through the process of remembering acts and events and then exploring why things went a certain way, and finally, taking possible actions for further experiences. In this context, we provided an online 15-question survey through which we explored, in three parts, the quality of the learning experience, the level of awareness about students' soft skills and the follow-up of the ideas developed during the hackathon. The soft skills' awareness was measured through the use of the IMI scale (Intrinsic Motivation Inventory), a multidimensional measurement device intended to assess participants' subjective experience (Ryan and Deci, 2000). The instrument assesses participants Interest/Enjoyment, Effort/Importance, Perceived Competence, Relatedness. In Paragraph 4, we discuss the main findings for each part of the survey. 12 out of 30 students answered the questionnaire.

3 FINDINGS

Analysing the results of the questionnaires, we found out that most of the participants (75%) judged the contribution of the mentors as really useful and 25% as useful. During the hackathon they succeeded in boosting team working leveraging two types of personal assets: expertise and charisma. Mentors have indeed been associated by some participants with the word "passion" and their presence has been labelled as "tangible and inspiring". These findings further underline the positive role model embodied by mentors during hackathons (Nandi and Madernach, 2016). More in details, students also evaluated in a positive way:

- the teamwork, the cooperation and collaboration among students coming from different disciplinary backgrounds;
- the friendly competition vibes;
- the creativity shown by every group;
- the positive and playful learning atmosphere – still remaining serious and challenging.

In fact, also from the IMI scale, most of the students found the activity pleasant but also empowering, due to the collaborational aspects with their team and the feeling of competence given by their work mixed with the guidance received by the mentors. They felt challenged, but not under-challenged, during the activity and this leaded to a full commitment to the task they were performing, “losing track of time”.

With regard to what could be improved in the future, suggestions were mainly related to the event duration and its expected outcome. Despite time constraint being a key factor in hackathons, participants would have preferred to have at least 24 full hours for solving the proposed challenge, which means starting earlier in the morning or/and staying overnight. Moreover, they would have appreciated more precise indications on what the expected outcome should have been (e.g. tangible vs intangible artefacts), even using real examples of previous hackathons.

4 CONCLUSIONS

This short paper illustrates some results of the DigieduHack initiative, as an education case study. In designing the activity we focussed on creating a participatory learning experience for the participants. Our goal was to provide students with the tools to reflect upon their soft skills, strengthen creative thinking and best express their own potential.

This result was achieved by mixing the topic of the challenge, apparently very stimulating for them, but also the support given by the mentors during the challenge. The informal - but challenging - climate made students feel challenged but also empowered by the results they managed to obtain, perhaps initially unexpected even for them given the limited time available. Reading their feedback in the questionnaires was very helpful for the research team, also in view of future events with this format. We believe that this combination has been successful in stimulating their creativity but at the same time increasing their awareness about the abilities and the results they can obtain.

5 ACKNOWLEGMENTS

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- the FabLab UniTrento and all its staff for the space and the great effort and contribution;
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STARTUPV: DIFFERENT APPROACHES IN MENTORING AND TUTORSHIP FOR ENTREPRENEURS IN THE THREE STAGES OF A UNIVERSITY ENTREPRENEURIAL ECOSYSTEM

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ABSTRACT

Year after year, a crowd of students from the Universitat Politècnica de València (UPV), a polytechnic university in Valencia (Spain) with over 30,000 students, are encouraged to start their own business projects. Since 1992, IDEAS UPV, the Entrepreneurial service at UPV, has been mentoring entrepreneurs. Up till now, IDEAS UPV has helped in the generation of close to 1000 new businesses with a survival rate of over 60% in five years.

In 2012, IDEAS UPV introduced new mentoring and tutorship activities for students by the creation of a business incubator within the university campus. StartUPV is currently a 5-year startup incubation programme and an entrepreneurial ecosystem with more than 300 startups and more than 50 million euros of overall private investment

StartUPV programme is divided into three different stages: (i) STAND UP, in which startups define a business model and complete a validation process; (ii) START UP, in which startups achieve a targeted market share and build their company management team; and (iii) SCALE UP, in which startups achieve maturity and scale to other international markets.

As university students and their startups face different needs in every step of the programme, different approaches for mentoring and tutorship are applied in every stage. For instance, a startup in the first stage is mentored in business modelling or market segmentation, while a scale up requires a more specific mentorship in dealing with corporates and venture capital. These different approaches are analysed in this work including the main findings of the 10 years of this programme.

1 INTRODUCTION

Universities are sources of talent in which their students are prepared to face the challenges of society. In addition to being trained in technical knowledge, the reality of the labor and professional markets shows that students must also be trained in transversal key skills in entrepreneurship [1]. It is for this reason that universities encourage and evaluate competencies such as teamwork, resilience and leadership. Moreover, these skills are vital for the creation of new companies.

In 1992, the Universitat Politècnica de València introduced IDEAS UPV, an advisory service for entrepreneurs from all the university community. Although initially only the first phases of the entrepreneurial process were covered, different factors such as the role of university in its regional ecosystem and the need for startups to stay close to the university have resulted in the creation of comprehensive university entrepreneurial ecosystems.

StartUPV is an entrepreneurial university ecosystem and a 5-year startup incubator programme managed by IDEAS UPV. Since its creation, more than 300 startups have gone through this programme that covers all stages of the entrepreneurial process. This paper presents the main initiatives carried out in each of these stages.

2 ACTIVITIES AND SERVICES IN THE PROGRAMME

Table 1 shows a review of activities and services in every stage of the StartUPV programme.

Table 1. Main activities and services of StartUPV in every stage of the entrepreneurial process

Stage	**Preincubation**	**Stand Up**	**Start Up**	**Scale Up**
Main users	*Students*	*Young entrepreneurs*	*Entrepreneurs*	*Business people*
Team	*Entrepreneur*	*Founding team, Assignment of roles*	*Complete a balanced team*	*Expansion of the team, new management*
Duration	*While they are students*	*1 year*	*1 year*	*Up to 3 years*
Innovation	*TRL 1-3, Idea*	*TRL 4-6, proof of concept*	*TRL 7-8, MVP*	*TRL 9, whole product*
Space	*School*	*Coworking*	*Private office*	*Custom space*
Main activities	*Business Opportunity detection, Mastering a technology, Starting a Business Model*	*Identify customer pain, Beachhead market, market strategy, Customer value proposition, competitive advantage, develop coherent set of assumptions*	*"Getting out of the building", Defining MVPs, Validation process, Customer development*	*"Cross the chasm", Expand to new (international) markets, Introducing new products and services, Getting investment*
Main supporting	*Mentoring, team building, hackathons, inspirational talks, business idea competitions*	*Mentoring, trainings on Marketing and Financials, Prototyping, funding, pitch competitions*	*Mentoring, trainings on validation, funding, intellectual property*	*Mentoring, Inverstor's Day, trainings on specific topics*

Although each cohort of startups is selected thinking of similar levels, then each startup advances at a different pace. For this reason, StartUPV programme allows the most advanced startups to go at a faster pace while the others can be properly assessed too.

2.1 Preincubation stage

This pre-stage is mainly designed for students who have a business idea. The university offers inspiring talks and hackathons to encourage entrepreneurial vocations and a team building platform to find possible cofounders in the project. The main mentoring activities are focused on defining a business model [2] and to acquire a correct understanding of the market needs, and whether the entrepreneur has or can access the technical knowledge required by the entrepreneurial project. Each of the university schools incorporates a space for its entrepreneurs.

2.2 Stand Up stage

This stage is designed for those students and graduates who decide to focus on creating a business project. At this stage, mentoring focuses on establishing and quantifying the key elements of a business model, such as the beachhead market [3] and the value proposition. In addition, the teams work on formulating hypotheses. Startups are incubated in a coworking space to facilitate synergies.

2.3 Start Up stage

In this stage, startups validate their business model through a validation process in which MVPs [4], prototypes and experiments are created, which in some cases can generate patents and other elements of intellectual protection. In addition, lean startup methodologies such as customer development are used for problem-solution fit and product-market fit. Startups are incubated for a year in a private office.

2.4 Scale Up stage

In this last stage, startups stop being startups to become successful companies. Instead of focusing on validating a business model, these companies carry out activities to expand and scale the project in various markets. For this reason, mentoring is focused on internationalization, market expansion and investment. This stage lasts up to three years in which the university provides a personalized space for the company.

3 CONCLUSIONS

For 10 years, StartUPV has been assessing startups built by students and graduates from the Universitat Politècnica de València according to the stages described in this short paper. More than 300 startups have been incubated in this ecosystem and these projects have achieved more than 50 million euros of overall private investment.

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VARIATION THEORY IN TEACHING AND PHENOMENOGRAPHY IN LEARNING: WHAT'S THEIR IMPACT WHEN APPLIED IN ENGINEERING CLASSROOMS?

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ABSTRACT

Although phenomenographic research approach has been widely used by education researchers to investigate students' learning, little attention has been paid to the relationship between a pedagogical approach adopted by teachers and students' learning outcomes, particularly in engineering education. This experimental study proposes integrating variation theory as a pedagogical approach to a face-to-face classroom environment for teaching complex engineering contents and adapting a phenomenographic approach to evaluate students' learning outcomes. The teachers who participated in the experimental group incorporated the variation theory in their teaching process. In contrast, the teachers in the control group, being ignorant of the variation theory, taught the same content to achieve the same specific learning outcome. Drawing on data from students' written responses both from experimental and control groups, this article illustrates how teachers implemented variation theory in the classroom and its impacts on student learning. The implementation of variation theory was confirmed by classroom observation, and the variation in understanding the topic was emerged from students' written responses and interview data through phenomenographic analysis. The findings indicate that teachers informed by variation theory use variation and invariance that creates necessary conditions for learning. This study demonstrates how, by incorporating variation theory, a faculty member designed different pedagogical approaches, which helps students conceptualize complex engineering topics more systematically than those who do not discern variation. The study concludes with theoretical, empirical, and pedagogic implications for teacher education in engineering.

1 INTRODUCTION

1.1 Rationale for implementing variation theory

Engineering education deals with complex engineering concepts that require diverse levels of teaching and learning methods [1]. For students to demonstrate such concepts, a few teaching methods are considered effective, such as face-to-face classroom teaching and project-based or problem-based learning [2]. However, the ability of these teaching and learning methods to set up the right conditions for learning is not clear yet. In this connection, the variation framework of teaching [3] claims that students learn to the extent to which the necessary conditions of learning are met. However, the theory has not been applied in engineering education. This research aims to explore the effectiveness of incorporating the variation framework into teaching engineering content.

1.2 Rationale for adopting phenomenography

Investigating 'how students learn' is often raised as an area of interest by academics. Over the last few decades, a substantial amount of research has explored students' conceptions of learning in different fields of education, adopting a phenomenographic approach. In engineering education, teachers and students need to deal with real-world practical problems that demand an appropriate 'object of learning' to be discerned by the students, and a phenomenographic approach is required to comprehend this discernment [4]. However, why and how students' conceptions of such problems vary is often surprisingly ignored by researchers, particularly in engineering education. This study fills this void by seeking answers to the following research question that guides the adaptation of variance and invariance in teaching engineering content.

Does the application of the variation framework in teaching engineering content enhance students' learning?

2 METHODOLOGY

2.1 Research Settings

The following flow chart (see Fig. 1) represents the steps involved in setting the research environment.

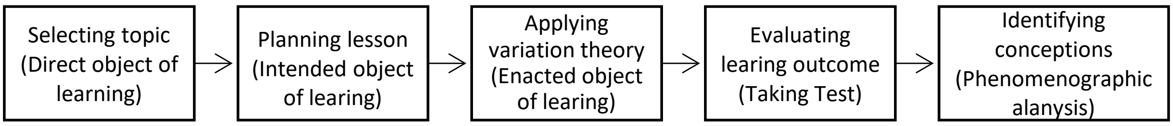

Fig. 1. Steps involved in this research settings

Two university teachers with more than five years of teaching experience participated voluntarily in this study. One of them is the third author of this study. Each of them developed their lesson plan independently to deliver the same *direct object of learning (content)*. The teacher in the experimental group, being aware of the variation theory, developed the lesson plan considering the relationship between students' learning and teaching patterns of variation and invariance. Whereas the teacher in the experimental group, having no knowledge about the variation theory, developed the lesson plan in traditional method.

2.2 Participants

63 third-year students (37 from the experimental group and 26 from the control group) enrolled in the *Industrial Quality Control* Course and two teachers from the mechanical engineering department of a teaching-oriented private university in Bangladesh participated in this study, where one of them applied the variation theory, and the other teacher taught the same topic adopting a traditional teaching method.

2.3 Lesson Planning

Three critical aspects of the phenomenon were identified, and four conditions were constructed to allow students to experience variation in those aspects as part of the lesson plan (see Table 1). The term 'critical aspect' was taken from Pang's research [5].

Table 1: Variation of different knowledge levels required to learn the lesson

	Critical Aspect 1	Critical Aspect 2	Critical Aspect 3	Intended object of learning
Conditions	Mean and Control Limits	Issue of Central Tendency/ Accuracy	Issue of Variance/ Precision	Level of Understanding the complexity
A	V	I	I	Evaluate Components related to Control Charts
B	I	V	I	Judge the Sample Acceptance/ Rejection
C	I	V	V	Complex Scenario Analysis
D	I	V	I	

Note. V = variation; I = invariance

2.4 Data collection

The two groups of students mentioned above were given the same written question (shown below) in two phases. In the first phase, teacher X taught the topic to the control group without using variation theory, and students had 30 minutes to respond. In the second phase, teacher Y used variation theory to teach the same topic to the experimental group. The students were asked to answer the identical question to assess how the variation theory had influenced their knowledge of the topic (learning objective).

<u>Question on Industrial Quality Control</u>

A quality control inspector at the Fun Fizz soft drink company has taken three samples with four observations each of the volume of bottles filled. The inspector collects the data on a regular basis. If the standard deviation of the bottling operation is 3 ml and 3 standard deviation limits for the 250 ml bottling operation are prescribed by the quality inspector, the control chart variables can be constructed with the sampled data. Assume you are the quality assurance manager of the company and are supposed to report to the operation manager to take any action you think is required. Comprehend the production line quality conformance for the data of 2 days as shown in Table 2 (please comment on each day's production operation separately). Justify your comments.

Table 2: Volumes of the sample bottles collected during Day 1 and Day 2 on different shifts of Morning, Noon, and Evening are as follows.

Sample / Observation	*Day 1*			*Day 2*		
	Morning	*Noon*	*Evening*	*Morning*	*Noon*	*Evening*
1	*249*	*251*	*250*	*239*	*253.5*	*256*
2	*250*	*252*	*252*	*243*	*251*	*256.5*
3	*246*	*249*	*253*	*239*	*252*	*256.5*
4	*249*	*249*	*251*	*246*	*252.5*	*256*
Sample Mean	*248.5*	*250.25*	*251.5*	*241.75*	*252.25*	*256.25*
Sample Range	*4*	*3*	*3*	*7*	*2.5*	*0.5*

Data Analysis

A phenomenographic data analysis technique was adopted to explore the extent to which the *intended object of learning* varied [6]. All the responses were combined into a "pool of meaning," and distinctions were made between qualitatively different explanations to form the category of the responses. Four categories of the object of study were emerged from the data. To arrive at the final categories, the following question was utilized as a guide:

How does 'quality of a production line' be understood by the students?

3 RESULTS

3.1 Comparison of learning outcomes

When exploring students' understanding of factors affecting industrial quality control, four qualitatively distinct ways of understanding the direct object of learning were identified.

A. Quality of production line can be expressed with control charts
B. Quality of production line can be rationalized for sample acceptance/rejection
C. Quality of production line can be explored by the offset from the mean
D. Quality of production line can be explored by the outlying variety of samples

Table 3. Distribution of the Conceptions for the Written Task

	Experimental Group (37 students) (Variation theory applied)		Control Group (26 students) (Variation theory NOT applied)	
Conception	Occurrences	%	Occurrences	%
A	34	91.9	22	84.6
B	30	81.1	16	61.5
C	34	91.9	1	3.9
D	36	97.3	1	3.9

3.2 Effect of variation theory on student learning

Table 3 shows how students in the experimental and control group understood *production line quality control* through the use of the presence and absence of variation theory in the classroom. The majority of students in the experimental group were able to recognize all four aspects of the phenomenon taught using variation theory. The students in the control group were able to understand the lower-order concepts A and B (85.6% and 61.5%), but they were unable to comprehend the higher-order concepts C and D (around 4% for each). In conclusion, this research confirms that variation theory has a better ability to create necessary learning conditions and thus has brought a positive impact on student learning in engineering education.

4 SUMMARY AND ACKNOWLEDGMENTS

This research investigates a novel phenomenon: using variation theory in engineering education and analysing its impact on student learning using phenomenographic principle. This short paper reports evidence of how, by incorporating variation theory, a faculty member designed different pedagogical approaches that ranges from less sophisticated (A to B) to higher (C to D), which facilitates students conceptualizing complex engineering topics more systematically than those who do not discern variation. An extended version of this article is expected to appear in future publications.

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WHAT DO WE NEED TO CONSIDER WHEN DESIGNING AND RESEARCHING STUDENT LEARNING IN CHALLENGE-BASED LEARNING?

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ABSTRACT

Challenge-Based Learning has become specifically popular in higher engineering education. CBL addresses the key characteristics of future engineering programs by embracing authentic, active learning, offering choice in problem-solving and learning practices as well as enabling training in interdisciplinary teamwork and decision-

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making. This responds to the desire of many students for a sense of meaning in their education. Just as with many other educational innovations, we see a large variety of many different initiatives under the CBL label which is why much research is being conducted on the characteristics of CBL implementation. But the goal for researching different characteristics of CBL experiments is to, in the long run, understand whether CBL influences student learning, and in which way, since prior research suggests positive effects of such active learning approaches. In this short paper we present a framework for capturing the prerequisites, context, process and outcomes of student learning in Challenge-Based Learning. We take a close look at CBL as an educational concept in contrast to the prior ways in which student learning has been described. We put forward a heuristic analytical framework that will allow researchers and educators to capture the different aspects of the CBL process and context that could guide further education innovation and research to foster student learning gain in CBL.

1 INTRODUCTION

Higher education institutions worldwide have implemented Challenge-Based Learning (CBL) as a response to calls for more future- and student-oriented education. While CBL puts students at the center of the teaching and learning processes, most CBL research has focused on CBL design characteristics and has not yet systematically integrated existing research on student learning. This short paper therefore presents a framework for capturing the prerequisites, context, process and outcomes of student learning in Challenge-Based Learning.

2 THE FUTURE OF ENGINEERING EDUCATION

Today's societal, political, and economic changes in the world yield numerous challenges that are often complex, open-ended, and ill-defined [1] and call for competencies, often referred to as 21st-century skills, that go beyond workers' traditional tasks and responsibilities. This is specifically true for future engineers, who need to possess a T- or Π-shaped profile, mastering in-depth disciplinary knowledge as well as broader professional skills that will allow them to develop technical solutions to current problems.

These requirements are also presenting new challenges for engineering education, as traditional teaching approaches focusing on transmission of knowledge have started to lose their functionality [2]. Thus, many educational practitioners have strived to create modern and powerful learning environments that allow for students' distributed and co-operative learning through social interactions in representative authentic, real life contexts that have a personal meaning for them.

3 CHALLENGE-BASED LEARNING

One relatively new approach, that has become specifically popular in higher engineering education is Challenge-Based Learning (CBL). CBL aims at creating "a learning experience where the learning takes places through the identification, analysis and design of a solution to a sociotechnical problem. The learning experience is typically multidisciplinary, takes place in an international context and aims to find a collaboratively developed solution, which is environmentally, socially and economically sustainable." [3, p.4]. In order to achieve these aims, CBL usually involves open-ended challenges or problems from real-world practice that require students to work in interdisciplinary teams. The uncertainty that naturally arises in such authentic project work is expected to trigger students' self-regulation and motivation as students can make sense of their education [4]. Apart from students' improved technical and problem-solving skills as well as a deeper understanding of disciplinary knowledge [5], students in CBL settings are also expected to interact in real-world settings, acquire knowledge and develop skills they can apply to respond to any kind of complex problems in the future, such as self-awareness, self-leadership, teamwork, and an entrepreneurial mindset [6].

Given these advantages of combining experience, cognition, and behaviour, CBL has become especially popular in higher engineering education with a large variety of approaches that are being adapted to and shaped by different contexts, needs and learning objectives [7, 5, 8]. Whether the advantages of students' active involvement in their learning that have been shown in prior research [9] also apply to student learning in CBL however is not clear, as the two fields have not yet been systematically integrated. In the following, we therefore suggest a framework for capturing the prerequisites, context, process, and outcomes of student learning in CBL.

4 STUDENT LEARNING IN CHALLENGE-BASED LEARNING

The framework for capturing student learning in CBL can be seen in Figure 1. We will present the parts in the following, starting from the core of the framework, students' learning patterns, before turning to students' learning outcomes, and finally personal and contextual factors specific of CBL environments.

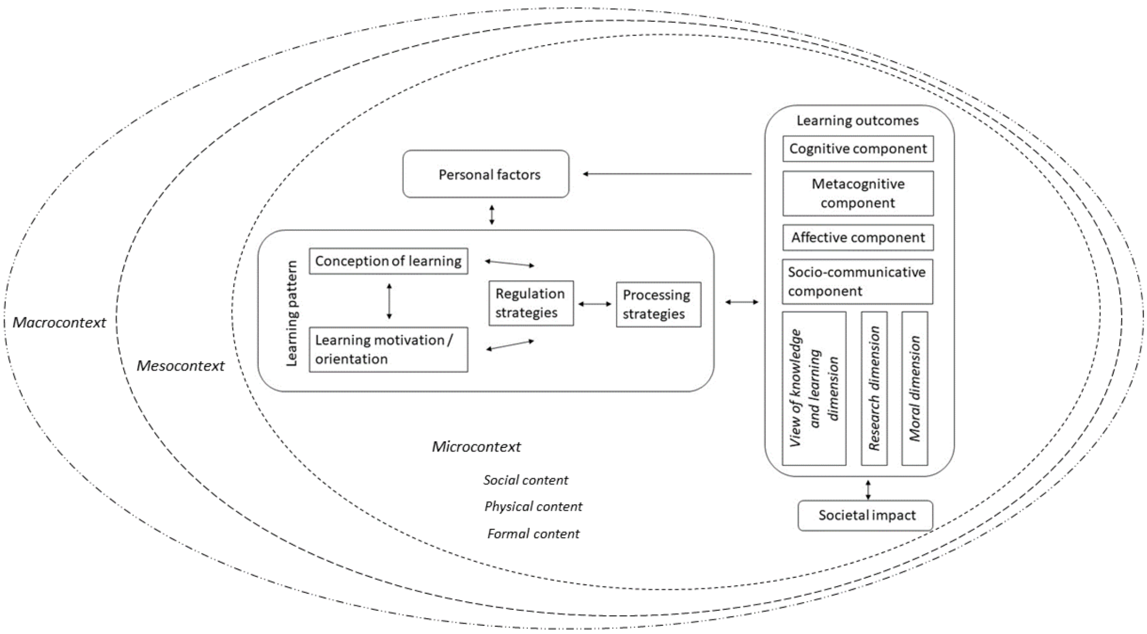

Fig. 1. Student learning in Challenge-Based Learning

4.1 Student learning patterns

A student's learning pattern has been conceptualised in prior research as "a coherent whole of learning activities that learners usually employ, their beliefs about learning and their learning motivation" [10]. These comprise students' cognitive processing strategies (what activities students employ to process subject matter), metacognitive regulation strategies (students' activities to plan, monitor, and evaluate learning processes), (metacognitive) conceptions of learning (students' views and beliefs about learning), and students' learning motivations and orientations (students' aims and goals). These strategies then result in four different learning patterns, i.e., reproduction-directed learning, meaning-directed learning, application-directed learning, and undirected learning [10]. Whether students' employ more or less beneficial learning patterns affects students' learning outcomes and is affected by students' personal and contextual factors, all of which will be described in the following.

4.2 Student learning outcomes

For describing the variety of student learning outcomes in CBL, we draw on Vermunt and colleagues' framework of learning gains in higher education, referring to "students' change in knowledge, skills, attitudes, and values that may occur during higher education across disciplines" [11]. This change may refer to the cognitive, metacognitive, affective, and socio-communicative components and three dimensions (view of knowledge and learning, research attitude, and moral reasoning) of learning gains. In CBL, specific emphasis lies on the socio-communicative component with students developing a professional identity, creative/ innovative and entrepreneurial thinking. Specifically important are the discussions of the cognitive component of student learning gains, as the specific contexts of CBL will allow for a large variety of learning outcomes. Further outcomes of students' work and learning in CBL, are that their solution or product developed in response to the challenge may have a societal impact, which may again affect student motivation and perceived usefulness of the CBL process [12].

4.3 Personal factors

Personal factors that affect student learning are usually described to be age, personal background, prior knowledge, educational experience, and epistemological stance. In our framework, we assume that students' experience with interdisciplinary and collaborative work in general and with CBL specifically, as well as their sense of responsibility for their learning and ability to deal with uncertainty affect them developing more or less beneficial learning patterns.

4.4 Contextual factors

The interplay between students' personal factors and learning patterns, leading to specific learning outcomes can be assumed to be affected by numerous contextual factors. Using a framework of context in higher education by Wosnitza and Beltman [13], these factors can be structured on three levels, namely the microlevel (i.e., the course level context), the mesolevel (i.e., the institutional level), and the macrolevel (i.e., the wider societal, local, national, international context). Each of these levels of context holds different content, namely the social content (e.g., the peers, coaches, teachers, external stakeholders the student interacts with, the frequency of meetings with them, the group atmosphere), the physical content (e.g., learning resources and space available for learners, learning technology), and the formal content (e.g., open-endedness of challenge, assessment/ feedback/ reflection methods, scaffolding on the microlevel, curriculum, institutional and departmental vision of CBL on the mesolevel, and global themes guiding the challenges on the macrolevel).

5 CONCLUSION

While some research has already emerged exploring various aspects of CBL implementation, not enough insights have been gathered about whether and how CBL influences student learning. As a first step, we therefore presented a heuristic analytical framework of student learning in CBL. This will allow researchers and educators to systematically relate the different aspects of the CBL process and context in future education innovation and research. Specifically focusing on the different levels and various content of the CBL context, such as student (interdisciplinary) team work in CBL, will allow for understanding how CBL can foster beneficial student learning patterns and outcomes and what configuration of CBL elements constitutes the most powerful pedagogy for educating future engineers.

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Developing Strategic Partnerships through a Sustainability Enrichment Week

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ABSTRACT

This paper describes the development of a mini-module focused on sustainability and timber engineering as a component of a strategic partnership designed to broaden Transnational Education, increase staff/student mobility, and further develop industry and community links within two universities. Edinburgh Napier University (ENU) draws students from around the world and is internationally recognised for timber construction and wood science. The New Model Institute for Technology and Engineering (NMITE) is a new higher education provider in England pioneering an innovative approach to engineering education integrating business, engineering, the liberal arts, and professional skills. ENU and NMITE leveraged these strengths to develop a strategic partnership that brings together staff, students, industry, and the community for opportunities that create impact beyond traditional learning approaches. This can be seen through the development of a Sustainability Enrichment Week hosted by NMITE's Centre for Advanced Timber Technology (CATT) and attended by ENU Master's in Environmental Sustainability students. Students investigated interfaces between buildings, humans, and nature through experiential learning based around the construction of the CATT building, which has been developed as a Living Lab. Each day featured activities aligned to identified learning outcomes and was themed around one of five sustainability competencies: systems thinking, values thinking, strategic thinking, future thinking, and collaboration. The Sustainability Enrichment Week also served as a trial for a short course soon to be offered as part of a Timber Technology, Engineering, and Design programme. This project could be a model for other universities seeking to create similar strategic partnerships and learning experiences.

1 INTRODUCTION

Universities have long recognised the value of strategic partnerships that can help achieve institutional goals such as strengthening links to industry, adding value to programmes through additional talent and resources, and increasing knowledge exchange, all of which can ultimately lead to new student recruitment markets and therefore additional revenue streams. However, it is often hard for administrators to find space within traditional programme structures to add these kinds of activities, and while academic staff may see the value in these initiatives, they may not have the time to embed them within their existing modules. What can be done to overcome these challenges to creating strategic partnerships?

The purpose of this paper is to show how the development of a short course or mini-module can provide the opportunity to build relationships with industry and the community, to focus on broader or more holistic themes that may help students tie together their academic knowledge and experiences, to provide staff and students at different institutions the chance to collaborate in new ways, and to trial innovative pedagogies and technologies.

2 CONTEXT AND LITERATURE REVIEW

Over the past two years, an educational alliance has emerged between Edinburgh Napier University (ENU) and the New Model Institute for Technology and Engineering (NMITE) located in Hereford, England. Given the track record of ENU in timber construction and wood science research, the relationship is centred on co-developing a timber technology, engineering and design educational programme aligned with the NMITE integrated and challenge-based learning ethos. ENU and NMITE aim to leverage these roles and institutional strengths to develop a mutually beneficial strategic partnership that brings together staff, students, industry, and the community to create impact beyond traditional learning approaches. Besides creating learning opportunities for students and staff, this alliance also has the potential to create financial and reputational advantages to both institutions. One of the actions taken to strengthen this partnership has been the development of a Sustainability Enrichment Week for students in ENU's MSc Environmental Sustainability programme hosted in Hereford by NMITE's Centre for Advanced Timber Technology (CATT).

The theme of Sustainability was chosen not only because of its intrinsic importance; it was also a theme that unites the mission of the the CATT (to promote innovations in timber technology and engineering that lead to sustainable construction) with content in the ENU programme, which contains modules such as water and waste management and building energy performance. The Sustainability theme was also broad enough that it enabled interaction with several companies and organizations that might not ordinarily consider partnering with an engineering programme, leading to new potential avenues of engagement and support for both universities. Additionally, Sustainability could easily be linked to the modules in NMITE's Master's in Integrated Engineering (MEng), meaning that learning experiences could be developed that benefited students from both NMITE and ENU and could be delivered collaboratively with faculty from both institutions.

Rationale for development of this themed mini-module rests in recent scholarship in several areas. Firstly, using sustainability as a theme can bring students and staff from different backgrounds together for a common goal [1]. Indeed, learning about sustainability in a way that is not dependent on specific technical knowledge and that speaks to integrated, interdisciplinary solutions will be increasingly important in both engineering education and for achieving breakthroughs in sustainability. Secondly, given that Scotland and England have two different higher educational systems, this experience can fall under the umbrella of Transnational Education. Research on students who engaged in short-term study abroad has shown that even these brief experiences can be effective at achieving higher-order learning outcomes [2]. Thirdly, more effective industry and community engagement can be fostered even through these short, intensive sessions [3]. Fourthly, faculty who are involved in these types of short-term study activities have viewed them as a professional development opportunity due to the difference from the roles they play and interactions they typically have in a confined classroom setting [4]. Finally, while there is not as much research about these types of non-graded enrichments weeks that sit outside the proscribed curriculum, there is anecdotal evidence to show that students find these opportunities a valuable part of their educational programmes [5].

Based on this research, several aims of the Sustainability Enrichment Week were articulated to address the needs and expectations of a variety of stakeholders:

1. To enhance knowledge exchange between institutions via ENU's School for Engineering and the Built Environment and NMITE's Centre for Advanced Timber Technology, and between each institution's industry and community partners;
2. To provide a template for further staff/student mobility that enhances learning opportunities for both groups;
3. To promote, develop, and further deploy NMITE's interdisciplinary and experiential pedagogy that is an innovation in engineering education;
4. To create learning opportunities that bring together people from diverse backgrounds, bridging international as well as urban/rural divides;
5. To contribute to efforts that advocate for socially and globally responsible and responsive engineering.

2.1 Determining Student Outcomes

After agreeing upon aims of the Sustainability Enrichment Week, it was necessary to determine what outcomes could be most beneficial and desirable to students registering on this extracurricular module. An informal review of the modules in ENU's MSc Environmental Sustainability revealed that they contain rigorous content in specific subject areas like waste, water, energy, and construction, but it was less clear how the modules worked together coherently to result in a holistic professional approach to and understanding of environmental sustainability. Since NMITE's curricular approach is based on learning taxonomies that culminate in synthesis (tying together knowledge) and phronesis (whether or not knowledge or action is wise or valuable), it became clear that the enrichment week activities should focus on professional competencies in sustainability that stretch across and beyond technical disciplines to encompass these higher-order concerns.

Therefore, it was decided that the outcomes of the enrichment week would be to develop skills in the five sustainability competencies as promulgated by Arizona State University's School of Sustainability: systems thinking, values thinking, strategic thinking, future thinking, and collaboration [6]. Each day in the week was to focus on one of these competencies as a learning outcome, and contain a variety of interdisciplinary, experiential activities to support that learning.

2.2 Determining Module Activities

The construction of the Centre for Advanced Timber Technology building allowed for a specific case study through which to frame the week's activities. The building is a 2,500m^2 purpose-built educational facility that reflects the NMITE pedagogical approach and combines it with the capability to service the needs of the growing timber engineering industrial sector. On this basis the building is a "Living Lab" creating the necessary conditions for research to be undertaken on the building itself and the innovations created within it. Formed as a hybrid structure combing cross laminated timber, glue laminated timber, closed panel timber systems and steel braced and portalised frames, the building is measured and monitored utilising sensors and digital technologies acting as an ongoing educational toolkit. Since construction was being completed in spring 2022, this building site enabled the sustainability enrichment week to focus on the interfaces between buildings, humans, and nature. It also provided real-world experience and engagement with timber and monitoring technologies, construction management, and place-based learning.

For instance, in a day themed around the outcome of Systems Thinking, activities included: an introduction to the Living Lab building monitoring system; a tour of the CATT building construction site with its project manager; a lunch and learn session with the Sustainability Lead of the construction company; a workshop on environmental impacts within construction supply chains, and a seminar to reflect on the variety of systems involved in products, buildings, and communities.

This combination of learning, doing, exploring, and reflecting allowed for a multidimensional perspective on the systems thinking outcome, and showcased how systems thinking is required by real-world professionals in authentic situations. These activities also had a dual purpose: not only did they help achieve the aims of the sustainability enrichment week, but they also served as a testing ground for some of the content in NMITE's Timber Technology, Engineering, and Design course now in development.

3 RESULTS

Some uncertainty surrounded the initial development of the Sustainability Enrichment Week: it was unclear if and how students would respond to the opportunity, or if administrators and industry/community partners would be supportive. Additionally, there was little time for planning since the idea was developed in mid-February 2022 and executed in mid-May 2022. However initial conversations with various stakeholders were uniformly positive, and 6 staff from ENU and 6 from NMITE participated in various activities, with 8 companies and organizations outside the universities also being involved.

15 students attended the enrichment week, and these represented diverse demographic backgrounds. Some of the students had never before been to England, and most had never been to rural parts of the country. This group engaged with a cohort of NMITE's MEng students, which created another opportunity for students from both rural and urban and local and international backgrounds to interact.

Students were asked to fill out a pre-survey and a post-survey in order to elicit a comparison between their existing understanding of the sustainability competencies and their understanding after engaging in the week's activities. 8 students completed the pre-survey and 9 students completed the post-survey; in both cases they rated their own knowledge on a scale of 1 being the lowest and 5 being the highest. Table 1 provides averaged results from the surveys which indicate that knowledge increased across all 5 competency areas:

Question	**Pre-Survey Average Rating**	**Post-Survey Average Rating**
How would you rate your understanding of **values** (that is the principles, attitudes, and qualities related to concepts of justice, equity, and responsibility)?	4	4.78
How would you rate your understanding of the **connection between values and sustainability**?	4.25	4.78
How would you rate your understanding of **futures thinking** (that is, the ability to anticipate how problems might evolve or occur over time)?	4.25	4.67
How would you rate your understanding of the **connection between futures thinking and sustainability**?	4.38	4.67
How would you rate your understanding of **systems thinking** (that is, the way that problems cut across different systems and domains of knowledge)?	3.88	4.67

How would you rate your understanding of the **connection between systems thinking and sustainability**?	4	4.56
How would you rate your understanding of **strategic thinking** (that is, how intentional plans and deliberate coordination can be leveraged to achieve transformational goals)?	4.25	4.67
How would you rate your understanding of the **connection between strategic thinking and sustainability**?	4.13	4.56
How would you rate your understanding of **collaboration** (that is, how communication, leadership, empathy, and negotiation can achieve goals)?	4.25	4.78
How would you rate your understanding of the **connection between collaboration and sustainability**?	4.63	4.78

Table 1. Comparison of student's self-rated understanding of sustainability competencies before and after the enrichment week.

These results demonstrate that even a short week of experiential learning can achieve significant gains in student understanding. Additionally, 100% of survey respondents said they would recommend the experience to another student.

4 CONCLUSION

The development process of the Sustainability Enrichment Week has been effective in terms of encouraging knowledge exchange between two universities and their industry and community partners, recruiting diverse students, and developing unique integrated and experiential learning opportunities that promote student and staff mobility. These learning experiences have shown to increase student understanding across five sustainability competencies.

The Sustainability Enrichment Week was developed by capitalising on what was already happening in the two institutions and leveraging existing resources and relationships. It took a themed learning approach that was not dependent on specific technical knowledge and that spoke to integrated, interdisciplinary approaches which will be increasingly important in both engineering education and achieving breakthroughs in sustainability. It got a lot of people within and beyond the universities excited about this work, and introduced students to a variety of perspectives and potential career paths. The experience in developing the Sustainability Enrichment Week can serve as a template for other institutions seeking to achieve similar aims.

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TECHNICAL AND PEDAGOGICAL CHALLENGES FOR IMPLEMENTING FEEDBACK STRATEGIES IN A VIRTUAL LEARNING ENVIRONMENT

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ABSTRACT

Pedagogical developments in the virtual learning environment (VLE) are constrained by technical expertise which impacts the design and delivery of online learning, including the implementation of varied feedback strategies. In recognising this dilemma, the paper addresses the question, *"What are the technical and pedagogical challenges of implementing feedback strategies in a VLE?"* This short paper presents an initial critical, reflexive account on the challenges to embed and manage feedback strategies, including automatic feedback, peer feedback, and tutor-led feedback, on the VLE of a blended module provided to over 1,200 engineering and business students at a UK university. As a result, the authors recognise the importance of upskilling engineering educators to technically innovate

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their VLEs to enhance student learning and connections through feedback. Further investigations to evaluate the impact of the varied feedback strategies on student learning will occur at a later stage in order to advance this work in progress.

1 INTRODUCTION

The Covid-19 pandemic has renewed interest in the development of feedback practices in a virtual learning environment (VLE) [1]. Yet engineering educators face barriers to implement a variety of feedback strategies, including automatic feedback, peer feedback, and tutor-led feedback, in online learning spaces. Therefore, this short paper addresses the question, *"What are the technical and pedagogical challenges of implementing feedback strategies in a VLE?"*

Feedback is important for student learning, because it can "raise students' consciousness of the strengths of their work, boost students' confidence and self-concept regarding personal strengths and abilities, provide guidance on areas for further development of skills and enhancement of work, [and] enhance students' own judgement, understanding of assessment criteria and ability to self-audit their own work" [2]. In addition, embedding a variety of feedback strategies is significant for curating a dynamic environment that facilitates flexible learning, individualisation, and connection. However, pedagogical justifications for feedback are compromised by a feasibility to manage resourcing of feedback provision and a technical ability to implement different feedback strategies. This is the case for the design of a VLE for a blended module on transferrable skills and research methods provided to over 1,200 postgraduate engineering and business students at a UK university.

The scope of the paper is on the feedback strategies implemented on formative learning activities embedded in the module's VLE. These activities are accessible to over 1,200 postgraduate students across 20 unique sessions delivered on a weekly basis. The activities were created and managed by the four authors who form the module teaching team. This high student-to-teacher ratio is a constraint that intensified the challenges of pedagogical and technical design and delivery of feedback.

This short paper is a reflexive account by the authors on facing and resolving challenges to embed varied feedback strategies in a VLE for a large student cohort. By presenting initial findings that interrogate the tension between pedagogy and technology, this work in progress provides initial suggestions for engineering educators who seek to innovate their VLE and enhance student learning.

2 METHODOLOGY FOR PROVIDING FEEDBACK IN A VLE

Five feedback strategies were employed on the VLE of the module. These include: (1) *'No virtual feedback'* for activities in which feedback was delivered outside of the VLE (e.g. a poll to engage students to see how their responses compare with other students). Another strategy was automatic feedback, or when feedback was provided immediately following the completion of an activity, and was divided into two categories. (2) *'Automatic feedback – quiz'* is contrasted with (3) *'Automatic feedback – response available',* as the former is individualised feedback based on incorrect responses while the latter is a 'good example' provided to students after activity submission to enable critical comparison. (4) *'Peer feedback'* includes forum activities in which students respond to other students' posts. This enables student learning communities to form online. Finally, (5) *'Tutor-led feedback'* is the provision of personal feedback on an activity by a member of the teaching team. This is important for creating connections between students and staff. Since the focus of this short paper is on feedback strategies in a VLE, *'No virtual feedback'* will not be discussed here. Nonetheless it is significant since in a blended module, feedback is also provided in a synchronous, face-to-face environment.

Each feedback strategy had its own unique benefits to support the different learning needs of students and enable connections between student and student, or student and teacher. Further, different feedback strategies may be more sustainable considering tutor workload at a time during module delivery. For instance, during an intensive work period in which the teaching team was reduced from four to two individuals, it was only feasible to provide automatic feedback since there was no flexibility to provide or technically support alternative forms of feedback.

To account for the number of feedback strategies employed on the module VLE, a frequency analysis is presented in Table 1, below. There were 85 formative learning activities on the VLE split across 20 asynchronous sessions. All 1,200 students could access these activities, though not all students completed them since only some of these students completed the module for credit. The number of activities varied across sessions; this caused concern about student workload. Hence, in response to mid-module feedback, the number of formative activities decreased for sessions 15-19 to enable deeper learning and higher engagement. Consequently, the number of opportunities for feedback on formative learning activities was also reduced as a result of this change in response to mid-module feedback.

Table 1. Feedback strategies employed in the module VLE

Feedback Strategies						
	No virtual feedback	*Automatic feedback -*	*Automatic feedback –*	*Peer feedback*	*Tutor-led feedback*	

		quiz	*response available*			
No. of activities	16	47	15	6	1	N = 85 (100%)

It is noticeable that *'Automatic feedback – quiz'* appears more often than other forms of feedback. This reflects the over-reliance of the teaching team on one form of feedback due to the technical ease of using an online quiz to provide feedback on student learning. In contrast, *'Tutor-led feedback'* did not occur frequently due to concerns that marking individual submissions and providing personalised feedback to scale would compromise the workload of the team while removing flexibility of student learning by imposing a deadline for submission.

3 CHALLENGES TO IMPLEMENTING FEEDBACK STRATEGIES IN A VLE

3.1 Balancing pedagogy, workload and technical ability

In analysing the reflexive accounts of the teaching team, a key dilemma to implementing various feedback strategies was balancing pedagogical design with academic workload and technical ability. For instance, a challenge of tutor-led feedback was managing the high student-to-teacher ratio on an online platform. While there are technical solutions for reducing feedback administration time, such as embedding a standard rubric to the VLE or viewing student submissions online rather than downloading, providing individual feedback en masse severely compromised the workload of the team. While a justification can be made for generating feedback by artificial intelligence [3], the extreme workload to provide individual, tutor-led feedback in the absence of technical confidence supported the design of *blended* learning in which synchronous, face-to-face seminars, drop-in sessions, and office hours offered the opportunity for tutor-led feedback.

The lack of technical ability by the team meant there was limited use of software and applications to create multiple modes in which feedback was communicated to enable students to select feedback relevant to their skill level and/or learning style. For instance, the team frequently utilised automatic feedback that was relayed in standardised text. This meant it was not possible to alter the vocabulary or meaning of the feedback to ensure it was understood by all students [4]. Therefore, upskilling educators on how to create and embed automatic feedback in creative ways, such as audio and/or video recordings, and pitched at different levels of knowledge, can enable students to select how they best learn [5].

3.2 Problematising student learning and connection

To support student learning, it is important that students engage and learn from feedback. However, in an online environment where students can move freely through activities, it is possible that students are not engaging deeply. For instance, in analysing the data on the time duration taken to complete a quiz, the tutors identified students who purposely failed a quiz to quickly receive the correct answers, so these can be inputted as fast as possible in order to complete the activity. Technical design can resolve this by reducing the number of attempts available to pass a quiz. Yet, while it appears students are moving quickly through activities as part of surface learning, there is no data available on how students engaged with the feedback. For instance, it was not clear if students moved quickly through the activity to spend more time with the feedback in order to learn from ‘correct’ or ‘good’ answers or how students applied this feedback to their future learning and practice. Hence, this work in progress plans to undertake further evaluations to explore student literacy of feedback in a VLE, as well as the unique influence of each feedback strategy on student learning [6].

Peer feedback is a means to develop virtual learning communities and a sense of belonging through frequent interactions that build student connections. This is important since students with a higher sense of belonging are more motivated to engage and learn, and therefore achieve [7]. Yet these positive outcomes were undermined by a lack of technical ability of the teaching team to create multiple small groups of students. As a result, each forum was shared by all students; this weakened the formation of meaningful and stable student connections due to the large class size. Therefore, technical upskilling also concerns an ability to manipulate organisational settings of the VLE, such as establishing unique user groups that exist across peer activities, to improve student connections.

Furthermore, while guidance was provided to students on how to give peer feedback on posts, this did not mean the guidance was followed, since forums are assessed on participation and not learning. To overcome this technical challenge, a pedagogical solution is to provide a marking checklist or rubric to enable depth and consistency to peer marking that can be embedded in the VLE for common use. This can enhance learning since expectations to the application, analysis, and evaluation of knowledge in the activity are clarified for students.

4 CONCLUSION

This short paper provides a reflexive, critical account of technical and pedagogical challenges to implement varied feedback strategies in the VLE for a module with a high student-to-teacher ratio. A key theme is the need to upskill educators on the technical capabilities of VLEs and use of accompanying software and applications, so the design of feedback is based on pedagogical innovation rather than technical comfort. For instance, resolving the team's over-reliance on text-based automatic feedback by ensuring time is made available for prototyping and testing feedback strategies so they can be embedded within the learning design. Enhancing the technical skills of engineering educators to innovate their VLE would benefit students' deeper learning. Also, in the case of this transferrable skills and research methods module, it would improve the quality of the learning experience, so students do not spend most of their time applying their knowledge in independent activities that receive monologic feedback.

Furthermore, greater consideration must be made to sustainable feedback that does not compromise the workload of the teaching team and students. Hence, when testing feedback strategies in a VLE, it is important to consider the time needed to create and disseminate feedback, particularly in regard to the quantity and quality of feedback provided to students throughout the module. Also, the decision to use one feedback strategy over another will be made following further evaluation of student preferences for, and impact of, different feedback strategies on student learning in the VLE. Therefore, this work in progress will extend these initial suggestions through further evaluation of the online feedback strategies on student learning and connections in order to advance engineering education.

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DIMENSIONS OF MULTIDISCIPLINARY ENGAGEMENT BEYOND THE CLASSROOM IN CHALLENGE-BASED LEARNING

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ABSTRACT

The study investigates and reports on the process of engagement in learning through the innovative pedagogical framework – Challenge-based Learning (CBL) – their changing perspectives of learning and their interaction with each other while conducting authentic challenges. This gives way to understanding how learners construct and create meaning out of learning activities, course content and beyond the course objectives. Our mixed method research explores potential impact dimensions of the implementation of challenge based learning on teachers and students. To reveal the potential impact we conducted a focused group interviews with the learners who took part in CBL-integrated lessons and surveyed 68 number of learners who participated in CBL trainings. Our preliminary findings showed that learners undertook news roles by driving their own learning, developing collaborative skills, exploring knowledge to be acquired, and establishing relevance of course content in real contexts which made it meaningful for them to understand. In our presentation, we would like to discuss the implications of CBL implementation on the way higher education can be redesigned by assigning learners a more active role in learning and the engagement that occured during their learning experiences.

1 INTRODUCTION

1.1 Why Challenge-based learning?

With long-standing experience and successful implementation of problem-based learning (PBL) we propose in this paper that the PBL concept should be taken one step further to strengthen modern European higher education institutions, instigating the pedagogics of challenge-based learning (CBL) together with external stakeholders to foster learner engagement and at the same time building communities by utilizing authentic challenges into the learning process. The difference between PBL and CBL is its strong emphasis on the opportunities to investigating real immediate world problems, the focus on the process and skills that they can then apply beyond the challenge and their education. While PBL´s aim is to identify diagnostic problem and the process or working out the solution, CBL addresses "societal challenges" and sustainable societal goals with engineering and business development (Malmqvist et al., 2015).

1.2 Definitions of CBL

Challenge-based learning (CBL) is is `a multidisciplinary approach that encourages learners to work actively with peers, teachers and stakeholders in society to identify complex challenges, formulate relevant questions and take action for sustainable development´ (Rådberg et al. 2020, p. 21). It follows a specific structure, which consists of three main steps: engage, investigate and act (Nichols et al., 2016). Implementation of CBL is recommended in engineering education to allow for combining technology, principles of modern industry, and at the same time skills of communication that are personalized, collaborative and relevant to the needs of society (Conde et al., 2017; Membrillo-Hernández et al., 2021).

1.3 Purpose of the study

This is an inquiry to look into the participation of UiS students partaking the challenge-based learning initiative where the main purpose is to investigate their collaborative work and engagement during the challenge-based learning experience. Beside their weekly regular lessons, all team members which consisted of learners, CBL experts, and external stockholders met and worked on the CBL project once a week over the semester period of three months. They also had several appointments with the stakeholders to collect information for developing their solutions. The challenges developed by the learners were, for example, sustainable digitalisation, food waste, sustainable construction industry, efficient army resources, and efficient warehouses. Each of the three main steps consists of smaller activities, 1) Engage: Big Idea; Essential Questions; The Challenge, 2) Investigate: Guiding Questions Guiding Activities and Resources; Analysis, and 3) Act: Solution; Implementation; Evaluation and Publishing. We can see that these challenges require multidisclinary efforts from innovative insights from all fields of study.

2 METHODOLOGY

2.1 Research objectives

The study employs a questionnaire survey and interviews as the methods of data collection. The aim is to reach the two following research objectives:

- To investigate the learning opportunities and engagement perceived by the CBL learners and teacher assistants during and after the trainings

- To provide pedagogical implications for CBL educators and recommendations for future trainings schemes

2.2 Participants

The first sampling was 68 Bachelor-level students who applied the ECIU challenge-based learning initiative in their project in a 9-ECTS course titled *Information and Technology Management* arranged by the University of Stavanger. They were contacted either through the CBL expert, or their advisor to complete our questionnaire survey. The second sampling consisted of five learners in the team, two students who expressed their interest in partaking in the interview and three teacher assistants.

2.3 Research instruments

A survey The survey took 15 minutes to complete. It had 4 questions that asked for name, department and whether they were an international or a local learner. The survey questions were divided into 2 parts, with the total of 21 questions. It had 5 scales, ranging from `strongly agree´ (5) to `strongly disagree´ (1).
An Interview The interview consists of around 10 questions. It took approximately 45 minutes per interview, and they were recorded. The interview included open-ended questions about their learning experience during the challenge. Because in CBL all participants are considered learners and life-long learners, the teacher assistants were included to be interviewed about the process of learning as well.

3 RESULTS

3.1 Survey results

The results in the first section will be presented in the following seven constructs distributed in the 20 questionnaire items. The learners´ perceptions of their CBL learning experiences. The result trends were found to be positive.

Table 1. Average perceptions of learners during the CBL engagement

Clusters	Average
Roles and engagement (defined, changed)	3,27
Feedback	3,4
Knowledge in CBL	3,4
Abilities gained during learning process	3,8
Interpersonal skills and team working	3,96
Knowledge in content of challenge	3,6
Real-world learning	3,3

Most leaners reported that their roles during the process of CBL were clearly defined but they were allowed to change the roles during their interaction with other team members. The learners found the feedback they received from their peers, the expert and the stakeholders to be equally helpful. They reported to learn about how to undertake challenge-based learning quite well and that they gained knowledge and skills and abilities from working on the challenge. Their interaction during CBL was reported to increase their interpersonal skills quite a great deal. Their knowledge in the content of the challenge was found to be high but they reported that real-world learning was just above average.

3.2 Interview results

In the following section, we will present the codes, categories and themes of the data base on our interpretation of the extracts. Ultimately, we have found three main themes from the overall analysis as follows.

Theme 1 Cognitive engagement

- Prolonging problem-solving process
  ´It's still really good to focus at the beginning or not rushing to the to the solution and really looking at the problem from all perspectives and bringing everybody in your team with their backgrounds and their skills too. (TA1)
- Personalising learning experiences
  It was also related to public policy and community asset development and my work background is in public policy because I worked in London for over 8 years in public policy rules for UK Health department.´ (TA3)
- Relating skills to CBL process
  So we have to make a connection between our knowledge or two hour course and our materials with the CBL process and also with the real world companies that we are working with their challenges or problems they're facing. (TA2)
- Constructing own understanding
  But in this CBL process, the main thing is no. Now it's not at the starting point. You don't have to think about solution that please first think about your problem. Think about the situation you are in. (TA2)
- Associating with life-long learning
  ´You have to zoom in your problem. And yeah, then you got the idea where you can implement a solution. OK, yeah, so that's what we also learned with the students and it was a really great experience and we are still learning. ´(TA3)
- Risktaking
  ´I wanted to meet and explore a lot of things, so I accepted the challenge. I applied for it and it was really really good because I was only there and actually I didn't know exactly what I'm I was there for, which was really interesting.´ (ST2)

We can see that the teacher assistants, as learners, stress that the process of CBL allows for cognitive engagement in different ways. One mentions that it occurred by prolonging the process of finding solution as long as possible, which is the principle of CBL to not jump to the conclusion quickly. In CBL, all members work as a a community of practice, to utilize their content knowledge and negotiate through different approaches to find possible solutions. This foster their capabilities of constructing their own understanding beyond classroom.

Theme 2 Social engagement

- Collaboration
  ´Collaborating there can actually create a real business proposition and online companies and leave it with all these connections and and new knowledge to go and make a difference in the in the real world as well.´ (TA1)
- Teamwork
  ´And all the members and how we just fix, you know the teamwork and CBL really help us to guide us´ (ST1)
- Learning environment
  ´Go with fellow for us, so that's why we were so motivated and the environment of the people actually help us because we were always discussing and adding, having more perspectives and was like the flexibility.´ (ST2)

The students and the teacher assistant reported that their contact with group members and external stakeholders brought them with experiences which facilitated their exchange of knowledge about business and real-world issues related to their studies. They reported that their CBL experiences led them to relate to the mechanism of group work and thus utilize this mechanism in this group work.

Theme 3 Connectivist engagement

- Relating theory with real life
  ´Actually read the materials and the professor actually give us some structure that that that's how the theory says you can do that.´ (TA2)
- Putting knowledge into immediate practice
  ´Organizations are national and local level on data on policy and how they can improve things like for example, waiting times in exit emergency. ´(TA1)
- Multidisciplinary collaboration
  ´really good because it's like a real challenge and we can integrate our knowledge and then get more new perspectives from the others.´(ST1)
- Sense of self-development
  ´We can integrate our knowledge and then get more new perspectives from the others. And that's what I really want. And I I'm here to try to actually expand my mindset as well.´ (ST1)

The learners reported the benefits of CBL as to contribute their ability to connect knowledge, skills and practice. They refer to their content subjects and how CBL can help them relate and integrate what they learned in new perspectives with the content interaction and current issues at hand. Potential advantages stem from their CBL experience when it is in combination with other theoretical perspectives (Leijon et al., 2021; Tang & Chow, 2020).

4 SUMMARY AND ACKNOWLEDGMENTS

These results indicate the importance and value that CBL can help place on the learner´s experiences while becoming prospective future workers. Higher education institutions should provide facilities with availabilities of learning environment, materials, technologies and social resources and trainings or teachers to become confident coaches and students to be self-directed learners (Pepin & Kock, 2021). During interaction in class and beyond, the facilitation of learning and opportunities to explore issues are needed. As educators in higher education, we ensure that facilitation of positive engagement, such as these ones are established. Activities that can contribute to learners' sense of trust, collaboration, shared educational achievements should be provided. We have also learned that students should be encouraged to engage in CBL integrated learning in multidimensional manner. With CBL, we can maximise meaningful interaction amongst themselves and with the experts. Interaction with stakeholders can provide real-world context-specific perspectives. This is found to be highly vital especially development of soft skills for students in the fields of hard sciences. Lastly, learning activities such as CBL can provide space for students to reflect critically on the challenge and their own learning.

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THE UTILITY OF A PEER REVIEW APPLICATION IN INTERDISCIPLINARY TEAMWORK ARRANGEMENTS

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ABSTRACT

Project and challenge-based learning typically require students to navigate personal and professional relationships within a team, in order to collaboratively solve authentic problems. These collaborations are often interdisciplinary in nature – an arrangement that adds increased complexity to the team's functioning. This is due to distinctions in approaches, epistemologies, ethos or jargon. The ability to provide (and receive) appropriate and constructive feedback to peers, within the team, is a key skill that can enhance team functioning and ultimately, output. Furthermore, it is a competence that aids in lubricating social and work impediments that may be causing bottlenecks to creativity, or the manifestation of ideas. The aim of this study, set within three different interdisciplinary bachelor modules, is to determine to what extent the use of the 'Buddycheck' application for peer review, is appreciated by students and teachers. The application, hosted within the learning management system of the university, allows students to rank their peers' performance according to teacher-set criteria, as well as through flexible open-format feedback; in order to facilitate opportunities for enhanced communication and expectation alignment. We wish to ascertain to what degree team functioning is enhanced through the scaffolded communication opportunities, by highlighting and creating openings to discuss undesirable behaviours, through the feedback application. Preliminary results appear to favour this mode of feedback facilitation, albeit with certain caveats,

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detailed later. Since teamwork is universal in tertiary education, these insights may be helpful for educators attempting to further improve the evaluation of the process of their projects or challenges.

1 INTRODUCTION

Teachers implementing project and challenge-based education, use collaborative teamwork as a conduit to facilitate, and practically apply, some of their intended learning outcomes. Cooperative or collaborative learning in tertiary settings is well established, as the knowledge, skill and cognitive benefits surpass alternatives such as individualistic or competitive learning [1],[2]. However, students working in teams can experience encumbrances such as unfair distribution of work or group process deficiencies [3]. Specifically, poor communication and free riding are noted as common deficiencies. Peer feedback on process and behaviour - not to be confused with peer feedback on tangible contributions, such as quality of written submissions - can encourage students to become self-analysing reflective learners [4]. Therefore, a facilitation mechanism where giving and receiving constructive peer feedback on team process and behaviour, could plausibly assist in mediating the above issues. This could be by opening avenues to personal development and, hopefully, improvement of individual conduct. It must be noted however, that the perceived credibility of peer feedback is mixed; some researchers indicate it may act as a deterrent to negative behaviour; but timing and frequency are crucial[5] thus must be opportunely planned. Further, there has been doubt cast on whether students are completely honest when giving feedback [6], rather choosing to temper their complaints and protect the team dynamic and maintain the status quo [7]. From an instructor's perspective, gaining evaluative or developmental insights from the peer review reports can be a valuable resource to draw upon when allocating rewards or identifying key moments to intervene [8]. With the above factors in mind, a trial was implemented to discover: 1) to what extent the peer-review application 'Buddycheck' was seen as useful to enhance team functioning (i.e. facilitate communication discord, etc.) within student groups; and 2) to what extent information gleaned by tutors from the feedback application was considered useful for evaluative or developmental purposes.

2 METHODOLOGY

2.1 Case study setting

Three interdisciplinary modules (15 European Credits) working on either challenge-based (societally linked) or project-based (authentic) assignments, incorporated the peer-review application (PRA) into their processes. The PRA enables students to rank their peers (from one to five, with clear descriptors) on teacher-set criteria (e.g. work ethic, communication, etc.) and give open feedback (a tip and a top) for each of the team members, on their unique contribution. The peer feedback opportunities were offered mid-way, allowing students the opportunity to reflect and improve, as well as near the end of each module. On both occasions, students were prompted to complete the forms. Furthermore, students were offered feedback skills scaffolding, in the form of either information slides, videos or micro-workshops, in order to practise and improve their feedback abilities.

2.2 Case study instruments & data analysis

Instrumentation: digital surveys were sent to all students of the 3 modules (see *Table 1*). The pertinent part of the survey consisted of 4 agreement statements (Likert scales). Furthermore*,* open-question answers from the PRA were collated. Tutor perspectives were gained from interviews or open question surveys. *Analysis*: open answers from the PRA and tutor perspectives underwent thematic analysis (separately), where recurring themes were grouped and defined (see *Table 2*). Poignant quotes of each theme are provided for reference to illustrate the range of student and tutor-themed perspectives, see results section.

Table 1. Summary of Cases and Data Sources.

Case Study and Module Details	**Student Survey Response**	**(Feedback Skills) Scaffolding for Students**	**Peer-review Application (Open Question)**	**Survey (Likert)**	**Tutor Perspective**
Case 1: Mathematics & Computer Science *N=280* *Year:2020/21*	*N*=47 (17%)	Self-directed slides	*N*=155 (55%)	Yes	N/a (no tutors)
Case 2: Engineering, Design&Management *N=380* *Year:2021/22*	*N*=56 (15%)	Self-directed videos	n/a (No open question)	Yes	Survey
Case 3: Multiple Discipline Minor *N=42* *Year:2021/22*	*N*=12 (29%)	Micro-workshops	*N*=24 (57%)	Yes	Interview

3 RESULTS

Our findings are summarised below, in *Table 2*. It shows the range of perceptions about the PRA, for both students and tutors. The students from the different modules had a range of value perceptions for the PRA, but were mostly positively inclined. Tutors, too shared positive to mixed perceptions of the PRA.

Table 2. Summary Table Student & Tutor Perceptions of Peer-review Application

	Case1	**Case2**	**Case3**
Students' Themes			
Likert Survey			
Useful for team	*N*=33 (70%)	*N*=31 (54%)	*N*=11 (82%)
Impacted outcomes	*N*=32 (68%)	*N*=22 (39%)	*N*=7 (48%)
PRA Open Questions			
Positive Perception	*N*=77 (50%)	-	*N*=18 (75%)
Mixed/Neutral Perception	*N*=57 (37%)	-	*N*=4 (17%)
Negative Perception	*N*=11 (17%)	-	*N*=2 (8%)
Tutors' Themes			
Open Questions			
Positive Perception	-	*N*=7 (58%)	*N*=3 (50%)
Mixed Perception	-	*N*=4 (33%)	*N*=3 (50%)
Negative Perception	-	*N*=1 (8%)	0

Sample responses of the students and teachers illustrate the positive, neutral and negative perceptions, below. Generally, students had more positive than negative comments on the PRA.

Positive perception - Students

"I believe the BuddyCheck was useful in two ways. First of all, I was able to better formulate feedback for my teammates. The Buddycheck allowed me to think about the project on a

deeper level then I normally would be, working in a team. Providing my teammates with good feedback enables them to improve their work and keep the team going forward. Working on the project goes smoothly and the quality of the final product is much better when we as a team have a good understanding of each other's ideas. Secondly, I can better orientate myself with the feedback my team provides me with. That way I can work on improving my weak skills much better as they would be pointed out by my team members."

Neutral perception - Students

"I don't feel like it impacted team functioning much either way."

Negative Perception - Students

"I see no use in using Buddycheck, it doesn't hinder progress. However, it seems kind of redundant, either a team member is responding just fine, in which case it seems like an awful idea to indirectly tell them: "Hey, you're doing a bad job" I think that's really bad for group chemistry. If a group member isn't responding, that's a different story, but I would assume people would instantly message one of the project organizers about it, instead of saying it via here. In short, giving each other indirect feedback seems like a great way to create a toxic environment during the project. Encourage direct feedback and a good healthy group environment where problems are quickly sorted out instead of building up only to find out via this buddycheck system."

Positive remarks - Tutors

"Useful, helps for students to consider their own work / contribution in context of others, and helps me in assessing if my own impression of group members is correct."

Neutral remarks - Tutors

"Useful in theory, but it's not by definition a representation of the actual perception of student's peers within their group. Students might tend to be too optimistic or 'soft', to not lose fragile team dynamics."

Negative remarks - Tutors

"Not very good. Although it could be useful for the students, as tutor it was more of a hassle than actually helpful."

With regard to tutor perceptions, the majority found it a useful addition that helped them gain insights to their teams; some even used the information to guide or justify feedback. However, some tutors felt that the students held back from openly criticising their peers, even when clear offences were committed. This is despite student training and encouragement to provide constructive feedback.

4 CONCLUSIONS & DISCUSSION

We conclude that across the three studies, the PRA is considered a useful tool. Either as a starting point for a conversation about team behaviour, an option as a formal and relatively safe space to express oneself, or as a means to gain insight into how peers perceive one. With regard to the application alone, making a large impact on the team functioning, there is less conviction. Highlighting the need for further process support from educators. This can be in the form of targeted skills training; mediation meetings with tutors, and making the consequences of poor performance more explicit. To summarise, simply assigning the PRA to a course as a panacea to resolve team issues is unrealistic, rather this type of aid is more beneficial when used in conjunction with well-considered soft skills support and process scaffolding with a tutor. Further, there are indications that some students remain reluctant to be completely honest when sharing negative feedback; this is in line with other studies. Educators must therefore be cognisant of this when allocating points based on peer assessment. For tutors, the PRA is mostly considered useful to gain insight into the inner workings of the team, as a reference for intervention, as well as a resource for feedback.

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TEACHERS' VIEWS ON COLLABORATING IN MULTI-CAMPUS COURSE CLUSTER FOR ENGINEERING STUDENTS

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ABSTRACT

At a European multi-campus university, parallel study programmes offered at every campus (e.g. engineering studies) and appurtenant courses are coordinated, to ensure similar quality and systematic development. In this paper, we present a case from such a multi-campus course, consisting of a cluster of basic courses in physics and chemistry for first-year engineering students. These courses are coordinated

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through identical syllabus and assessment practice but are taught locally at each campus.

The authors had noted some frustration among the teachers involved in these courses, and were interested to investigate the reasons for this frustration, and ultimately to inform the development of these multi-campus courses.

This project emerged from a realisation that literature on multi-campus courses is often associated with distance learning, while in this case, the actual teaching is provided locally. Concepts associated with teacher collaboration, such as collaborative culture versus contrived collegiality, collective versus fragmented collaboration, and depth of collaboration seem like a viable way forward in understanding the dynamics between teachers in a context like this.

In this paper, we present early results from this ongoing project, which include interviews of teachers involved in these physics/chemistry courses. Preliminary results from these interviews suggest that the expressed frustrations stem from contrived collegiality. Although the teachers experience sufficient freedom in terms of choosing their own teaching methods, several teachers raise concerns about the lack of common aims for this course cluster, which reduces collaboration to coordination of mere practical tasks.

1 INTRODUCTION

At a European multi-campus university, parallel study programs such as engineering and nursing studies are offered at every campus. The appurtenant courses are coordinated, to ensure similar quality and systematic development. How these courses are coordinated and organised differs - some courses have joint lectures and identical course content for all students and appear as one course, while others only have the syllabus in common. As these multi-campus courses are fairly new to the university, and also scattered across different faculties, there are few regulations and structures to support course development.

The organisation of these multi-campus courses has been developed independently across the different study programs. This has made way for a flexibility in terms of tailoring courses in accordance with aims, scope and external conditions. However, this also means that teachers, who have been used to working in solitude, find themselves in a collaborative state, with potentially little structure to guide their collaboration.

In this paper, we present a case from such a multi-campus course, consisting of a cluster of basic courses in physics and chemistry for first-year Bachelor engineering students. These courses are coordinated from the university's vice-chancellor level, with requirements to develop identical syllabus, assessment practice, and to use the same learning management system. However, the courses are *taught* locally at each campus. To meet these requirements, the teachers involved in these courses have regular digital meetings all through the academic year, where frequently visited topics are course content, mandatory exercises and assessment practice.

As colleagues of some of these teachers, the authors had noted some frustration regarding the collaboration, and we wanted to investigate the reasons for this, to inform further development of this course cluster. Six of the teachers involved in the physics and chemistry course were interviewed individually, to investigate and gain deeper insight into how the collaboration is organised and perceived by the teachers. Ultimately, the case presented here is part of a larger project that will investigate how multi-campus courses in general are organised and perceived, as a basis for further informed development.

2 FRAMEWORK

The term multi-campus teaching is often associated with remote (digital) teaching [1], some exceptions aside [2], whereas the teaching in the case described here is provided locally by teachers at each campus. Therefore, perspectives and concepts associated with teacher collaboration may offer valuable insights and provide explanations to the challenges that collaborative teachers may face that are not primarily rooted in geographical distance.

Teacher collaboration is seen by some as a prerequisite for realising the aims of students acquiring collaborative competence [3]. Furthermore, teacher collaboration is associated with increased self-efficacy among teachers [4]. Literature offers several terms to describe contexts where members of faculty are engaged in some form of joint activity towards teaching. However, there do not seem to be communal agreement about the definitions of these concepts, and thus they are to some extent used interchangeably [5]. Instead of trying to capture the collaboration among the teachers in this case into a single, and possibly ill-suited concept, we would investigate the activity in terms of characteristics associated with the joint activity. For this purpose, we have found the comprehensive literature review on teacher collaboration by Vangrieken et al. [5] very useful.

Vangrieken et al. [5] draw attention to the necessity of a collaborative culture, in which collaboration is considered the norm. Teaching in higher education is often associated with solitary work, which implies that a sudden shift towards collaboration probably will be regarded as contrived collegiality, which may weaken the teachers' motivation to engage in collaboration. The depth of collaboration is another important issue [5]. Whether collaboration is a matter of mere coordination of practical tasks, or a matter of sharing and negotiating pedagogical motives [6] will influence the development of both the outcomes and the process of collaboration. However, deeper levels of collaboration mean tapping on people's personal beliefs about teaching which may induce disagreements and conflicts [5], [7]. Lastly, without a sound collaborative culture, a collective of teachers may be prone to balkanisation, in which fractions of the teachers collaborate, at the expense of the teacher collective[5].

3 METHODOLOGY

To gain insight and in-depth knowledge to how a multi-campus course is organised and how the coordination and collaboration is manifested, the teachers involved were interviewed individually. The interviews were semi-structured, and the interview guide initially addressed practical aspects, such as number of students, profile of the study program, preferred teaching and learning activities. This introduction was followed by questions concerning the teachers' views and reflections on students' learning in relation to teaching and assessment practice. In the last part of the interview the teachers were asked to describe how the multi-campus course was coordinated and organised, how the teachers collaborated and how they interpreted their own role compared to the other teachers in the group.

The project and interview guide were validated by the Norwegian Centre for Research Data, which approves data collection and management. The teachers all volunteered to participate in this project, and were informed about the purpose of the project, and subsequently asked to sign an informed consent. Each interview lasted between 45 to 60 minutes and were recorded and then transcribed verbatim by the authors. In this paper we present preliminary findings based on an initial familiarisation with the data material and thorough discussions between the authors.

4 RESULTS AND DISCUSSION

All teachers reported that the collaboration they engaged in collectively through the physics and chemistry course cluster were basically concentrated on coordination of practical tasks, which corresponds to a relatively low level of collaboration, according to Havnes [6]. Initially, the reasons for this could perhaps be found in a perception of contrived collegiality [5]: The teachers have been instructed to come up with common syllabus and assessment scheme, the collaboration is not a result of a "bottom up" initiative.

However, there are other findings which suggest that the reasons for this rudimentary level of collaboration could rather be found in a fragmented collaborative culture [5]: While several of the teachers reported an appreciation for being able to choose their own teaching methods, they also raised concerns about the lack of common aims for the course and signaled a wish for better and deeper communication and collaboration. The teachers all independently agreed that they were teaching prospective engineers and not physicists. This meant little emphasis on derivations of formulas and the fundamental aspects of physics expressed in rigid mathematical terms. The point at which the teachers diverge concerns what they *do* emphasise: Some reported taking a pragmatic approach, concentrating on solving contextualised problems, while others emphasised a teacher-driven, multimodal approach, where practical and simulation-based experiences with phenomena and physical theories became central.

From this we can make a provisional explanation of the relatively rudimentary level of collaboration: The divergence in emphasis may render deeper levels of collaboration irrelevant from the teachers' perspective. The fact that the teachers in question untill recently were used to manage their own courses individually, suggests that the basis for developing a collaborative culture is currently fragile, and may act as an obstacle for pursuing common aims and emphasis, overcoming this apparent irrelevance. Perhaps the mere coordination of practical tasks can be seen as an implicit, collective measure to avoid possibly destructive conflicts between the collaborative teachers. In a well-established collaborative culture, disagreements would be perceived as necessary and constructive for development, rather than an element which might weaken collaboration. This interpretation may also provide some clues to balkanisation, as some of the teachers reported collaborating closer with a fraction of the teacher collective. The differences in emphasis across the teacher collective combined with an expressed lack of common aims, and an implicit wish to avoid conflict may explain why teachers who find themselves sharing similar views on aims and means collaborate on a deeper level, at the expense of the teacher collective.

It should be noted that deep levels of collaboration are also dependent on external conditions. In this case, different study programs, the number of students per course, online students mixed with campus students in the same course, available teacher resources locally at each campus, and classroom affordances varied across the physics and chemistry course cluster. These local differences will influence the degree of alignment regarding teaching and learning among the collaborative teachers.

5 SUMMARY AND FURTHER RESEARCH

The teachers sketch a complex picture of their inclination toward collaboration: they report a wish for more and deeper levels of collaboration, but at the same time they wish to preserve a certain level of flexibility. This balance between ownership and autonomy on one hand, and collaboration and negotiation on the other is something that needs to be addressed in the forthcoming analysis of these interviews. We still have interviews with teachers from other courses and campuses we want to add to this project, at a later stage.

We see the need for establishing a forum where teachers can exchange ideas and experiences from multi-campus courses, to improve course development. We also recon that this will benefit the students if the course structure and elements are more similar and recognisable. Establishing a collaborative culture seems necessary for obtaining robust and sufficiently deep levels of collaboration. But getting there is by no means a trivial matter [5].

6 ACKNOWLEDGEMENTS

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ASSOCIATIONS BETWEEN TECHNICAL TEACHERS' CONCEPTIONS OF, AND APPROACHES TO, ICT-ENHANCED TEACHING AND THEIR CONCEPTIONS OF ICT USE IN THE INDUSTRY

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ABSTRACT

This paper builds upon the authors' previous research on Technical and Further Education (TAFE) teachers' conceptions of (first paper), and approaches to (second paper), ICT-enhanced teaching in professional education (third paper). This paper aims to examine relationships among the above three aspects, that is: between TAFE teachers' conceptions of, and approaches to, ICT-enhanced teaching

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and their associated view about ICT use in the workplace. Phenomenography, a qualitative research approach that emphasizes the importance of people's experience of a phenomenon, was selected as a research methodology for this study. A cohort of 23 teachers from three TAFE institutions in NSW, Australia, participated in semi-structured, in-depth interviews. This study found that teachers' conceptions of, and approaches to, ICT-enhanced teaching, and conceptions of ICT in the workplace are linked. More specifically, TAFE teachers who hold a particular conception of ICT-enhanced teaching tended to adopt related approaches to ICT-enhanced teaching that are further linked with conceptions of ICT in the workplace. TAFE teachers who expressed 'student-centred/activity-oriented and/or industry-oriented' conceptions of ICT-enhanced teaching were more likely to adopt a 'student-focused' approach to ICT-enhanced teaching. The teachers within this group were more likely to hold an understanding of the role of ICT in the workplace as an effective or essential tool in professional activities. This paper offers new insights that contribute to bridging the gap between ICT in teaching and ICT in workplace practice. These findings could help develop new initiatives to address the existing gap between teaching in TAFE institutes and current practices in the workplace.

1. INTRODUCTION

Discrepancies between what is taught in engineering education and what is practiced in the industry is a fact that has been reported in the literature [1]. In order to address this claim, the short paper builds upon the authors' previous research on Technical and Further Education (TAFE) teachers' conceptions of, and approaches to, ICT-enhanced teaching in professional education. It investigated three aspects related to ICT use in technical (engineering) education. The first article (published) identified two broad conceptions of ICT-enhanced teaching in technical education: (i) teacher-centred conception, which comprises three categories of description: ICT is used to meet external expectations, ICT enables to gain access to information and resources, and ICT is a delivery tool, and (ii) student-centred conception, which includes two categories of description: ICT is a media for active learning, and ICT is a means of preparing students for their future profession [2]. The second article (published) found two broad orientations with five approaches to ICT-enhanced teaching: (i) teacher-focused orientation with three teaching approaches: comprising information-oriented, feedback-oriented, practice-oriented, and (ii) student-focused orientation with two teaching approaches: activity-oriented and industry-oriented teaching [3]. The third article (published), further investigated how TAFE teachers conceptualized the role of ICT use in the workplace and found three conceptions: using ICT for various regular work-related tasks; helping accomplish a job more effectively; and using ICT as an essential tool in professional activities [1]. In order to build a relationship among these three articles (above three aspects), this short paper aims to examine relationships between technical teachers' conceptions of, and approach to, ICT-enhanced teaching and their associated view about ICT use in the workplace. The rest of the short paper is organized into three sections: 'Methodology' explains phenomenographic research approach and brief procedure of the study; 'Results' provides associations among prior studies; 'Discussion and Conclusions' synthesizes the results and discusses its contributions.

2. METHODOLOGY

Phenomenography, a qualitative emerging research approach for engineering education that emphasizes the importance of people's experience of a phenomenon, was selected as a research methodology for this study [4]. In phenomenographic research, it is often depicted as how people understand, perceive, discern, conceive or experience the aspect of the world around them which is articulated by the one word “conception” [5]. Sample selection, data collection and analysis of data, therefore, was followed by the principle of the phenomenographic approach. A cohort of 23 teachers (P01 to P23) from three TAFE institutions in NSW, Australia, participated in semi-structured, in-depth interviews. Interviews data were transcribed verbatim and analysed by following seven steps, such as *familiarisation*, *compilation*, *condensation*, *preliminary grouping*, *preliminary comparison of category*, *naming of the categories*, *and outcome space* [2]. From this analysis,three outcomes were revealed (i) teachers’ conceptions of ICT-enhanced teaching, (ii) teachers’ approaches to ICT-enhanced teaching and (iii) teachers’ conceptions of ICT in the workplace. In the second stage, we identified 23 participants’ dominant attributes(qualities) towards these three findings. Each of the participant’s dominant attributes was placed in the relationships and was built into two relationships: *Associations between conceptions of ICT-enhanced teaching and conceptions of ICT in the workplace*; and *Associations between approaches to ICT-enhanced teaching and conceptions of ICT in the workplace.*

3. RESULTS

This study found that teachers’ conceptions of, and approaches to, ICT-enhanced teaching, and conceptions of ICT in the workplace are linked. Table 1 shows associations between conceptions of ICT-enhanced teaching and conceptions of ICT in the workplace for which students are prepared. The associations indicate that the two conceptions are related.

The table 1 presents two areas of association for 21 teachers out of 23 teachers. The first area, circle one (1), conceives of ICT-enhanced teaching as a ‘teacher-centred/content-oriented’ and this is linked with Categories A and B in the workplace. In this area, technical teachers who hold ICT-enhanced teaching as a ‘teacher-centred/content-oriented’, tended to understand the role of ICT in the workplace from supplementary to effective. The second area, circle two (2), perceives ICT-enhanced teaching as ‘student-centred/activity-oriented’ and ‘student-centred/industry-oriented’ conceptions and these conceptions are connected with Categories B and C in the workplace. In this area (2), technical teachers who viewed ICT-enhanced teaching as ‘student-centred/activity-oriented and / or industry-oriented’, tended to understand the role of ICT in the workplace from effective to obligatory in nature. However, two teachers in this study did not express conceptions that followed the stated associations. Therefore, they were not placed within the two marked areas (See Table 1: P01 and P08).

Table 1 *Associations between conceptions of ICT-enhanced teaching and conceptions of ICT in the workplace*

Conceptions of ICT-enhanced teaching		Conceptions of ICT in workplace		
		A	B	C
Teacher-centred/ content- oriented	A	P22	1	
	B			
	C	P16, P23	P07, P10, P15, P17, P21	P01
Student-centred/ activity-oriented	D		P11, P18	P02, P03, P04, P14, P19
Student-centred/ industry-oriented	E	P08	P06, P09, P20	2 P05, P12, P13
Conceptions of ICT-enhanced teaching, ICT is used: (A) to meet external expectations. (B) to gain access to information and resources. (C) as a delivery tool. (D) as a medium for active learning; and (E) for preparing students for their future profession.		Conceptions of ICT in workplace, ICT- (A) could be used for various work-related tasks (supplementary). (B) helps to accomplish a job more effectively (effective); and (C) is an essential tool in professional activities (obligatory).		

The associations indicate that both approaches to ICT-enhanced teaching and conceptions of ICT in the workplace are related (Table 2). The table presents two groups of associated areas for 21 teachers out of 23 teachers. The first group, highlighted as circle one (P1), conceives of approaches to ICT-enhanced teaching as a 'teacher-focused approaches and this is linked with Categories A and B in the workplace. In this area, technical teachers who hold ICT-enhanced teaching as a 'teacher-focused' teaching approach tended to understand the role of ICT in the workplace from supplementary to effective. The second area, marked as circle two (P2), is included under a 'student-focused approaches' and these approaches are connected with Categories B and C in the workplace. In P2, technical teachers who viewed ICT-enhanced teaching as a 'student-focused' teaching approach, tended to understand the role of ICT in the workplace from effective to obligatory in nature.

Table 2 *Associations between approaches to ICT-enhanced teaching and conceptions of ICT in workplace*

Approaches to ICT-enhanced teaching		Conceptions of ICT in workplace		
		A	B	C
Teacher-focused	A	P22		
	B	P1	P07	P01
	C	P16, P23	P11, P15, P17, P21	
Student-focused	D		**P06, P18**	**P02, P03, P04, P14, P19**
	E	P08	**P09, P10, P20** **P2**	**P05, P12, P13**

Approaches to ICT-enhanced teaching: (A) a teacher-focused, information-oriented strategy with the intention of effectively delivering subject content. (B) a teacher-focused, feedback-oriented strategy with the intention of achieving intended course outcomes. (C) a teacher-focused, practice-oriented strategy with the intention of linking theoretical and practical knowledge. (D) a student-focused, facilitation-oriented strategy with the intention of providing active learning for developing students' understanding; and (E) a student-focused, industry-oriented strategy with the intention of developing students' knowledge and skills to meet the industry's needs.	Conceptions of ICT in workplace, ICT- (A) could be used for various work-related tasks (supplementary). (B) helps to accomplish a job more effectively (effective); and (C) is an essential tool in professional activities (obligatory).

However, two teachers did not express approaches to teaching that followed the above-stated associations; therefore, they were not placed within the two marked areas (See Table 2: P01 and P08).

4. Discussion and Conclusions

Technical teachers who hold a particular conception of ICT-enhanced teaching tended to adopt related approaches to ICT-enhanced teaching that are further linked with conceptions of ICT in the workplace. The relationships of this paper have an impact on teachers' pedagogical practices in technical education (Tables 1 & Table 2). For instance, teachers who conceived of ICT as obligatory and effective instruments in the industry are more likely to introduce knowledge and skills related to ICT in their teaching. This means that, the students will be acquainted with using different forms of ICT in the classroom instruction (teaching and learning) that will facilitate them linking with their future workplace (industry). This paper provides further insights that contribute to bridging the existing gap between teaching in technical (engineering) educational institutes and current practices in the industry where there is a particular focus on using ICT. These findings could help improving engineering teacher professional development programs, minimising the existing gap between teaching practices in engineering institutions and real practices in the workplace. The extended elaboration of these associations and the reasons for showing this nature would be discussed in the upcoming journal article.

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STUDYING MATHEMATICS STUDENTS' LEARNING EXPERIENCES IN CHALLENGE-BASED EDUCATION

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ABSTRACT

This paper is of methodological nature. We present the empirical research methodology of a study that focuses on student learning experiences, in particular of mathematics students in an innovative learning environment, such as Challenge-based Education (CBE) at a Dutch university of technology. In this study, we present the case study of CBE in an innovative mathematics course on modelling, the mathematics "Modelling Week". We draw attention to the methodology used to study this modelling course, where we investigated students' learning experiences in a monodisciplinary CBE-oriented master course. We explain the design of the study and the associated data collection strategies regarding students' use of resources (Schematic Representation of Resource system- SRRS) and their learning processes. In the poster presentation, we will show selected results that come from the different

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instruments to help us understand student learning experiences in innovative/CBE related mathematics courses.

1 INTRODUCTION

An increasing number of universities of technology are attempting to adopt challenge-based education (CBE- we use the term to include approaches to teaching and learning). In CBE students work on authentic and real-world focused engineering tasks, generally in multidisciplinary teams, with technology-enhanced learning and multi-stakeholder collaboration [1]. In this educational approach, students learn how to create connections between real-world problems and engineering concepts, principles, and methods. This paper addresses the issue of CBE learning experiences, which Malmqvist et al., identify as [1]:

> "A challenge-based learning experience is a learning experience where the learning takes place through the identification, analysis and design of a solution to a sociotechnical problem. The learning experience is typically multidisciplinary, takes place in an international context and aims to find a collaboratively developed solution, which is environmentally, socially and economically sustainable."

We hold that essential characteristics of CBE can also be applied in monodisciplinary courses, for example in mathematics, where the application of advanced knowledge in a multidisciplinary setting is not straightforward for students. In such a context, we seek to grasp and understand the students' learning experiences in an innovative first year master course in mathematics: the Modelling Week.

In this paper, our aim is to present the methodology used to produce and manage the data in this course so as to account for the way students perceive their learning experiences while orchestrating different resources.

2 THEORETICAL FRAMEWORK

2.1 Challenge-Based Education (CBE)

Challenge-based education is a student-centered educational approach that arises from the concern to prepare engineering students for the new challenges of this century and aims to contribute to the solution of societal problems through collaboration between industry and universities. This type of effective collaboration and hands-on experience is characterized by encouraging students to work with peers/tutors, teachers/instructors, and experts to develop in-depth knowledge and skills on various topics.

2.2 Lens of Resources

In our research we link the development of students' knowledge and skills, during the solution of a problem in the context of CBE, to the use of different types of resources. Thus, we draw on the instrumental approach [2] to observe both how different resources influence students' practice and understanding, and how they modify and adapt them according to their own needs. We follow the categories of resources outlined by Pepin and Kock [3].

3 THE STUDY

This ongoing study uses a case study approach, to investigate and develop a deeper understanding of students' learning experiences in several courses in the curriculum of an Applied Mathematics program (Bachelor and Master) in a university of technology in the Netherlands. One of these courses is the Modelling Week.

3.1 Modelling week

The Modelling Week is part of a mandatory course (Professional Portfolio) in the Applied Mathematics master program on professional skills development. During one week, first year master's students work in groups on realistic problems posed by company/research institute representatives (the ”problem owners”). The main outcome of this process is students' interpreting and proposing a solution and recommendations for companies via formulating a mathematical model of the given problem and applying mathematical methods in their solutions. Our study has taken place during the Modelling Week of November 2021. Before the modelling week started, two different activities took place. First, a “Kick-off” lecture was given by the course organizers in order to give relevant information regarding the modelling week process and the creation of the student teams related to their interest areas. Eight teams (6-8 students) were created, four of which agreed to volunteerly participate in our research. Next, a team building workshop (“Lego workshop”) was organized with the intention of helping students to get to know their teammates and to learn about team dynamics. Following these events, the Modelling Week started for a period of one week (all day, Monday to Friday). On the first day , problem owners presented the problems for the first time and students were allowed to discuss the details with the problem owners, ask questions for clarification and also request for resources. During the week, students worked as teams to find a feasible and effective solution to the problem. They were guided and supported by university supervisors and problem owners, who also provided feedback on their work. The Modelling Week was concluded on Friday afternoon with the presentations of each team sharing their results. For the majority of students, Modelling Week was the first time they worked on a realistic mathematics problem, posed by an external stakeholder.

3.2 Data Collection strategy

In table 1 (below) we present the data collection strategies used to investigate students' learning experiences in the modelling week.

Table 1. Data collection instruments of the modelling week

Participants	Data Collection Strategy
Students	Exit Cards, Interviews, Observations, Schematic Representation of Resource System-SRRS [4], Survey
Supervisors (Applied Mathematics)	Interviews and Observations
Problem owners	Interviews and Observations

In our poster presentation, our main focus is on demonstrating how the instruments would allow us to analyze student learning experiences [5].

4 PRELIMINARY RESULTS

In terms of results, we present below the different instruments and in which ways they helped us to investigate student learning experiences:

1) With the help of the exit cards, at the end of three data points during the modelling week (Monday- Wednesday- Friday), we were able to get ‘snapshots’ of students’ views regarding their learnings, their feelings towards the achievement of their goal up to that time, their best liked activity, and problems they encountered. This helped us to trace a trajectory of their learning development throughout the week.
2) We made daily observations of students’ team work session and interactions with their supervisors and problem owners. We made field notes and took photos (e.g. of student whiteboard notes, calculations, screenshots of software used, schemes). This gave us information about their conversations, the concepts they used, the guidance they received and about their ways of progressing in solving their problem. The observations also showed how ideas from the resources used by the students reappeared in their work-in-progress.
3) The interviews with both the supervisor (university teachers from the Applied Mathematics department) and problem owner helped us to get a better understanding of how their expectations and experiences developed in terms their roles (e.g., from instructor to coach). The interviews also helped us to triangulate the observations of students’ learning experiences in class.
4) The student interviews provided us insights into what and how the students perceived and learned in this challenge-based learning environment. The interviews helped us to interpret students’ SRRS, so that we obtained an overview of the resources students used (material, digital, social/human), the support they received, different phases and tasks they experienced in the process of solving their challenge/problem, and the important decision making moments in their learning paths.

Together these different kinds of data provided us with a rich picture of students’ learning experiences. For example, they helped us understand the role of the resources provided to and found by the students in the teams’ work towards developing prototype solutions to the challenges. Moreover, the data gave insights into the characteristics of the problems (posed by the problem owners), as well as their affordances and constraints; the mathematical problems students encountered and how they sought help and support for solving them; the critical incidents and breakthroughs during a ‘pressurised’ week; the roles students assigned to different participants of the group; the different roles of the problem owner and mathematics tutor, and the alignment and nature of their feedbacks. We will share further explanations and examples during the poster presentation.

5 ACKNOWLEDGMENTS

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Remote Energy Lab – Experience and Improvements of European Cooperation in Remote Labs (SHORT)

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ABSTRACT

Due to the COVID-19 pandemic, online teaching methods have gained more interest. Most formats of teaching can be easily transferred into an online format from a technical point of view. However, this is more difficult for practical courses in a laboratory. Together with partners from three European universities, we tackled the issue of providing a practical online course for higher education levels in the framework of the EuroTeQ university. In this work, we present our concept of the course and discuss the course goals and further improvements. We tested the remote lab setting in order to offer the course on a yearly basis in future.

The remote lab was focused on energy engineering and was open to students from different engineering disciplines and countries. The course was comprised of three blocks, each consisting of one lecture on the broader context of the topic and one experimental laboratory session. The experimental session was streamed via a video broadcasting service. Students were required to either deliver a written report or to write a newspaper article for each of the three blocks.

The learning outcome of the course was that students on the one hand learn about the technologies discussed in the course and on the other hand learn about intercultural communication skills. The goal was to show the diversity of technologies and to show the significance of each technology for a specific country. The online experimental sessions proved to deliver a clear explanation of the topic for the students when provided with sufficient course material adapted to online formats. Contrary, keeping a high level of interaction with students during remote experiments was found most challenging.

1 INTRODUCTION

With the COVID-19 pandemic, a new urge for developing remote labs was born [1]. Due to the pandemic, many countries restricted the access for students for on-site learning in university premises. Classical teaching formats like lectures can easily be transformed into an online format from a technical point of view. For laboratory and practical exercises this is more difficult. Transforming existing experimental setups or developing new experimental setups is challenging in terms of time and cost. Nevertheless, to limit the consequences of the pandemic on students' practical education, many approaches to teaching practical experience were undertaken [2]. Remote labs were already developed and used before the pandemic (for example [3] and [4]). A review on remote labs indicates how former reasons for these types of labs were for example space constraints or cost savings, as well as advancements in information technologies, which facilitate their implementation.

Additionally, the concept of "European universities" was developed in 2017 [5]. EuroTeQ emerged from this, as a platform for European engineering education between six partners (Technical University of Munich, Technical University of Denmark, Eindhoven University of Technology, École Polytechnique, Czech Technical University in Prague, Tallinn University of Technology). Offering online formats in teaching is an alternative way to provide courses to the students. In order to also provide students with hands-on teaching and practical experience, remote labs are a necessary solution for situations when on-site practical learning is not possible, and when the cooperation between institutions allows students the possibility of doing remote practical work in facilities and equipment their institution does not possess.

The remote lab concept presented here satisfied the need for practical education during the pandemic and contributes to the EuroTeQ course catalogue. The “Remote Energy Lab” offers an international cross campus education involving three partners from European universities. Our course is classified as remote lab since it comprises a real experimental setup and distant access of the user [6].

2 THE COURSE CONCEPT

The course “Remote Energy Lab” was offered in the framework of the EuroTeQ University in the winter semester 2021/2022. The course was designed for master's students in engineering. A graphical representation of the course is shown in Fig.1. A prerequisite is a bachelor's degree in engineering. The number of participating students was not sufficient for a robust survey. Therefore, the valuable student’s feedback was not incorporated.

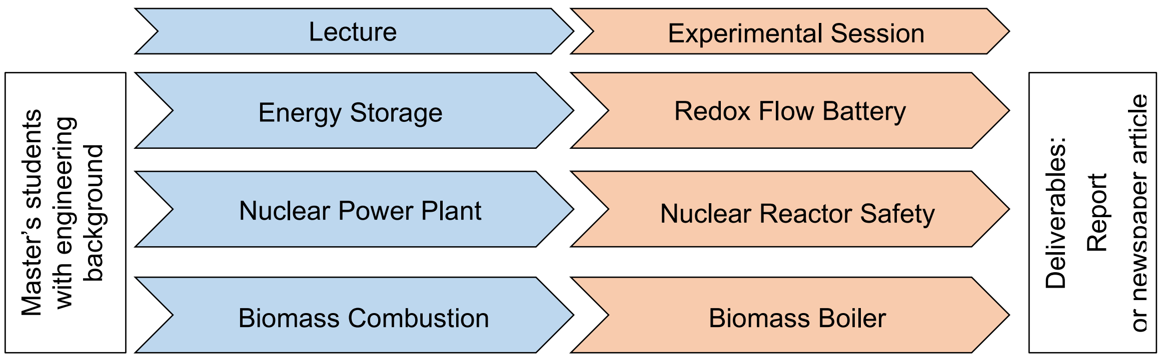

Fig. 1. Schematic representation of the course layout

2.1 Learning Objective

The learning objectives of the course focus mainly on communication skills in an international context. Additionally, students should learn new technologies related to energy engineering solutions. Students are supposed to:

- Learn how to work effectively in an international team.
- Learn to communicate and work with people from different disciplines and cultures.
- Learn how to communicate online.
- Present technologies in an easy and understandable manner.

2.2 Course Content

The course was split into 3 topics. Each block consists of one lecture and one experimental session. The following blocks were offered:

1. Redox flow battery for energy storage

2. Low emissions household heating with a biomass boiler
3. Nuclear reactor safety

The lecture (90 minutes) was given before the experiment and introduced the students to the broader perspective of the topic. Additionally, the lecture introduced important concepts and background information needed for the experimental session. This is important since students with a broad variety of study backgrounds can participate in the course. The experimental session took between 60 and 180 minutes. Students participated during the experimental session via an online conference platform like Zoom for example. For topics 1 and 3, the experiments were performed live during the session. For topic 3, students used a software at their computer that allowed them to directly read data from the reactor. This enhanced the hands-on feeling. For topic 2, the experiment was recorded and played during the experimental session, due to the inherent long duration of the experiments (over 5 hours).

2.3 Deliverables

Students were asked to write either a short report or a newspaper article. The type of deliverable was determined before the course by the instructors. Reports and newspaper articles were graded, and a mean grade was assigned to the students based on the grades from all three topic blocks.

The report was limited to 5 pages and should include only necessary information and results of the experiments. The idea behind the newspaper article was to make the students write about the investigated technology for a general audience. The focus of the article was not further specified to not limit the creativity of the students. With this deliverable the fourth learning objective to present the technology in an easy manner could be assessed.

3 IMPROVEMENTS AND CHALLENGES

The most relevant challenges and possible improvements are listed here based on our experience from the winter semester 2021/2022. Some challenges were already overcome before the course started. Others were noticed during the course. A total number of 7 students split in 2 groups participated in the course. We received 4 reports and two newspaper articles. The following challenges and improvements were identified:

1. <u>Group work:</u> In the remote lab, the student's work was done individually, as student split their tasks. In a typical lab setting, student’s collaboration within their group would be more intense. A solution would be the creation of breakout rooms within the video broadcasting platform to foster collaboration between students. The collaboration for the preparation of the deliverables is organized by the students and cannot be influenced by the instructor.
2. <u>Complexity of the topics:</u> Considering that the students could have different engineering backgrounds, the complexity and depth of the topics could hinder a proper understanding of the remote practical sessions. Each topic selected was

specific to an energy technology solution, whose working principle was connected to a different engineering field (energy storage, solid fuel conversion, nuclear energy). Therefore, it was necessary to have a practical session joint with a theoretical session to introduce the scientific background, operating principles, and basic concepts related to each topic. We were able to contextualize and introduce the technology with the help of the lecture before the experimental session.

3. Time of experiments: The experiment “biomass combustion” requires over four hours for completion due to the need for a complete analysis, collection of data, and the need to explain the experimental setup and procedure prior to the experiment. A solution to this was recording the experiment and dividing it into multiple video records of each experimental step from the start up to the data collection. Compared to an on-site experiment, the time of interaction with students was shortened during the online version. Therefore, we see the advantage of showing longer experiments in a shorter time period.
4. Visibility: It was observed the impediment of a small field of view for some experiments due to the large size of equipment (for example biomass boiler and peripheral equipment) that is used in the experimental process. This prevented a proper recording or display of the equipment, affecting the student's understanding. To avoid misestimation of the real measurements a schematic, flow chart, as well as diagrams and description of the equipment were provided to counteract this weakness. Compared to an on-site session, this material would also be provided, but less detailed.
5. Interaction between students and instructor: During the experiments, it was hard to interact with the students. Questions were only asked via the chat. A lively discussion did not take place. Activating the students to participate with online quizzes did work. Nevertheless, in comparison to an on-site lab, the interaction needs to be improved to foster the learning outcome. Triggering the interaction during an on-site experiment is easier than for the online session.

On the other hand, remote practical sessions can overcome some of the challenges that are commonly faced in on-site laboratories. For example, one challenge in on-site laboratories is that students are often grouped together in large groups to perform experiments, this can compromise the student chances of success at a meeting. This challenge is addressed in remote labs, by providing the students the possibility of rewatching the recorded practical session as many times as necessary, until conceptual clarity is obtained.

4 SUMMARY

The course was a first attempt to offer hands on experience to students via an international remote lab. The concept of three partners offering one experiment each guaranteed a variety of different topics. The observed challenges contributed to determining what aspects can be further improved in a future remote energy lab course. The course with the improvements mentioned above will be offered again in winter semester 2022/2023. Our experience gained throughout the course can also be transferred to remote labs in other fields except engineering.

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RECOMMENDATIONS FOR A MULTICAMPUS COURSE DEVELOPED THROUGH A "STUDENTS AS PARTNERS" PROJECT

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ABSTRACT

This paper presents recommendations for a Multicampus course, developed through a Student as Partners project. In this project students, a teacher and an educational developer collaborated following the principles of the Students as Partners framework. Through interpretation of previous course evaluations and discussions, we created a shared understanding of how the course had worked and what to improve. Our main recommendations are to have lectures and learning activities that are diverse and adapted to the students' different needs. These recommendations are not groundbreaking in themselves, however, the grounding in a common understanding through the use of the Student as Partners framework is novel and gives new perspectives to course development and educational development in general.

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1 INTRODUCTION

1.1 Students as Partners

Evaluations represent a source for information and quality assurance in course development. In these evaluations it is not only the ratings that are essential but the discussions they may lead to and possible improvements of teaching and learning activities [1]. To ensure sustainable development both student and teacher involvement are important in this process. A way to include students in course development is through a Students as Partners approach. This framework challenges the traditional roles and responsibilities of students and teachers. Cook-Sather et al. define *"student-faculty partnership as a collaborative, reciprocal process through which all participants have the opportunity to contribute equally, although not necessarily in the same ways, to curricular or pedagogical conceptualization, decision making, implementation, investigation, or analysis"* (p. 6-7) in [2]. According to Matthews, a good Students as Partners practice should aspire to the five propositions: *"1. Foster inclusive partnerships, 2. Nurture power-sharing relationships through dialogue and reflection, 3. Accept partnership as a process with uncertain outcomes, 4. Engage in ethical partnerships, 5. Enact partnership for transformation"* (p. 2) in [3].

We used the Student as Partners framework in a pilot project where a resource group was formed which consisted of six students, a teacher, and an educational developer. The students were selected through a recruitment process. To foster an inclusive partnership the students received a salary. The aim of the project was to develop recommendations for a first-year introductory course in physics and chemistry.

1.2 Course description

Ten teachers are involved in this first-year introductory course in physics and chemistry. It is a multicampus course that runs for 11 different Bachelor of Engineering programs at The Norwegian University of Science and Technology. Students and teachers are situated at three different campuses. The teachers have cooperated regarding exams, exercises and course content. All teaching resources, such as notes, calculus exercises, and lecture recordings are shared and available to all students and fellow teachers in the learning management system as described in [4].

2 METHODOLOGY

2.1 Data

Previously collected data from three anonymous questionnaires were used as a source for information. The first two surveys were conducted in the spring of 2020, before and after the online transformation, and the last one in 2021 when almost all activities were online. The questionnaires consisted of questions where the students were asked to rate how satisfied they were with lectures and mandatory exercises on a Likert scale. To get detailed and rich information about their experiences the students were asked to elaborate their ratings through open questions [5]. In the questionnaires, the students were encouraged to describe what had worked well, and what had not, and also come up with suggestions on what to improve. In addition, the students answered questions about: their previous knowledge of physics and chemistry, how often they used the different online resources available in the course, and what they would recommend the teachers to preserve from the online format.

2.2 Work method

The questionnaires were used as background information which we in the resource group examined. We divided the data material among us and split into pairs to extract the essence, which then was presented to the whole of the group. These presentations laid the foundation for deeper discussions which formed the basis for a common understanding in the group. After each group meeting, all participant wrote individual reflections which were shared online. All elements: the essence of the original data, our discussions and individual reflections, formed the basis for the course recommendations that we developed. These were presented to all the teachers involved in the course.

3 RESULTS

3.1 Short summary of findings

The results from the questionnaires showed a decline in students' satisfaction regarding the lectures in 2020, due to the transition to an online format. However, in 2021 the students rated the lectures higher, compared to the pre-pandemic situation, even though they were still in an online format. There are, however, some variations between the campuses.

Several students mentioned that the difference in students' prior knowledge both in physics and chemistry, is a challenge. Some students have had courses that go beyond the admission requirements. There seems to be a tendency that these students do not participate in the lectures or engage in the course as long as they are familiar with the topics. At the same time, other students find it challenging to master the course and ask for a more thorough introduction to the syllabus.

Further, the students found it engaging and motivating when the teacher used quizzes to activate them. This was especially important in the online format, where the students reported that they easily got distracted. In addition they reported that using breakout rooms lowered the threshold for asking questions, but they still missed not having the opportunity to talk with the teacher individually.

There are differences in student satisfaction between the campuses regarding the mandatory exercises. The students that had mandatory attendance and did the exercises as part of a group work with practical exercises, were the most satisfied. While the students that had individual multiple choice tests were least satisfied. After the onset of the pandemic, it was not possible to have physical attendance and practical exercises, and the overall satisfaction decreased.

Recurring in all the surveys is a frustration with the online textbook, which is open source. This dissatisfaction is mainly because it is digital and the fact that it is an English textbook. Most of the students report they rather use the lecture notes produced by the teachers. The students that report reading the book use it as an encyclopedia.

3.2 Recommendations

Our recommendations for improving the course are divided into three categories: Lectures, Learning activities and Online resources.

Lectures adapted to the students' different needs

To facilitate the different needs and enhance the students' understanding we recommend replacing some of the lectures with short thematic videos, where the aim is to give a brief and pedagogical presentation of the topics. These thematic videos will be used asynchronously, and the students should be encouraged to watch them at their own pace, and as many times as they want. In this way, the videos can serve dual purposes, both as introduction and repetition. The remaining lectures should be synchronous, preferably physical lectures, and use active learning methods to increase students' learning and understanding. Since the students already are familiar with the topic, the teacher can to a greater extent design for student activity as well as give further explanations and show practical demonstrations.

Response systems can be implemented to activate and increase students' motivation and engagement, for example by using quizzes to check the learning outcome, or by asking questions about their learning experience. We also recommend that the teacher involves the students to a greater extent in the design of the lectures, to better align the teaching and learning activities to the students' different needs.

Learning activities and support adapted to the students' different needs

For online supervision, we recommend having digital tools available, for example, tablets for drawing and doing calculations by hand. These notes can be shared and made available to the students online.

When it is possible to meet in person, we see it as valuable to have the teacher present in addition to student assistants during exercises. Long response time or inadequate response can affect the students' work effort and motivation, and influence whether they participate or not. In addition, the teacher achieves valuable information about the students' learning.

Another recommendation that applies to both optional and mandatory exercises is to have variation and flexibility. Students should to a certain degree have the opportunity to choose whether they want to collaborate with other students or work individually. In addition, these should include both practical and calculus exercises.

The exercises should preferably have a connection to the specific study program and contribute to contextual learning. This can be challenging since the resources are shared among the different study programs, but nevertheless something to strive toward. One way to embed the basic physics and chemistry course into the specific study programs is by introducing a larger project that allows different content.

Online resources

To make the textbook more accessible for the students we recommend that terms and words are introduced using both languages, to improve the students' vocabulary and understanding. Another recommendation is to have a shared discussion forum where all 1000 students have access, and where both students and teachers make comments and answer questions. The discussion forum should have a well-defined structure where it is easy to navigate and find related questions. To lower the threshold for participation we recommend that it should be possible for the students to be anonymous.

4 AFTERTHOUGHT

The suggested recommendations were presented to the teachers involved in the course. In an open dialogue, we discussed the recommendations and our interpretation of the course. Afterwards, the teachers used this information for course development. One of the suggestions that has been implemented is the use of short videos as part of a flipped classroom design. A set of videos are now distributed to all students and followed up by student active sessions facilitated by the teachers. This is a course design that has been discussed earlier among the teachers but needed encouragement from the students to be applied.

The recommendations we suggested are not novel in themselves, however, the Students as Partners approach where students and teachers are collaborating on equal terms might have contributed to higher credibility.

Using the Students as Partners framework contributes to a more holistic view on course development. The students have first-hand experience not only with the specific course but with the entire study program, while the teachers on the other hand, tend to focus on their own courses.

Course development is an ongoing process and this paper presents a pilot project. For a continuous and sustainable course development, it will be valuable to use the Student as Partners framework not only in a pilot project but on a regular basis.

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EMPOWERING MASTER STUDENTS TO SOLVE REAL-WORLD ENGINEERING PROBLEMS

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ABSTRACT

In engineering, the importance of multi-disciplinarity and the need to “think outside the box” are obvious. However, subjects in engineering education are often treated in an isolated fashion. The kind of problems solved in these subjects are often just simplified artificial exercises. To ensure employability of new engineers, students need to practice how to “convert a mess into a problem”, and then use the scientific method in context to solve it.

Good data skills (including data collection, exploration, and modeling) are essential to solve problems. These data skills are the “backbone” of the scientific method. The use of real data (coming, for example, from real applications in industry) can be motivating in teaching and stimulating to connect engineering topics.

This paper explores possible reasons why many subjects in engineering are still taught in a way disconnected from real life. It also suggests solutions, and shares teaching tools and resources to improve student employability.

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1 INTRODUCTION

1.1 The importance of multi-disciplinarity and real-life problems

If we ask engineering teachers if they think multi-disciplinarity is important in their field, probably all of them will answer affirmatively. However, when we look at subjects in engineering degrees, they often look isolated. How many subjects are taught together by teachers from different departments? Real-world problems bring multi-disciplinarity in a natural way. One given situation in a process may require chemical knowledge, but also statistical analyses to make the process stable, and economics to make it viable, plus an environmental study, and so on.

Students in engineering degrees are usually young. Most of them have never worked in industry or business. However, it is obvious that we wish our students learn the skills needed to solve real-life problems. How can they learn these skills at university if they are only exposed to prepared “artificial” exercises? While these exercises have the benefit for the teacher making reviews easier, it is not what happens in real situations where problems are more complex and somewhat blurred [1].

A hands-on approach with cases that use real situations and data also require many soft skills as needed today, like being able to learn autonomously, working in teams or communicating efficiently.

If we agree on the importance of multi-disciplinarity and the need to prepare students to real-world problem solving, why do we have difficulties in achieving this?

1.2 Some difficulties when using real world problems

Facing students with real world problems implies shifting the focus from the teacher to the students. There are still many teachers that feel comfortable conveying knowledge in a unidirectional way: the teacher speaks (and sometimes fills blackboards), and the students listen and take notes. Probably something similar happened before Gutenberg invented the printing press: it was the only way to make copies of written knowledge. This passive approach is no longer possible when using real-world problems, that necessarily encourage discussion. The teacher becomes more a supervisor, a colleague who walks together with the students through a discovery process. Therefore, a required first step is changing the paradigm in how we teach engineering subjects [2].

The second requirement is having case studies to be used in the classroom. This teaching material could mainly come from three sources:

1. The teacher (or team of teachers) invents an industrial or business situation that looks realistic, adds the context information, and simulates the data. This is extremely difficult to do well. The teacher needs more imagination than J.K. Rowling writing Harry Potter and requires a deep subject understanding of the process at hand. Even if this can be done at the end, it is very time consuming.
2. The teacher has done some consultancy work or research with a company, perhaps working together with operators and technicians in industry for many months. She/He has learnt a lot about the process, and the data are accessible

that can also be used in the classroom. Teachers can then write a case study but will probably need the help from the industry people also involved in this collaboration. Finally, the result can be good, but it also requires a lot of time.

3. The teacher uses cases from a collection of well-curated real-world situations. As before, these cases often come from commercial projects, but they are already designed for classroom use. The fact that these case studies are used by many educators also implies that they can be improved in every iteration of use. Also, the range of topics is huge: something that cannot be achieved otherwise.

The next chapter introduces a good example for the third option.

2 THE JMP CASE STUDY LIBRARY

More than 50 problems are shared for teaching use in the JMP Case Study Library [3] (Fig. 1), listed by field, subject, statistical concepts, and complexity. Each case can be downloaded for free including dataset(s) and a PDF documentation. Many cases have been directly developed by practitioners in industry. Some companies are named in their cases, while others are anonymized.

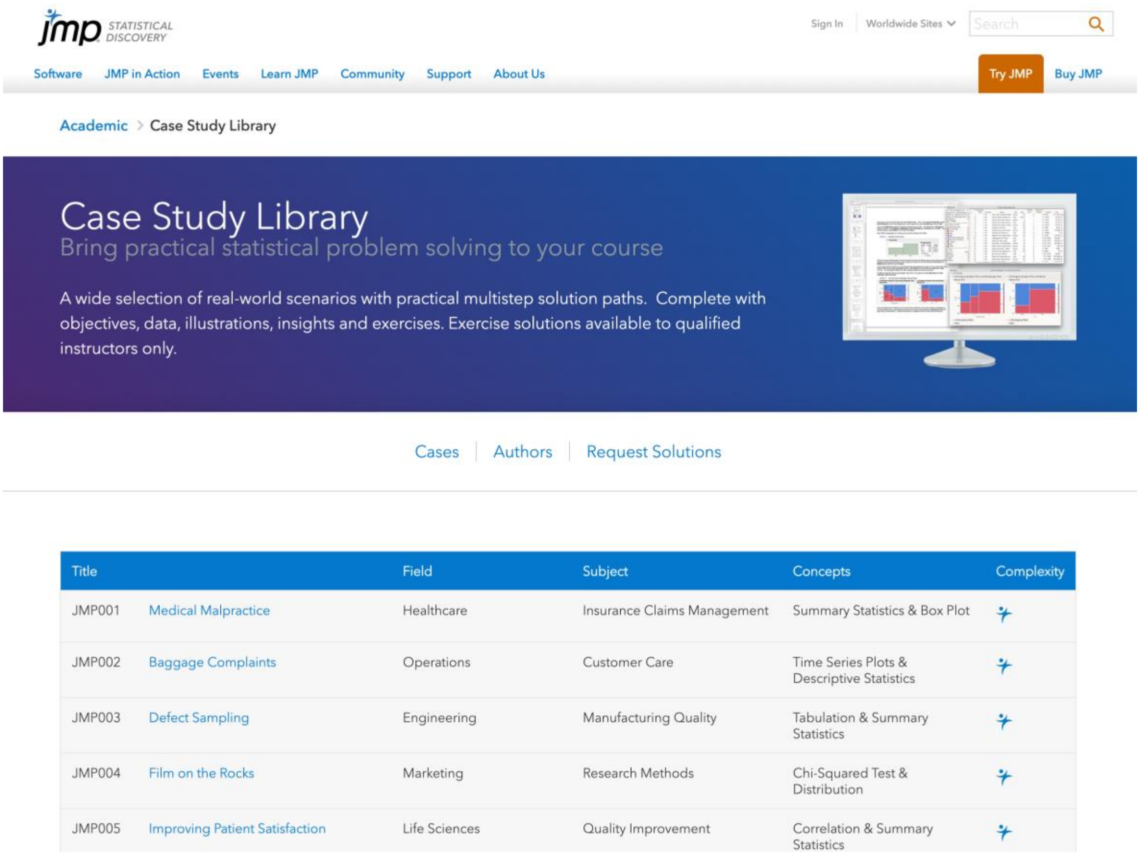

Fig. 1. Examples from the JMP Case Study Library published at jmp.com/cases

All case studies follow a consistent format and scenario which starts with a description of the problem, followed by questions or tasks at hand and a description of the data. This is followed by a multistep illustration of the solution followed by a summary of the statistical and managerial insights. These are followed by exercises that expand or pose “what if” scenarios, which solutions can also be shared upon request.

While educators can use case studies for in-class demonstrations, the most effective use are assignments to students as homework or group projects. The cases can stimulate discussions about which steps to take or comparisons of alternative solutions. Students can also be asked to present the learning outcome to “other decision makers”, or to explain why and how certain methods have been applied.

2.1 Compliance with GAISE recommendations

As outlined in [4], the JMP case studies support extremely well the recommendations for teaching statistics to college students, especially these four: 1. Teach statistical thinking 2. Focus on conceptual understanding 3. Integrate real data with context and purpose and 4. Foster active learning.

More information about the JMP Case Study Library and hands-on experience using some select cases for engineering will be offered during a SEFI workshop [5].

3 SUMMARY AND CONCLUSIONS

Multi-disciplinarity and empowering students to solve real-world problems are needs in engineering education nowadays. The use of case studies can facilitate achieving these objectives. When you talk with former engineering students who have entered the workforce, they invariably explain the value that real case studies had in their learning. Moreover, they can remember and refer to many case studies. The authors have confirmed this by talking to engineering students some years after they finished their degrees (the live presentation of this paper does include some of these video testimonials).

As creating realistic case studies from scratch is difficult and time consuming, good case study libraries can be very useful. As an example, select engineering cases from the JMP Case Study Library have been introduced. All cases from that collection are freely available, proven by hundreds of educators worldwide and will be continuously enhanced to cover more problems, applications, and engineering skills in the future.

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IS THE ENGINEERING STUDENTS' SELF-ASSESSMENT ACCURATE? ANALYSING MIDTERM TESTS IN TERMS OF SELF-ASSESSMENT ACCURACY

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Conference Key Areas: *Mathematics at the heart of Engineering, Assessment*
Keywords: *self-assessment accuracy, Dunning-Kruger effect, feedback, constructivist learning theory, drop-out*

ABSTRACT

There is a high drop-out rate in engineering higher education, the reasons can be grouped into four categories: economic explanations, individual pedagogical-psychological, learning-related reasons, socio-cultural influences. This paper discusses the problem of the accuracy of self-assessment among the individual pedagogical and psychological reasons.

During the maths midterm tests, students self-assessed on each task, which was compared with the points given by the teacher. More than 80% of students overestimated their actual performance in all midterms, and this overestimation was moderate. Based on the relationship between accuracy scores and test results, students who achieved better results in the midterms gave more accurate self-assessments than those who performed poorly, which confirms the Dunning-Kruger effect in engineering education. Feedback based on their performance may affect the accuracy of self-assessment. Feedback from the midterm caused a significant improvement in self-assessment for students who met mid-term requirements, while there was no such improvement for those who did not. Thus, underperforming students did not benefit enough from the feedback from the first midterm, and the accuracy of their self-assessment did not improve.

The fact that there is a significant difference in the accuracy of self-assessment between students who fulfilled mid-term requirements and those who did not. The self-assessments of the former was closer to the teacher's evaluation than those of the latter. This may be problematic because weaker students are less aware of their deficiencies due to their inaccurate self-assessment, and thus they may stop their preparation short of what is necessary, and may not ask for help when needed.

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1 INTRODUCTION

The high drop-out rate in engineering education can be reduced in several ways, one of them is a step-by-step growth supported by an instructor. Next to a personalised tutoring, self-assessment activities can be a simple way of supporting learners to organise their personal learning and to learn to self-manage their learning [1].

Self-assesment is a descriptive and evaluative act carried out by someone concerning his personal abilities, processes and products [2] which is an integral part of learning according to constructivist learning theory. It assumes that the individual learner actively builds new knowledge and skills on his current constructs (schemas), for which external environment only provide the opportunity. In order for learners to progress and move towards their personal development goals, they need feedback (formative) and assessment (normative) on their performance [3] (Fig.1).

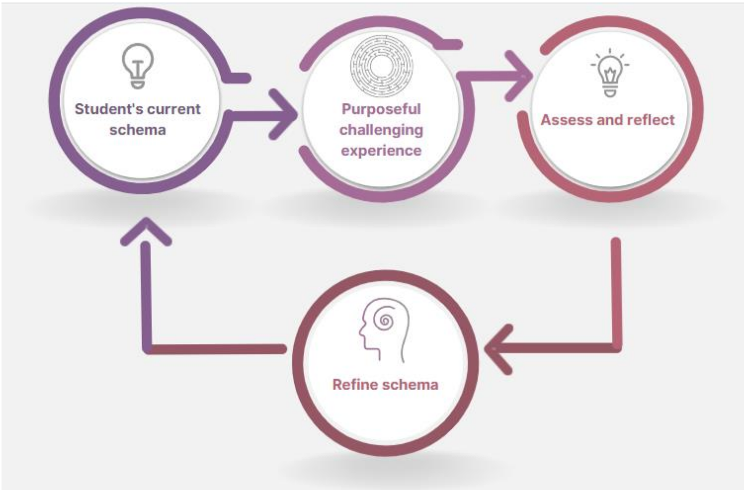

Fig. 1. Constructivist learning model (based on [3])

Harlem and Belski's [4] research refined the constructivist learning model by showing that novice and expert engineers reflect at different stages of the learning process. Their study found that novice engineers reflect only when they make mistakes while expert engineers tend to reflect continuously when they solve problems. In addition, expert engineers reflect on both problem solving processes (planning and implementation) and personal assumptions (understanding the problem), novice engineers reflect only on processes.

Differences in self-assessment are not only observed on the basis of proficiency in a particular field, but also on the basis of competences. Self-evaluation errors of poor and top performers differ too. Based on Dunning–Kruger effect, poor performers in many social and intellectual domains appear largely unaware of their lack of competence. Their deficiencies make it doubly difficult - on the one hand, they make mistakes because of their incomplete and incorrect knowledge, and on the other hand, these same deficiencies prevent them from recognizing when they are making mistakes [5].

2 OBJECTIVE

The purpose of this short paper is to reveal accuracy of self-assesment of engineering students, some relationships between self-assesment and performance, and the impact of feedback on self-assesment. Therefore, the present study aimed to answer the following questions:

1. To what extent are engineering students overestimating and underestimating their performance in the course Mathematics 1?
2. Is there a significant interrelationship among accuracy scores and performance?
3. Is there a significant difference in the accuracy of self-assessment between students who fulfilled mid-term requirements and those who did not?
4. Does the accuracy of assessment change during the semester?

3 METHODOLOGY

3.1 Measure of self-assesment

Several indices of self-assessment can be distinguished, e.g. the accuracy (reliability) and the direction of the bias (validity). Based on the literature [6] the accuracy and direction of students' self-assessment was measured using two indicators: the realism/bias score and the accuracy score.

Realism/bias score = (Average self-assesment score over all items in the test) – (Average performance score[2] over all items in the test)

Accuracy score = the absolute value of the difference between the self-assesment score and performance score for each test item, summed over all items on a test, and divided by the total number of items

During the semester, students wrote two midterm tests and an exam. To take the exam, students must achive a score of 50% in the two tests together. Those who did not meet this requirement could take a make-up test. Each test consisted of 6 tasks for 2 points per task. Before the test, students were given the opportunity to take a mock test and learn the scoring rules for each task. Students graded each task scoring 0, 1 or 2 points. Teacher assessment could also be 0, 1 or 2 points. Based on this, the bias value could take a value between -2 and 2, where a positive value indicates that the student overestimated his performance, while a negative value indicates underestimation. Values close to 0 indicate a lack of bias. The accuracy score could take a value between 0 and 2, where 0 indicates complete accuracy and 2 indicates complete inaccuracy.

3.2 Participants

258 engineering students took the course Mathematics1, 235 students wrote the first midterm test, 214 the second and 114 the make-up midterm test.

[2] Performans score is given by the teacher.

4 RESULTS

The realism and accuracy scores were calculated from the results of self-assessment following the midterm test and from the teacher's assessment which provided the two indices to evaluate the accuracy of self-assessment. More than 80% of students overestimated their actual performance in all midterms (Table 1), and this overestimation was moderate (Fig.1).

Table 1. Distribution of realism scores

	Realism score midterm test1			Realism score midterm test2			Realism score make-up test		
	<0	0	>0	<0	0	>0	<0	0	>0
Number of students	16	18	197	29	12	166	6	8	88

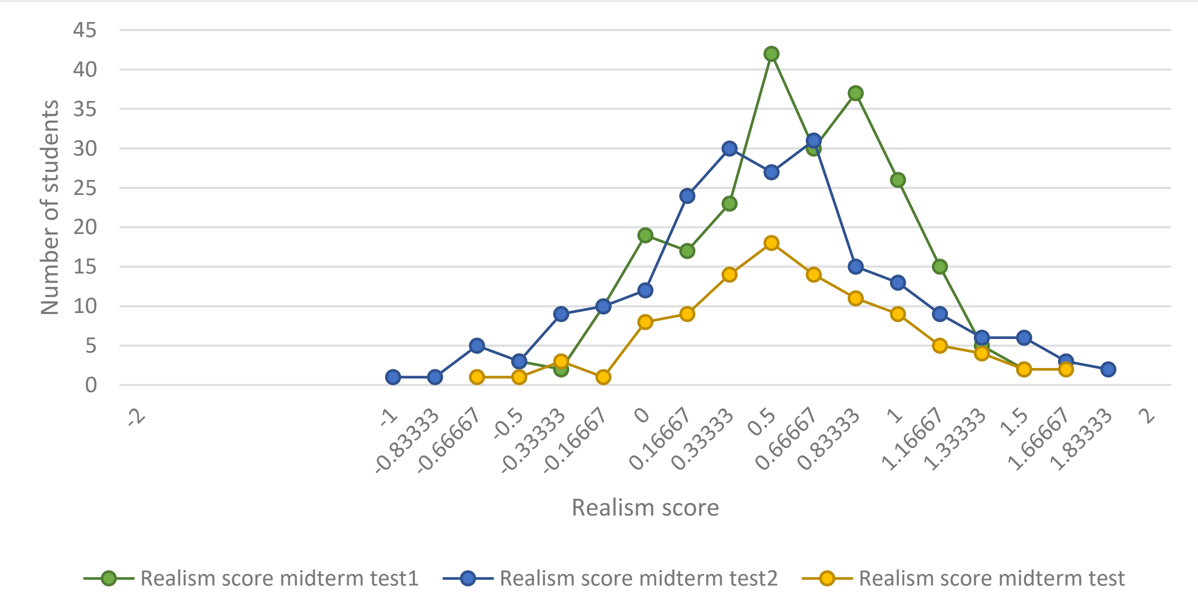

Fig. 1. Realism scores in the tests

In the following, we compare the accuracy scores with the tests' results. The results of the correlation calculation are shown in Table 2, which shows a negative correlation between the accuracy scores and the test scores. Thus, students with better results in tests have an accuracy score close to 0, i.e. they give a more accurate self-assessment of their own performance than students with weaker results. This result confirms the Dunning-Kruger effect in engineering education.

Table 2. Correlation between accuracy scores and test scores

	Accuracy score midterm test1	Accuracy score midterm test2
Midterm test1 score	-0,378**	
Midterm test2 score		-0,372**
Total score of tests	-0,312**	-0,305**

**p<0,01

The fact that there is a significant difference in the accuracy of self-assessment between students who fulfilled mid-term requirements and those who did not, adds nuance to this picture. The self-assessments of the former was closer to the teacher's evaluation than those of the latter. A similar difference is evident between those who pass the exam and those who fail. This may be problematic because weaker students are less aware of their deficiencies due to their inaccurate self-assessment, and thus they may stop their preparation short of what is necessary, and may not ask for help when needed.

Feedback based on performance (i.e. test result and mistakes made in the first midterm), and the opportunity to see the corrected test may affect the accuracy of self-assessment. Feedback from the midterm caused a significant improvement in self-assessment accuracy for students who met mid-term requirements, there was no such improvement for those who did not [Table 3]. Thus, underperforming students did not benefit enough from the feedback from the first midterm, and the accuracy of their self-assessment did not improve.

Table 3. Accuracy scores among students who met mid-term requirements and who did not

	Accuracy score midterm test1		Accuracy score midterm test2	
	Average	SD	Average	SD
Students met mid-term requirements	0,65	0,30	0,57	0,31
Students did not met mid-term requirements	0,76	0,33	0,79	0,45

5 CONCLUSIONS

Self-assessment and feedback can help the individual to make decisions on his developmental path, such as how much time and energy to invest in development, whether to seek external help, whether to continue on the path he has started. The results of the research confirmed that less talented engineering students are less aware of their deficiences and thus have a less realistic self-image to plan their development path which can easily lead to drop-out. One of the benefits of self-assesment can come from active participation in the learning process. There are two ways to enhance participation in this way, firstly by increasing the number of self-assesment opportunities and secondly by training in self-assesment.

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Experiences from using formative feedback in entrepreneurship course

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Keywords: *Formative feedback, peerfeedback.*

ABSTRACT

Formative feedback is a valuable tool that enables educators to provide an immediate and ongoing feedback to improve the student learning [1]. Formative feedback can be done in a variety of ways and can be administered at various times during a learning process [1].

Many studies about feedback and assessment in entrepreneurship educations focus on measuring, assessing and evaluating the contribution of the entrepreneurship education to society etc. and only a few studies have focus on how the didactic question of assessment and feedback are done in entrepreneurship educations [2].

In this concept paper, we report and reflect on our experiences and learnings from implementing formative feedback as a mandatory part of an entrepreneurial introduction course. The paper builds on experiences from one course, which ran in January 2021, in June 2021 and in January 2022.

The feedback design used in this course can be categorized into three situations: (1) from student to student and (2) from student to educator, and (3) from educator to student. The purpose and outcome from using the feedback design is described and evaluated concerning further development. The discussion also includes which initiatives, we consider there are needed to support the further development and the implementation of formative feedback in entrepreneurial courses.

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1 INTRODUCTION

The didactic question of how assesssment and feedback are used in entrepreneurial education are rarely described in literature. Instead the main focus is about how to measure, assess and evaluate the post-course contribution of the entrepreneurship education to society or the contributions of entrepreneurship education to students entrepreneurial attitues or intentions [2].

In general, two types of feedback exist - summative and formative feedback. The summative feedback is the assesment for certification and the formative feedback is the assessment for immediate learning. In this concept paper the focus will be on the formative feedback. Formative feedback can be carried out in many ways and is a well-known valuable tool to improve the student learning [1]. Formative feedback can be given from one student to another student, from the student to the educator, from the educator to the student and from one educator to another educator.

The feedback from one student to another student is also called peerfeedback [3]. Peerfeedback is known to increase the amount of feedback the students receive and furtheremore it is known to strengthens the students skills in giving and receiving feedback. However, as other forms for feedback, the peerfeedback needs to be instructed and supported, for example by having rubrics. One way to do the peerfeedback is to use the program Peergrade.io. The program Peergrade.io supports the assignment submission and the feedback process itself. The system provides overview of the students'activity as well as their feedback process [4].

The student's feedback to the educator is valuable data for the improvement of the course. In addition, the feedback can be used to ensure and optimize the quality of teaching and to enable the alignment between the intended goals and the actual learning [5]. Very often this feedback comes from the course evaluation performed at the end of the course. However it can also be done on a daily basis which enables for an immediately improvement of the course.

To give and receive feedback can be complicated and therefore the students need to learn how to do this to be able to do it in practice. There is therefore a need for a framework which clarify the roles and the rules regarding how to give and receive feedback. It is often the educator, who constructs this framework and sets up the criteria for the feedback, but it can also be done together with the students.

In this concept paper, we report and reflect on our experiences and learnings from the implementing of the formative feedback as a mandatory part of an experiential-based through learning entrepreneurship course. In this study, we do not have focus on the final evaluation (the summative feedback).

2 METHODOLOGY

The data are based on reflections from a three week course, which ran in January 2021 (52 students), June 2021 (22 students) and January 2022 (55 students) and were held at the Technical University of Denmark (DTU). The students came mainly from the bachelor of engineering education in Global Business Engineering with some few students from other bachelor of engineering programs at the University.

During the course the following feedback activities were carried out:

- Student to student feedback (peerfeedback) using the online program Peergrade.io
- Student to educator feedback done on a daily basis and at the end of the course
- Educator to student (individual/groups) several times during the course and final on the poster session

For the group work, the students were mixed in groups of 5-6 students by the educator. The group formation was performed based on a preference test, which the students did before the course. Students with different preferences where put together in the groups. During the course, the students worked with their own idea as an experiential process of learning through entrepreneurship. At the end of the course each group presented their solution at a poster session and documented the solution in a business report, which they submitted on the final day of the course. During the course, there were presentations and several hand-ins both as an individual and as a group.

Student to student feedback (Peerfeedback)

After the first week of the course the students handed in an individual report. The individual report concerned the entrepreneurial methods which the students had used and refleced upon. The maximum length of the report was set to five pages. The submission was done in the program Peergrade.io [4].

The peer feedback session consisted of four parts:

1) An introduction to the peerfeedback session and an introduction on how to give and receive feedback. Furthere more a short introduction to what constructive feedback is and how to use the feedback afterwards was given.
2) The peerfeedback session took place using the program Peergrade.io. The rubrics consisted of two criteria:
    a. Mention something your classmate did well.
    b. Mention something your classmate could improve.
3) After the peer feedback session each student met with the educator and reflected on the peerfeedback session.

4) In the final report, each students reflected on the peerfeedback session and the results (learning).

Each student had two hours to read and provide feedback to three fellow students. Afterwards each student received feedback from three other students and they had to respond to the feedback and do self reflection concerning the feedback given. Afterwards the educator read the feedbacks and had a follow up meeting with each student.

Later almost at the end of the course, there was a poster session. At this session, the groups gave feedback to each others presentations in regards to the content and the presentation itself.

Student to educator

Two types of student to educator feedback were used. At the end of the course, a survey-based questionnairy was sent to each student.This survey was carried out by the university and will not be discussed in this paper.

On a daily basis the students gave feedback to the educator. Two students volunteered to be the feedback persons for the day. The two students had to make notes during the day about the teaching material (papers, videos etc.) as well as the teaching activies like the activation of the students, the informations load etc. At the end of the day, the students and the educator sad together and the students gave feedback to the educator. On the next teaching day two other students were feedback persons for that day.

Educator to student (groups)

Several times during the course, formative feedback from educator to student (groups) were provided. This feedback was concerning the process.

The educator also provided feedback to the students after the individual report, so the students receive feedback from three fellow students and the educator with regards to their learning report (individual report).

Near the end of the course all student groups did a poster presentation. For this event the external censor was present. The student group received feedback from other groups, the censor and the educator. The feedback was given as formative feedback and the groups had the next two days to incorporate the feedback in the final report before submission.

3 RESULTS

A framework for giving and receiving feedback has been presented and the learnings and findings from using this framework will be presented here.

Student to student feedback (peerfeedback)

In this course, the student to student feedback is concerned with the entrepreneurial process and the students learning from using different entrepreneurial methods and tools. For the peerfeedback, the online progam peergrade.io was used. The output of using the program peergrade.oi has been described in previous paper for a similarly course [6]. The feedback from students were that they appreciated the way of giving and receiving feedback (see some statements below). However it is important to be clear about the expectations to the type of feedback. For example it should be made clear if the feedback is concerning the format of the report or the content. Therefore the framework for the student to student feedback can still be improved and in the future more introduction and clear expectation to the give and received feedback will be included to ensure a high output.

Statements from the students from the peerfeedback session:

- *" Overall, I liked the concept and I think feedback from other students is a good idea".*

- *"Peergrade was really a good tool to improves one's own report by both seeing how others have handled the task and but also by getting constructive feedback from others".*

- *"I personally got a lot out of giving feedback to others as I was required to familiarize myself with the report in order to provide a good contructive feedback to the person".*

At the poster session, each group had to provide feedback to another group concerning the content and outline of the poster presentation. The feedback was used to up date the final report. The student were very active in relation to give feedback in this session.

Student to educator

The focus for student to educator feedback is regarding the teaching activities and the teaching material. In this course, the feedback from the student to the educator is given in two ways – on a daily basis and at the end of the course. The feedback on the daily basis was informal semi-structured dialogues between the student and the educator concerning the teaching material and the teaching activities. The feedback giving on a daily basis was used to make directly changes when needed or to include extra material for the next lessons. The students were good at being volunteers and new students were giving feedback every day.

At the end of the course, the course was evaluated by a survey-based questionnairy. These evaluations were performed by the University and will not be discussed here.

Educator to student

The focus for the educator to student feedback is based on the entrepreneurial process. In this course, the feedback from educator to students are conducted several times during the course. The feedback from the educator to the students (group) with regards to entrepreneurial process is essential for the students to be able to create, to adjust and to help them to move forward with their projects.

Experiences from running these courses show that the students are actively involved in the feedback process and they positively appreciate the different ways of receiving and giving feedback. However a framework with clarify the rules and the roles for the feedback process is important to have.

4 SUMMARY AND ACKNOWLEDGMENTS

In this paper we have presented a feedback design used in an introduction course concerning entrepreneurship. The main focus in entrepreneurial education is often on the outcome of the entrepreneurial process and only rarely with focus on the didactical aspect. In this paper, we describe how feedback can be used to provide feedback between students, and between students and educators with a focus on both the entrepreneurial process and the students learning. The feedback from the educator to the students is essential for the students in entrepreneurship courses as the students projects and learning outcomes are created and modified based on the feedback they receive throughout the entrepreneurial process [2].

Our experiences show that the students appreciated feedback and they appreciate having an open dialogue about it. To have a feedback system is essential for the students learning process. But there is also a strong need to communicate to the students how the feedback is conducted and it's purpose in the particularly course.

The forms of feedback presented in this paper are all dialogue based with the aim of creating, adjusting and supporting the development of the entrepreneurial learning process and improve the teaching. However the framework for feedback can also be applied to other fields.

In this study, we have not had the possibility to conduct the educator to educator feedback. Feedback from one educator to another educator could be about having focus on how the course is progressing and to what extent the teaching is supporting the students in their entrepreneurial process.

Based on our learnings we will continue working with the framework for feedback and make more guidelines regarding how to give and to receive feedback.

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A MATRIX FOR MAKING SENSE OF DIGITAL COMPETENCES IN FORMAL ENGINEERING EDUCATION CURRICULA

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Keywords: *curriculum design, digital competences, engineering education, problem-based learning*

ABSTRACT

In this paper we present the development of a matrix used to assist study boards and stakeholders in embedding digital competences into their engineering curricula. The matrix was developed by reviewing existing frameworks of digital literacy and competency at the citizen, upper secondary and higher educational levels and modifying them to suit the context of problem- and project-based learning (PBL) in engineering education. The matrix draws together three categories of digital competences (general academic competences, problem-based learning competences, and discipline specific competences) and an interdependent taxonomy of digital competences (user competences, development competences and reflexive competences), resulting in a matrix of nine distinct types of digital competences. The resulting matrix makes accessible the concepts of digital competences enabling different stakeholders in the curriculum design process (study boards, industry advisory bodies, students etc.) to make meaningful contributions to the curriculum development process.

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1 INTRODUCTION

In the aftermath of Covid-19 lockdowns, online semesters etc., a focus on digital competences and general digitalization of higher education have received renewed attention worldwide. In Denmark, most major comprehensive universities have recently (re-)defined strategies for further digitalization of core practices, both at the organizational infrastructure level and across the main activities of research, teaching and learning. In most cases, this includes a revision of curricula for implementing learning goals for digital competences. Within engineering education so far, there has been an inherent tendency to attend more to technical digital skills, such as modelling and other user and developer skills in relation to technology. However, over time digital competences have developed from being regarded as purely instrumental to technical skills since digital technology has permeated more and more aspects of life. To further develop students' digital competences and digital practices, including practices related to the development of PBL skills, such as problem oriented, interpersonal, organizational, and metacognitive competences [1], a curriculum revision is necessary, guided by and grounded in theory and frameworks of digitalization, PBL and curriculum development.

At Aalborg University, curriculum development involves inclusion of different stakeholders, such as the university study boards, which are comprised of internal academics and students, as well as meetings with stakeholder panels including industry partners, representatives from relevant organizations, other related educational institutions, alumni, regional and municipal councils. Each of these members brings a valuable perspective to the curriculum design process; however not all have an in-depth theoretical understanding of the frameworks involved. To facilitate the contribution of all members, we reviewed the existing frameworks and expanded them to fit the purpose of implementing digital competences in higher education engineering education curricula. The resulting matrix makes complex concepts of digital and PBL competences more accessible to all stakeholders in the curriculum design process, as well as provide a framework and shared language for discussing engineering students' digital competences and digital practices across different higher education institutions as well.

2 FRAMEWORKS AND CONCEPTS OF INSPIRATION

It can be difficult to distinguish the abundance of existing frameworks and concepts, especially for non-experts. Furthermore, the concepts are to some extent tied to specific domains, identities, or professions, such as citizens, education, and industry, each of which need different digital competences.

Concepts include e.g., digital competences, digital literacy/literacies, critical digital literacies, digital skills, digital key competences and more [2]. A review of the two most commonly used concepts, *digital literacy* and *digital competence*, has shown that digital literacy has been linked to technical "know-how" via cognitive skills but also social practices and proactive engagement, whereas digital competency is often linked to competences related to values and ethics, but often also expands to include other areas towards professional contexts, such as higher education teachers' ability to use ICT in learning activities [2].

The different roles and characteristics that digitalization can take have already led to ideological debates concerning the purpose and direction of the digital futures for universities [3]. This is also illustrated by the lack of theoretical frameworks guiding the processes of implementing digital and transversal competences in higher education. Frameworks have been developed for primary and secondary school levels and citizens in Denmark and EU by researchers, and national and supranational councils [4,5]. However, in higher education, including the different disciplines and modes of education, mainly local, more generic frameworks are available, some of the more prominent being the JISC project [6], Near Future Teaching [7] and STAK [8].

These frameworks formed the basis for the matrix presented in this study [9]. From STAK, we adopt the following definition of digital competences: *"Academic digital competences are expressed when students combine digital technology, research methodology, and domain specific knowledge at the same time and with the same purpose; and when the three aspects support and complement each other* [authors' own translation]*."* [8]. DigComp 2.2 [5] was used to discuss the understanding of taxonomy. Whereas the DigComp 2.2 framework is based on a taxonomic understanding of progression from user competences (remembering, understanding) to developing and reflection (applying, evaluating, creating), our framework regards 'use', 'developing' and 'reflection' as distinct categories each incorporating their own taxonomic levels. The results of this work were coupled with the work with digital competences for citizens and in primary and upper secondary school in Denmark by Danish IT [4], which highlights three different categories of digital competences: user, creator, and reflexive competences that are partly overlapping and mutually dependent. Thus, they are not hierarchically ordered, but rather interdependent, and competences within all three categories are needed. The three categories cover:

- *User competences:* needed for the use of technology, that is to know and understand digital tools, access and evaluate information, and lastly manage information efficiently.
- *Creator competences:* enabling a person to create using digital technology, that is to e.g., produce, assemble, process, and exchange information for a specific task and repurpose digital elements. In an engineering context, this would include competences related to collaboration, design and development of IT-systems, analysis, modelling and structuring of data and data processes, i.e., to use algorithms and models to describe phenomena and processes.
- *Reflexive competences:* enabling individuals to act with awareness of possibilities and risks when using and creating digital technology. This also relates to handling ethical and legal issues, being able to create and present oneself in digital spaces as intended and understanding how digital technology affect society.

3 THE FINAL MATRIX

These three categories of digital competence furthermore need to be coupled with and contextualized within domains of student learning. At Aalborg University, the curriculum is strongly PBL based, which means that a third category is added to the distinction between ‘general’ academic competences and domain or discipline-specific competences; namely PBL competences:

- General academic digital competences such as searching, collecting, sharing and processing information, creating and using databases, producing and disseminating knowledge in different formats, i.e., competences typical across academic learning environments.
- PBL competences such as problem-orientation, interpersonal skills, management and leadership skills, and meta-cognitive competences, i.e., competences needed specifically in problem-based project work.
- Domain-specific digital competences such as modelling, simulation, grouping of data and others that are that are typical for a specific discipline or profession.

The distinction between the three types of digital competences is essential for capturing the complexity of digital competences and help guide the focus on the purpose of each of these competences, and the contexts in which they will be used. The final result is a 3 x 3 matrix that synthesizes the frameworks of the different domains of digital competence, making them accessible for non-experts in digitalization and PBL to contribute their perspectives to the curriculum design process. A copy of the matrix is represented below in table 1 with generic examples.

Table 1. Copy of the matrix with generic examples

	General academic	**PBL-specific**	**Discipline/domain specific**
User	*e.g. literature searches and use of academic databases*	*e.g. using digital tools to improve the team’s time/ resource management*	*e.g. use tools to solve discipline-specific problem*
Creator	*e.g. writing reports and making presentations*	*e.g. creating a collaborative hybrid working environment*	*e.g. designing new digital solutions to discipline-specific problem*
Reflexive	*e.g. reflecting on how to maintain motivation in online/hybrid teaching*	*e.g. reflecting on how online communication affects group dynamics and conflict management*	*e.g. reflecting on how digital solutions might bring new, unintended problems*

The adapted framework now orients itself towards higher education and especially universities using PBL or similar student-centered educational models. The multi-dimensionality of the framework allows for reflection on the complexity of digital competency in higher education and offers staff, students and study boards a point of departure for analyzing existing learning outcomes and for creating a shared language and practice around future digitalization within their discipline. The matrix also facilitates the elicitation of feedback and input from external stakeholders.

4 CONCLUSION AND FUTURE WORK

This paper has presented the development of a matrix that builds on and increases accessibility to complex concepts and frameworks that can be challenging and time consuming to understand. The matrix thereby helps to include internal and external stakeholders in the process of developing curricula by enabling them to contribute with their viewpoints on complex concepts in relation to digital and transversal competences, i.e., PBL competences. The matrix can be of use, or inspiration, for others who are facing the same process of implementing digital competences in higher education curricula in the near future. While this paper has presented the development and theoretical background of the matrix itself, future work will include reporting on the practical application of the matrix in curriculum development processes and identified potentials and challenges as well as the mapping and analysis of the types of competences that resulted from working with the matrix.

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A 3D PRINTED F5 NEWTONIAN TELESCOPE: DEVELOPMENT OF A STUDENT PROJECT FOR OUTREACH, EDUCATION, AND DISSEMINATION

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ABSTRACT

An Engineering student´s Final Degree Project based on the design and manufacturing of a 3D printed telescope is presented. The project involves both optical, mechanical, and electronic design, the construction of the instrument, and the numerical and experimental analysis of the prototype. Furthermore, the project explores the possibilities offered by the current 3D printed technologies for the manufacturing of telescopes that may be used both for teaching and disseminating Astronomy and the basis on how to build such instruments.

In this communication the current development of a student Final's Degree Project, consisting of the design and construction of a 3D printed Newtonian telescope, is presented. Both the project and the learning experience are shown as an example of the possibilities of this kind of study at the final stages of the academic formation of engineers, and the possibilities for outreach, education and dissemination of both science and engineering are explored.

1 INTRODUCTION

1.1 3D printing technologies

Since early 2000's, 3D printing technologies, which were originally introduced in early 80's [1], have done nothing less than keep expanding through the globe and becoming key in technological developments in fields such as medicine, fabrication methods or even in the aerospace industry with the design and fabrication of new rockets with many of its components 3D printed.

As an example, a recent work [2] has shown the possibilities of the practical implementation of 3D print optomechanical hardware with high-performance rates and with a cost much lower than if conventional commercial hardware was bought. This reference is an illustrative example (among many others) on how 3D printing technologies can be a game-changer in research and development in many areas of the optical industry.

1.2 Amateur Astronomy

Amateur Astronomy is a field in which different technical skills and needs converge. The amateur astronomical community is formed by thousands of motivated people that want to know more about the Cosmos and to transmit that knowledge to the public. Furthermore, a huge fraction of that community is also interested in do-it-yourself projects, such are specific arrangements and adaptations for the cameras used in astrophotography, among others.

The basic tool for amateur astronomers is the telescope. Telescopes are optical instruments that, in the context of amateur Astronomy, can be divided into three types: refractors, reflectors and catadioptrics [3].

Refractors ara based on the use of refracting elements (lenses). Despite there are several configurations and designs available, the main basic design for this type of telescope is the so-called Keplerian telescope, which is compound by two positive (i.e, converging) lenses (the objective and the eyepiece), and it is the principal design used nowadays (despite optical corrections such as the use of achromatic doublets or inverters for the case of terrestrial telescopes). Another common design is the Galilean telescope, which uses a negative (divergent) lens as eyepiece.

On the other hand, reflecting telescopes are based on reflection law instead of refraction. The objective is in that case, a mirror (the so-called primary mirror). Parallel beams of light enter the tube by the top opening and travel through the whole telescope until they reach the bottom, where a parabolic (or spherical) mirror reflects the light to a secondary mirror mounted on the spider at the top of the telescope. This secondary mirror reflects light to the eyepiece. One of the most popular designs of reflecting telescopes used by amateurs is the Newtonian telescope.

Finally, catadioptric telescopes are a combination of the characteristics of both refractors and reflectors, combining the benefits of the two approaches in order to obtain better images.

2 METHODOLOGY

2.1 Design and development of the telescope protoype

Considering the different commercial configurations used by the amateur community, and the commercially available low-cost optical components, a Newtonian configuration was chosen for that project.

The optical specification of the design is a F5 Newtonian telescope. The aperture of the instrument os 6 inches (152 mm) and the focal length of 760 mm.

For the mechanical design, a CAD software (SolidWorks) was used. Several iterations were done for the design and development of the components and a numerical analysis (by enas of finite-element analysis, FEM) has been carried on.

Figure 1 shows a view of the final CAD design.

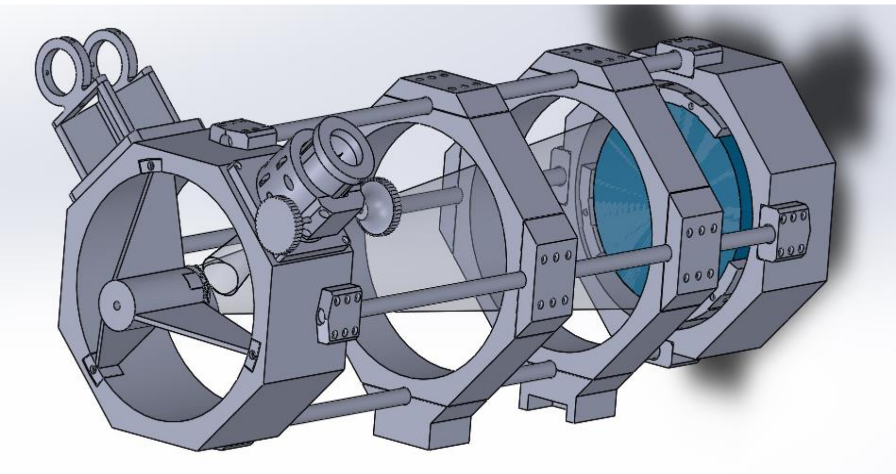


Fig. 1. Telescope design CAD. The shadowed surface represent the light-cone inside the optical path.

Despite the optical components (mirrors and eyepiece) and some aluminium and other metals parts (such as the bars), the instrument is fully manufactured with 3D printed components using PLA.

A wavefront analysis is going to be implemented in the next months for evaluation of the laboratory optical performance of the telescope, and the mechanical performance and stability of the instrument would be tested. Preliminar field observations had been done, as shown in the third section of this work.

2.2 Activities

The final objective of this project would be to present a free kit, which will cover the following topics:

- Building your telescope: a 3D printing workshop. A full workshop based on the basic development of the Final Degree Project presented in this configuration. The 3D files and an assembly annual will be available for students and motivated individuals to build their own 3D printed telescope.
- Fundamentals of telescope optics. A basic course of optical principles (refraction and reflection), telescopes and Astronomy, with experiments and experiences using 3D printed components.
- Hands-on activity: astronomical observation. The telescope would be used either as a demonstrator in fairs or schools, or to perform educational public observations.

At the time this short paper is written, the different tool-kits and manuals are being developed, and the implementation of this different activities has been scheduled for next months.

3 RESULTS

A final prototype has been built ensuring each piece was correctly printed and all the components fits precisely without any critical load. The final assembly is shown in Figure 2.

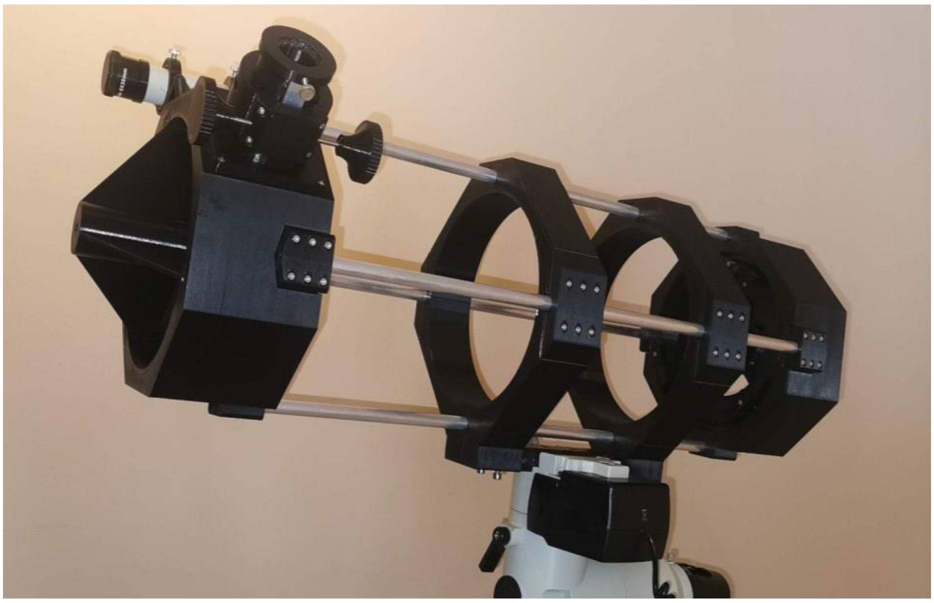
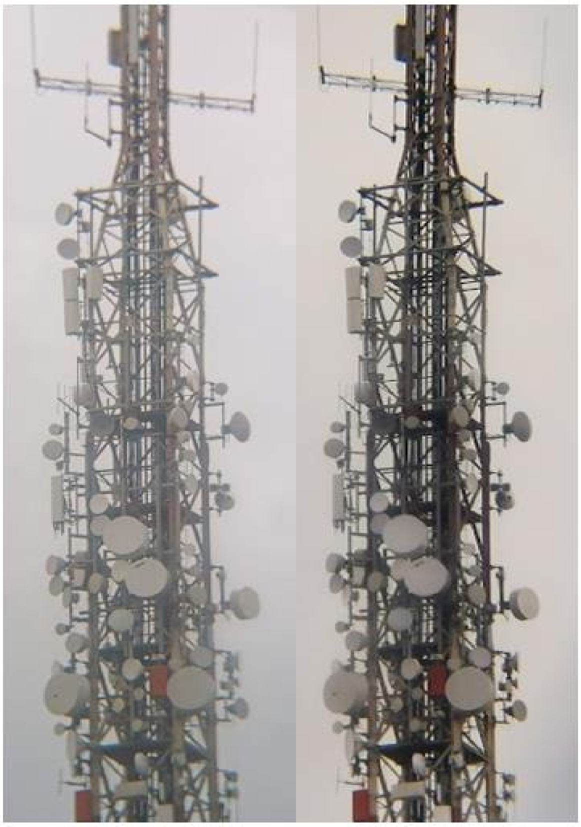


Fig. 2. Final assembly of the 3D printed telescope.

In order to test the capabilities of the designed instrument, an equivalent commercial system was borrowed to the COSMOS Mataró amateur astronomical association. The first test comparison is shown in Figure 3. Authors are currently waiting for an optimal observation night, to obtain full results of the telescope's real resolution and capabilities.



a) b)

Fig. 3. Image of a telecommunication tower obtained with the Meade LXD75 telescope (a)) from COSMOS Mataró, and with the 3D printed F5 Newtonian (b)). Both images were obtained using the same equatorial mount.

4 SUMMARY AND ACKNOWLEDGMENTS

This work presents an engineering Final Degree Project based on the deign and manufacturing of a 3D printed telescope for educational purposes. A set of tool-kits and experiences using and working with such instrument are defined and will be implemented in the months after the SEFI conference.

Authors acknowledge their University and the COSMOS Mataró association for the possibility of develop such project. The corresponding author also wants to thank his family and friends, especially his parents, brother and uncle, who had inspired and encourage him to become a greater engineer.

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Student motivation and disciplinary expertise in Challenge-Based Learning

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ABSTRACT

Challenge-based learning (CBL) seeks to help students acquire skills necessary for collaborative real-world problem solving. It generally favours self-learning, in which students should seek out their own role in a problem-solving environment and choose their own set of skills to develop which are relevant to the challenge. However students from traditional degree programmes may enter with an expectation that their disciplinary expertise will count and be valued in the context of a project, but face a situation that the problem chosen by a group or the dynamics of a group render their expertise less relevant. In survey-based studies of two CBL modules, we explore the relationship between the roles students play and their levels of motivation. We find no evidence that the lack of a disciplinary role strongly affects student motivation. Rather the data suggests that if a CBL environment is properly framed around self-development and multiple potential learning goals students can relax any commitments or expectations related to their expertise, and take on different roles. This is good news for the CBL aims and goals. That said students do have a tendency to revert to disciplinary roles over the course of projects and are against their disciplinary roles being excluded when they are clearly relevant. Instructors can potentially avoid problems by having students evaluate their role choices against desired project outcomes.

1 INTRODUCTION

Challenge-based learning (CBL) is increasingly advocated as an important option for scientific and engineering curricula, as a means of preparing engineers and other scientific groups for solving real-world problems and engaging better with societal interests and values [1,2]. CBL aims to train interdisciplinary skills, important for real-world problem solving [2,3]. CBL is often (although not exclusively) offered as part of disciplinary programmes [3]. Such courses operate across university programmes and draw students from different disciplinary backgrounds. As such students bring their own expertise and potentially their own expectations regarding the roles they should play in a project team. For example a psychology student may enter a technological design-based challenge with a view that he or she will have a role evaluating how users might engage with a technology, only to find out that the most pressing issues are technical and there is little time or place to consider the psychological dimensions. This might be manifest in the way the challenge is constructed or the decisions groups reach about how best to complete the task. As a result though it is plausible to hypothesize that such events affect negatively student motivation. While the effectiveness of self-learning has been studied [4] the interdisciplinary aspects of CBL have lacked attention [5]. In this paper we pursue the research question: is the motivation of students from bachelor programmes entering CBL courses affected by their ability to apply their disciplinary expertise?

2 METHODOLOGY

2.1 Study design

To explore whether disciplinary roles (and resulting expectations) might affect student motivation we performed surveys of students in two CBL courses. Students were surveyed once in the first two weeks, and again in the last two weeks. Intrinsic motivation was measured with the nine-item version of the intrinsic motivation inventory in both surveys to detect variations [6]. Both surveys also included a variety of statements related to their more explicit motivations, expectations, based on their roles, and responses to behavior of fellow group members (1 to 5 Likert scale; strongly disagree = 1, disagree, neither, agree, strongly agree = 5). See Table 1 below for examples.

2.2. Included Cases

The first course titled “Course 1”, is taught in the third year of bachelor students and is open to students from across a Dutch technical university for one quartile (10 weeks; 15 ECTS). Students collaborate in interdisciplinary groups on a real-world product design problem provided by a “challenge-provider”; either a government agency, foundation or corporation. Challenge-providers provide a problem description and relevant group skills, and provide help on request from students. Learning goals for the module concentrate on developing collaborative and communication skills, integrating stakeholders into a solution and sound design-based decision-making. Students may be from technological or social science backgrounds.

The second course “Course 2” is run for European consortium of universties (5 ECTS; two semesters). Students collaborate on real-world tasks constructed by challenge-providers. Students may come from any background. For learning goals students should develop skills in analyzing complex societal problems and working in teams. But they are also given a choice regarding others; such as whether to work on presentation or leadership skill, design skills, or stakeholder involvement. Project outcomes are not graded. Students are asked to provide reflections on their personal targets, and personal and team development

3 RESULTS

3.1 Figures

Table 1: Sample of questions from the first survey round. Results are Likert averages.

Questions Round 1	Course 1	Course 2
	n=17 (/40)	n=17 (/31)
I selected the programme to work… on a real world challenge	4.2	4.5
…apply my disciplinary expertise to a real world problem	3.5	3.9
…apply non-disciplinary skills	3.5	4.1
… on new skills	4.3	4.3
I chose my challenge..…as societally relevant	4	4.5
…as relevant to my disciplinary skills	3.2	3.5
…as relevant to professional skills	3.2	3.5
.. to develop new skills	4.2	4.2

Table 2: Sample of questions from the second survey round. Results are Likert averages. Some questions, marked ‘X’, were only developed after surveys of “Course 1” students.

Questions Round 2	Course 1	Course 2
	n=7 (/40)	n=12 (/31)
Most of my challenge contribution has come from…my discipline	X	3.2
… professional skills	X	3.8
….new knowledge and skills	X	3.5
My contributions fit the kind of role I expected to play	X	4.0
The challenge did not offer all members the same chance to use their expertise.	2.9	2.3
We would have a more optimal solution if I had used my disc. expertise more.	3.3	2.7

3.2 Discussion

In neither course was there evidence that a failure to contribute disciplinary expertise played a substantial role in student motivation. This holds despite many students having a non-disciplinary role geared towards the use of professional skills or development of new academic skills (roughly half of Autumn Challenge students).

Overall student intrinsic motivation increased for each programme rather than fell, likely as a response to students becoming more familiar with their challenges, their roles and their group members.

In terms of the explicit motivations guiding their choice of these CBL programmes or their challenges students put more weight on developing new scientific/engineering skills outside their area of expertise or working on a societal problem over use/development of disciplinary skills or professional skills (see Table 1 below; first question round). As both courses explicitly allow students to consider and take different roles beyond their background expertise, not being able to use one's expertise is likely not considered an issue. The vast majority of students in the Autumn Challenge felt they performed a role in line with their expectations going into the programme. Students from neither programme felt that they were excluded from playing a disciplinary role if they wanted to. Fellow group members were generally open to including any approach. Further students did not feel it necessary to have a disciplinary role if this was not relevant to an optimal or indeed just a good enough outcome. This is good news for CBL which stresses flexible and personal outcomes.

However there are a few notes of caution before drawing the conclusion that students will always be happy to look passed disciplinary roles and be flexible. In the first place many students (around 25%) do still express a primary preference for having a disciplinary role, and for a fraction of students, being excluded, particularly those from the social sciences, is demotivating. Secondly in Course 2 projects were not formally assessed or graded, relaxing incentives for producing an optimal result. A majority of students in both groups did not feel that taking a disciplinary role would have improved the overall project outcome. However most students still felt that they would not be happy if their disciplinary expertise was excluded when it would produce a more innovative outcome. Most students agreed that if their discipline was equally important to a problem solution it should have an equal role. Further while students generally think that their group members respect their disciplinary expertise, and to a lesser extent are willing to learn from it there is a measurable change in how students perceive the willingness of their teammates to work outside their disciplines over the course of a programme. For the statement "*My fellow group members are willing to experiment with methods and ideas outside their background disciplines.*", which was asked both rounds average agreement dropped 25% in both groups. This suggests that students do revert somewhat to disciplinary approaches or familiar skills, even if initial attitudes are towards acquiring new skills, possibly because it takes time to recognize a disciplinary role or because it turns out easier.

Students were free to choose these programmes. Both were offered additional to their normal disciplinary education, rather than part of it. Applying CBL as say part of normal disciplinary education, in which projects are graded, thus might face motivational issues related to disciplinary roles on the basis of these student preferences. However with the right expectations, self-selection of students and opportunities for transversal skill development, educators should avoid potential motivational problems. Regardless there are different possible responses educators can take to manage such problems were they to arise. Students might be given an innovation management strategy (such as knowledge cross-fertilization or Scrum) which help students plan upfront their roles, and systematically integrate their expertise [7]. Students can be otherwise guided to explicitly consider their desired project aspirations when making role decisions; e.g. “Is my role choice likely to generate the most optimal or practical outcome? Do I want that?”. Further it can be useful for groups to consider the potential contributions of all disciplines before settling on an approach.

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The influence of gender stereotypes on women's spatial abilities and their underrepresentation in the field of engineering

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ABSTRACT

Technological innovation and scientific progress are important components for improving human condition and economic success. Therefore, a workforce that includes a critical amount of experts in science, technology, engineering, and mathematics (STEM) domains is needed. Evidence supports that males and females often present differences in their performance and preferences towards some STEM courses and occupations, especially engineering. Specifically, the number of women that decide to pursue careers in the engineering field is relatively low. One possible factor contributing to this gender gap that has gained a lot of interest recently is gender stereotyping and distinct gender roles among societies. Segregation between women and men's societal roles result in psychological gender differences, emerging from early childhood, and can later affect career choices. Additionally, different gender related standards imposed by the society drive women towards activities, majors and careers perceived as more "feminine". Another way gender stereotypes contribute to these differences is by affecting the development of cognitive skills that are hugely involved in engineer learning and thinking. Spatial abilities are part of such skills that play an important role in academic and occupational achievements in STEM domains, is strongly correlated with engineering education and can, on average, be less developed among women relative to men. In this paper we are going to review the literature on the influence of gender stereotypes on women's spatial ability development, and how this may later prevent them from pursuing a career in engineering.

1 INTRODUCTION

The topic of women's underrepresentation in certain science and engineering fields continue to attract the interest of many scholars [1][2]. Even though, women outpace men in higher education, earning 57% of all baccalaureate degrees, some disciplines remain sharply gender segregated. This phenomenon is very evident in engineering, an area where women complete approximatelly 19% of undergraduate degrees [1]. There are few explanations for the high rates of attrition among women, for example: 1) the chilly or unwelcoming environments that women come across and drive them to exit these majors [1][3]; 2) gender stereotypical approaches towards career among societies, for example people often paint certain professions and activities as masculine and other feminine [1][4]; 3) spatial abilities [3][4]. In general, segregation between genders and strong gender stereotypes among societies do influence a person's view of themselves and their perspectives, and ultimately their behaviour and participation in certain activities that contribute to their development[1][4]. These influences are observable from a very young age, even from 5 or 6 year old. Moreover, girls who are strongly influenced by their social role might not participate in activities (e.g., playing with blocks, using tools) that embrace the development of cognitive skills that play an important role in engineering learning and thinking [4]. While the levels of general intelligence do not differ between men and women, gender differences are sometimes present in more specific cognitive abilities. In particular, spatial abilities are one of the cognitive abilities that present the largest gender gap; on an average level men tend to outperform women in spatial abilities tasks [3][4]. In the following review we are first going to cover the important role of spatial abilities in STEM education, followed by the gender stereotypes, and then how the gender stereotypes may affect women's participation in engineering.

2 THEORETICAL BACKGOUND

2.1 Spatial Abilities & STEM

Early expertise in spatial abilities in children builds the foundation for the development of quantitative reasoning, a collective term encompassing science and mathematics. According to literature, early differences in spatial abilities show important implications for students' achievements in science, technology, engineering, and mathematics (STEM) fields [3]. But what exactly do we mean with the term spatial abilities; Linn and Petersen [5] defined spatial ability as the "skill in representing, transforming, generating and recalling symbolic, non-linguistic information". In other words, it includes the ability to realise and perceive spatial connections, to visualise spatial related stimuli like objects, and be able to transform or manipulate them – for example using mental rotation to imagine how an object would appear from a different point of view or perspective [3]. Therefore, it is understandable how these skills are important in STEM curricula, since tasks in these fields include identifying, explaining, and classifying the shape, position, and orientation of objects; manipulating spatial representations in the form of diagrams, graphs, or scientific models; picturing the processes of objects' movement in 3D coordinates; and tangling non-spatial phenomena by using spatial-thinking strategies [3].

Moreover, evidence from longitudinal studies strongly support this link between spatial abilities and STEM [6][7][8]. This evidence demonstrate that: (a) spatial abilities are a "salient psychological characteristic" to advance educational achievements in STEM among young people, who subsequently succeed in similar fields later in life; (b) spatial abilities are involved in shaping the academic and occupational outcomes for intellectually talented individuals and the general population; (c) recent talent searches lose many intellectually talented individuals by limiting their selection criteria to verbal and mathematical abilities measures [6][7]; and (d) students with higher spatial abilities show more interest towards STEM related subjects [8]. In addition to these longitudinal studies, research has highlighted the correlation between spatial abilities and mathematics [9], physics [10], computer science [11], geometry [12], chemistry [13], and engineering [14][15]. Therefore, it is understandable why this topic has drawn the attention of numerous researchers, and why the gender differences in this area pose a concern.

Prior research that focused on gender differences in spatial abilities have made the following observations: (a) not all categories of spatial abilities present gender differences, (b) most gender differences are in mental rotation tasks, (c) once gender differences are found they are detectable across the lifespan [5]. Due to evidence supporting that spatial abilities can be trained and improved via interventions, practice and training [16] and there seems to be a developmental progression of these differences through childhood with an increase later in adulthood, most researchers argue the gender gap is a result of social influences and sociocultural processes more so than biological changes [4]. Research has shown that gender differences in spatial abilities are due to gender differences in spatial experience, for example playing with spatial toys and participating in spatial school subjects [16]. These ideas created the foundations for socio-cultural theories, where the relevance of the stereotyping factor is clear [4]. Especially in late childhood, gender stereotypes offer a reasonable explanation for the gender differences in spatial abilities; and considering the implications of spatial abilities in STEM domains it can also explain females' underrepresentation in some of these fields [3].

2.2 Gender Stereotypes

One commonly held stereotypical belief is that spatial ability is an inherently male aptitude, that males are naturally gifted in this ability. In the long term, these beliefs regarding the masculinity of spatial abilities potentially result in gender differences in spatial achievements by affecting the consistency of how often girls and boys participate in spatial activities at home and school and by influencing their self-concept of ability [4][16]. Example of spatial activities that contribute in the development of spatial abilities include playing team sports and engaging with workshop activities, such as practicing with tools and repairs. Different gender socialisation may encourage boys to participate more in these activities than girls [16]. Moreover, in the short term, gender stereotypes, by activating negative or positive beliefs about a boy's or a girl's abilities, could result in performance differences between males and females during a spatial test situation [4].

The influence of gender stereotypes has similar effects in some STEM courses. For example, a general idea that boys are better than girls in mathematics might effect girl's performance in math tests and make them internalise this perceived general group characteristic ("girls are bad at maths") as a personal characteristic ("I must be bad at maths"); which off course is not true. Children from the age of 6 are aware of the existence of stereotypes and make important steps towards the development of self-concepts and abilities; and stereotypical beliefs are already present by the age of 10 [4]. It appears that boys and girls from young age adopt behaviours and characteristics in order to fit their gender roles as imposed by society, according to psycho-social theories [4]. The power of stereotypes can be very salient, they can occur unconsciously, get internalised and effect ones' image and behaviour without the person realising it.

2.3 The Role of Stereotypes in Engineering

Gender stereotypes towards the field of engineering potentially affect women's participation in this field. Stereotypical claims portrait engineering as a masculine domain and project the male dominance in this field [2]. Even though, women are more involved in the field than they used to be and they have made great contributions, based on stereotypes engineering is still commonly considered to be more suitable for men [2]; making women to often feel the need to prove themselves in the field. There is one issue which is often overlooked in this topic, it is the fact that women are not equally underrepresented in all engineering majors; but most of the studies do not specify in which fields women are more underrepresented [1]. For example, in 2013, women completed 40.6% of biomedical engineering degrees, and 36% of chemical engineering degrees, but they comprised only 13% of degrees in electrical and mechanical engineering [1]. The bigger percentage of women in the biomedical and chemical majors, suggests an interesting contrast within the area.

The reason for that could be explained by a theory suggesting gender dualistic approaches among practicing engineers. This dualistic thinking fit engineering practices, jobs, and even personal identities into mutually exclusive categories, for example: 1) technical versus social, 2) hard versus soft, 3) even abstract versus applied [1]. Although, not inherently gendered, the more technical, hard and abstract factors are tailored to the cultural understandings of masculinity, hence more suitable for men, while the social, soft and applied ones are perceived more feminine, hence more suitable for women [17].

In their study Blosser [1] observed that engineer faculty members give feminine or masculine characteristics to different disciplines and then imply that women’s seemingly natural taste and proclivities guide them to choose accordingly. For example, faculty members pointed out that biological and industrial engineering carry communication and socially relevant characteristics and this assumingly would attract more women and justify their presence in a major. On the other hand, the future workplace from the male dominated majors were considered by the faculty members as technical and dirty, characteristics that were deemed unappealing for female students [1]. Giving certain activities and majors feminine or masculine identities influence how women’s, and generally people’s, abilities and preferences are perceived from both their own and other people’s perspectives [2].

3 SUMMARY

In conclusion, cultural stereotypes about gender differences are still influencing people’s view, assisting to the maintenance of segregation between men and women across professional fields [1][2]. Of course, women are able to and do embrace parts of engineering that are considered more masculine. However, normative standards of appropriate masculine and feminine behaviour stand as guides and people are expecting to be judged by them; therefore, this leads to behaviour alterations in order to keep social sanctions to the minimum and adopt ways that are consistent with cultural understandings of the gender roles [1]. These risky notions drive women to avoid masculine engineering fields, as well as the opposite, it can drive them towards feminine fields by projecting their biased assessments of their abilities and strengths, by both themselves and others [1][5]. There is a need to understand that these stereotypical behaviours and ways of thinking do not suddenly emerge when people choose their majors, but rather start very early on throughout the development of a person’ s identity, from childhood to adulthood. Educators need to take under consideration the impact of gender socialization in a person’s abilities and preferences, and how this can be changed and reshaped.

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ENGINEERS' PERCEPTIONS OF THE IMPORTANCE OF EMPATHY AND CARE: INITIAL INSIGHTS FROM ENGINEERS PRACTICING IN AUSTRALIA

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ABSTRACT

Empathy and care influence aspects of engineering practice including collaboration and teamwork, stakeholder engagement, and quality of work. Empathy has been identified as a key employability skill for professionals, and is the foundation for many skills and attributes anticipated as required by future engineers. Therefore, the understanding of empathy and care, and consideration of the development of empathetic and caring competencies are increasingly relevant for engineering education. Recent studies have explored the conceptualisation of and value placed on empathy and care in engineering practice, from the perspectives of practicing engineers in US and German contexts. We broaden this to include the Australian setting. Engineers' perceptions of empathy and care within Australian engineering practice were collected using an online version of the Empathy and Care Questionnaire (ECQ) instrument developed by Hess, Strobel, Pan and Wachter Morris (N = 183). Statistical analysis of survey questions relating to the perceived

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importance and benefits of empathy and care to engineers, and relevance within a range of engineering practice situations was undertaken. Analysis of gender, years of experience, and organisational role indicated that female engineers perceived empathy and care to be more important, and more impactful on engineering practice than male engineers. Perceptions of empathy and care did not vary with duration of engineering work experience, however engineers in positions of organisational leadership placed greater importance on empathy and care in their roles than others. These differences contrast with results of the US and German studies. Further analysis is required to understand where, when and why these differences occur.

1 INTRODUCTION

1.1 Empathy and Care in Engineering Practice

Empathy and care can be considered a core skill within engineering [1], underpinning many skills and attributes required by current and prospective engineers. The understanding of empathy and care, their role within engineering practice, and the consideration of the development of empathetic and caring competencies are increasingly relevant for engineering education.

The conceptualisation and relevance of empathy and care in engineering practice, from the persective of practicing engineers, is an emerging research area. Research in the US and German contexts indicate that practicing engineers perceive empathy and care as most important within relational aspects of their engineering work [2, 3]. Empathy and care relate to improved understanding of others, broadened perspectives, enhanced relationships, effective two-sided communication, collaboration and teamwork, relevant to meeting clients' needs [2, 4]. Empathy and care are perceived to impact engineering outcomes. Empathic and caring orientations promote an other-centric focus, awareness of broader impacts of engineering decisions, and an altruistic orientation to design and solution generation, impacting engineering outcome quality [4]. Organisational, task-related and individual factors influence the perceived importance and impacts of empathy and care within engineering practice, indicateing their contextual nature.

1.2 The Current Study

This short paper builds on recent research on empathy and care within engineering practice in US and German contexts [2-4], by exploring perceptions of the importance and benefits of empathy and care within engineering practice in the Australian context. This study contributes to a more expansive understanding of empathy and care within engineering practice, offering an increasing contextual and granular view of these concepts by considering diverse geographic and demographic variables. The research questions that frame this paper are: i) do engineers in Australia perceive empathy and care as important to and impactful upon their engineering practice?, and ii) what are the differences in perceived importance and impact of empathy and care, by gender, years of working experience, organisation role, and national context?

2 METHODOLOGY

2.1 Empathy and Care Questionnaire (ECQ)

Engineers' perceptions of empathy and care within Australian engineering practice were collected using an online version of the Empathy and Care Questionnaire (ECQ) instrument [2]. The online questionnaire was created within the Qualitrics™ platform. The survey contained 37 scale items to investigate the existence, nature and importance of empathy and care within engineering practice. In addition, the questionnaire sought information relating to respondents' demographic and work-related characteristics, and provided opportunity for additional written comments.This short paper reports on statistical analysis of responses to closed questions relating to: i) 2 items rating perceived importance of empathy and of care to respondents as engineers on a 100-point scale; ii) 12 items rating perceived importance of showing empathy and care in a range of engineering practice situations on a 6-point scale, (e.g.: Based on your experiences in engineering, rate how important it is for engineers to show empathy and care in the following situation - Working in teams); and iii) 7 items rating perceived potential impacts of an empathic and caring approach in engineering practice on a 6-point scale (e.g.: If empathy and care are effectively incorporated into engineering, to what extent do you think the following impact will occur? – Engineered products will fulfil users' needs).

2.2 Participants

Data were collected progressively from November 2019 to March 2021. Respondent recruitment was both purposeful and opportunistic, leveraging the researchers' professional networks. An invitation to participate with a link to the online questionnaire was distributed, consistent with ethics approval, by researchers and email by senior engineers in organizations and networks, and in engineering faculty alumni newsetters of two universities. Participation was voluntary and anonymous.

Respondents were 248 degree-qualified engineers practicing as engineers or working in related roles in Australia. This was reduced to 183 respondents (n_{male} = 125, 68.3% ; n_{female} = 58, 31.7%), with removal of 59 reponses due to insufficient questionnaire completion and three responses due to lack of demographic data.

Respondents were well-distributed according to years of engineering work experience, with the largest proportion indicating that they had been working as engineers for under ten years (n = 57, 30.2%), across a range of engineering disciplines. The most common organisation role held by repondents was 'technical role' (n = 71, 38.8% of respondents). Respondents frequently indicated two or more current organisational roles. For analysis purposes, organisational roles were catergorised as: i) technical role only, ii) manager/leader of a technical team (including in combination with other roles), iii) technical role, and other business roles, iv) leadership of company, and v) other.

3 RESULTS

3.1 Analysis

Mean scores were generated across the items for each of: *importance to respondents* (M = 79.22, SD = 15.69), *importance for practice* (M = 5.00, SD = 0.66), and *potential impacts* (M = 4.59, SD = 0.93).

To address the research questions, responses were compared by gender, years of experience, and organisational role. A multivariate analysis of variance (MANOVA) was performed (one for each of the potential moderator variables identified – i.e., gender, years of experience, and role). In each MANOVA, the three dependent variables were *importance to respondents*, *importance for practice* and *potential impacts*. Data were screened for conformity to multivariate analysis of variance assumptions, which produced satisfactory results.

The MANOVA for gender indicated a significant difference across males and females on the composite linear dependent variable, λ = .95, $F(3,179)$ = 3.04, p = .03, partial $\eta 2$ = .05. Univariate ANOVAs indicated significant differences across males (M = 4.47, SD = 0.97) and females (M = 4.85, SD = 0.79) on the *potential impacts* variable, $F(1,181)$ = 6.89, p = .01, partial $\eta 2$ = .04, and also on the *importance to respondents* variable, (M_{male} = 77.27, SD_{male} = 16.41; M_{female} = 83.45, SD_{female} = 13.18), $F(1,181)$ = 6.33, p = .01, partial $\eta 2$ = .03, but not on *importance for practice*, $F(1,181)$ = 1.41, p = .24. Both significant results reflected higher ratings for females than for males.

The MANOVA for years of experience indicated no significant difference across groups on the composite linear dependent variable, λ = .91, $F(18,493) < 1$. Therefore, years of experience was not a significant moderator of ratings across the three dependent variables.

The MANOVA for role indicated a significant multivariate difference across groups, λ = .88, $F(12,466)$ =1.78, p = .05, partial $\eta 2$ = .04. Univariate ANOVAs for each dependent variable indicated that using a Bonferroni-adjusted alpha level of .017, there was a significant difference across roles only on the *importance to respondents* measure, $F(4,178)$ = 3.37, p = .01, partial $\eta 2$ = .07. Follow-up Tukey HSD tests on this variable indicated that there were no differences that were significant or that approached significance across any groups other than differences in comparison to the 'Leadership of company or business' role group. Based on the Bonferroni-adjusted alpha level, this group differed significantly from the 'Technical and business roles' group (M_{lead} = 91.39, SD_{lead} = 8.44, n_{lead} = 14; M_{techbus} = 72.25, $SD_{techbus}$ = 19.89, $n_{techbus}$ = 22; p = .003). Differences between those in the Leadership of company or business role group, versus those in the 'Technical role' and 'Manager / Leader of technical team' groups also approached, but did not reach significance (ps =.04 and .06, respectively). All differences that reached or attained significance for role indicated higher scores for the 'Leadership of company or business role' than for those in other groups.

3.2 Discussion

The high mean rating for the three variables of *importance to respondents*, *importance for practice*, and *potential impacts*, indicate that Australian engineers perceive empathy and care to be important to themselves in their professional roles, and important and potentially beneficial to their engineering practice.

Female engineers in the Australian context perceive empathy and care to be more important to their professional role, and more impactful to engineering practice and outcomes, than male engineers. This contrasts with an absence of observed gender differences in the US study [2]. Gender has previously been associated with empathic tendencies. In the Australian engineering context, higher empathic tendencies have been reported in female engineering students [5]. Our findings suggest that female engineers' perceived value of empathy and care is sustained on entry to engineering practice rather than diminished through assimilation with male-oriented engineering values as suggested by [2].

The perceived value of empathy and care did not significantly vary with years of engineering work experience for Australian engineers. This contrasts with the greater levels of perceived prevalence and importance of empathy and care among more experienced engineers reported in both US and German studies [2, 3]. Engineers in organisational leadership roles placed greater importance on empathy and care within their professional role, in comparison to engineers in other organisational roles. Empathy is a vital leadership competency, and this finding may reflect effects of leadership development or presence of selective promotion processes within engineering organisations. The same level of value or relevance of empathic and caring orientations to engineering roles, other than organisational leadership, are not reflected by the respondents.

4 SUMMARY AND ACKNOWLEDGEMENTS

4.1 Implications and Further Work

Our study supports previous work that has established the importance of empathy and care to engineers and engineering practice, and the impetus for inclusion of these concepts into engineering education. Findings relating to perceptions of empathy and care and organisational role provide opportunities for both pre-professional and continuing engineering education. To progress the development of empathic and caring competencies in engineering, relevance of empathy and care to all engineering roles needs to be established and communicated through strategies targeted at students and practicing engineers. Our initial analysis reveals areas for additional research, including a detailed exploration of observed gender and organisational role differences, engineering practice situations and impacts. Interactions between the demographic variables should also be considered.

4.2 Acknowledgements

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Challenge Based Modular Education Upscaled: Piloting and Evaluating an Implementation Procedure

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ABSTRACT

Modular approach in education provides the advantages of student self-pacing, autonomy, and receiving frequent feedback from the instructor. In 2021, the project; CMODE-Up (an Upscaling of the earlier undertaken project Challenge-based Modular On-demand Digital Education) provided evidence-based design principles and an accompanying teacher guide for modular courses in engineering education. A next step towards actually implementing the design framework, is piloting it. In this pilot, we will ask teachers from our university to work with the framework to redesign their course into one or more challenge-based modules. We started off with a short workshop to get teachers motivated to work with us. Teachers were recruited based on willingness and experience with modular courses. During the workshop, the teachers engaged in course design exercises using the design framework. Transcibed audiotapes of the workshop discussions constituted the data for this study. To further improve the framework, the results from the workshop data were combined with results of a descriptive literature review. Relevant articles and conference preceedings were located that can shed light on issues such as design of a course with elective modules. Results collectively will lead to an adapted version of the design framework.

1 INTRODUCTION

Online learning environments and modular structures in higher education enable learners to define and pursue a personal learning path [1]. The modular approach is rooted in educational pedagogies such as programmed-instruction, learner-centered pedagogies, and computer-assisted instruction [2, 3]. Prominent characteristics of a modular approach in education include frequent feedback, self-paced learning, and flexibility in time and location [4]. Such characteristics have an important role in addressing the changing nature of the workforce towards sensitivity to individual interests and learning needs and to autonomous learning experiences [5].

Although a modular approach to course design has been frequently adopted in higher engineering education literature, design principles tailored to modular courses did not exist. In order to address this need, a conceptually grounded template for modular course design was developed in a previous study [6]. The design principles were: (1) course content, (2) module category, (3) alignment of content, (4) module development, (5) implementation, (6) learner engagement, and (7) evaluation.

The need to support teachers with empirically-grounded frameworks to design modular courses has been highlighted by previous studies. Felix-Herran et al. [7], for example, designed and delivered a training program to support engineering instructors' in designing modular courses. This study addresses the need to improve the developed course design framework [6] through a workshop for teachers and a descriptive review.

2 METHODOLOGY

2.1 Design

The first part of this research was piloting our empirically supported framework for modular courses in higher engineering education. Beginning with design principles based on existing research and expertise facilitated the process of piloting and testing during a teacher workshop. The second part included a descriptive literature review to further broaden our understanding on issues such as alignment of modules with other course components, modules in a challenge-based learning (CBL) course, and ways to offer mandatory and elective modules. Descriptive literature reviews are helpful in understanding similarities and differences in studies, while putting the focus on the certain features of interest [8]. In this study, qualitative methods of data collection and analysis were adopted.

2.2 Participants and data collection

Approval from the university Ethics Committee was received prior to data collection. Two teachers at the authors' university participated in the workshop, a full professor at the department of Chemical Engineering and a lecturer at the department of Applied Physics. During the two-hour workshop, the teachers engaged in structured discussions and exercises on modular courses using the framework.

The workshop was organized face-to-face and consisted of: a) an introduction about modular approach in education and the goals of the workshop, b) exercises for the teachers to reflect on designed courses using our framework, and c) a reflective discussion. The discussions were audiotaped. The discussions triggered the teachers to use the framework and to reflect on its improvement. In the descriptive literature review, 20 research studies were included, based on reporting on CBL and on elective modules; articles (n = 9), conference preceedings (n = 9), and book chapters (n = 2).

2.3 Data analysis

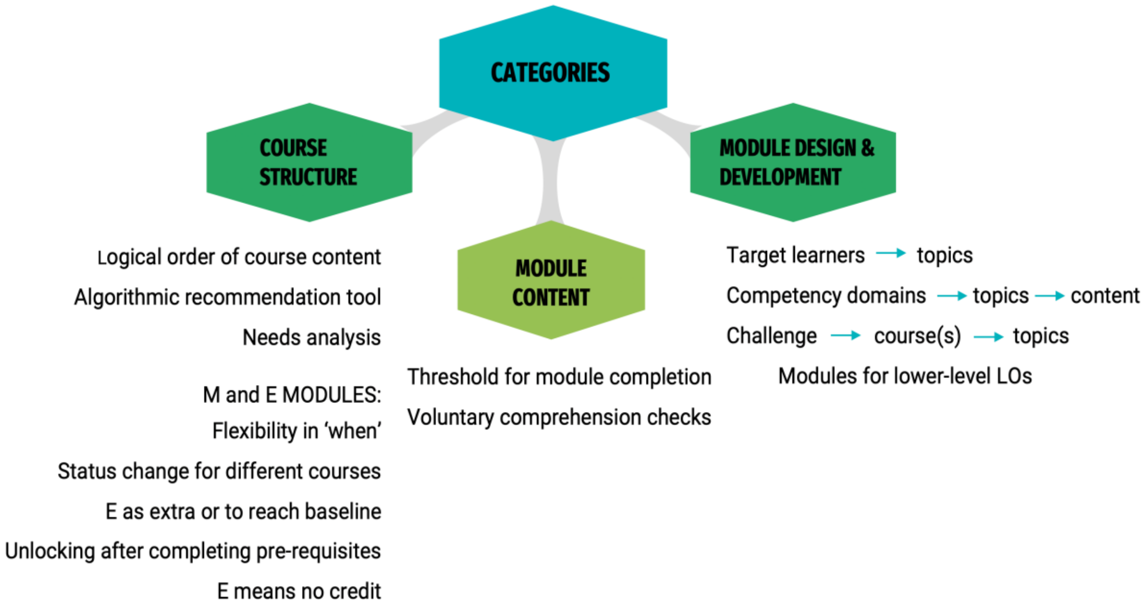
First, the audio recordings of the workshop discussions were transcribed verbatim. The qualitative analysis of the transcripts and the located research studies (n = 20) followed a content analysis method [9]. Following the separate analysis of the transcripts and the research studies, results were combined to reach a comprehensive overview.

3 RESULTS

Results are summarized in three categories: a) modular course structure, b) module content, and c) module design and development (see Figure 1). Figure 1 shows the codes that emerged under the categories. M and E stand for 'mandatory' and 'elective' respectively on the figure. The codes reported under each category represent new ideas to modify the design framework. For example, the codes given under the category, 'module design and development', reveal that the modular course design process can begin with considering learner profile first, the course topis, or the challenge. Similarly, the code; ‘status change for different courses’ under the category ‘modular course structure’ show that modules can be used as M or E in different courses. The researchers will now work on integrating the codes meaningfully into the course design framework [6].

4 SUMMARY AND FUTURE DIRECTIONS

Using the evidence-based design principles created during our former work, it was now time to focus on a practical implementation, as well as studying what place challenge-based education can hold here. The next step in this research is



incorporating the results presented here into the first version of the framework [6], to make it more practical for the teachers. Examples to that are, in a course with mandatory and elective modules, presenting elective modules as extra support for interested students or to help students reach an expected baseline level. The next step in the entire project is to collaborate with a teacher willing to modularize a course using the revised framework (with several elective modules) and work on the redesigned course.

Fig. 1. Combined results.

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Factors that Influence Multidisciplinary Teamwork in a Challenge-Based Learning Course

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ABSTRACT

For our students to work on the global challenges facing humankind, they should be raised to appreciate the importance of science and engineering in real-life contexts. Challenge-based learning (CBL) courses have merit in accomplishing this goal by facilitating students' innovative solutions to authentic, complex problems. The fundamental characteristics of CBL include real-world challenges, collaboration, and multidisciplinarity. The presented work describes a CBL course where applied physics and mechanical engineering students worked in multidisciplinary teams. An instrumental case study was conducted to identify factors that influence multidisciplinary teamwork in this CBL course. Data were collected using interviews, reflection reports, and observations of team meetings. Transcribed video recordings were searched for instances of demonstrating the codes revealed with analysis of interview transcripts and reflection reports. The research results showed the significant factors influencing multidisciplinary teamwork: a) disciplinary connections to the challenge, b) receiving tutor guidance, c) making presentations in teams, d) exchanging science and engineering perspectives, e) readings and videos on course Canvas, and f) student motivation. Implications are discussed, and suggestions for future research and practice are presented.

1 INTRODUCTION

Learning environments that address multiple disciplines have the potential to contribute to learning and to develop competencies such as critical thinking, problem solving, communication, and an awareness of societal problems [e.g., 1, 2].

Approaching an overarching theme or a problem with the knowledge and methods of multiple disciplines lies at the core of challenge-based learning (CBL) courses [3]. A recent systematic literature review revealed one of the core characteristics of CBL as multidisciplinarity [4]. In a CBL course, students work on real-world challenges such as food safety and sustainability as they gain or deepen knowledge and skills [3].

Having students work on challenges in multidisciplinary teams is a common practice in CBL courses [e.g., 1]. In multidisciplinary teams, students apply the knowledge and methods of their disciplines to communicate and to solve open-ended problems [5]. Multidisciplinary teamwork in CBL and similar project-based courses in higher education is evidenced to have positive impacts on students' skills development and learning of course content [e.g., 6].

This study addresses the need to identify factors influencing multidisciplinary teamwork in the context of the first pilot of a CBL course.

1 METHODOLOGY

1.1 Design

A case study approach was adopted to explore multidisciplinary teamwork in the course context [7].

1.2 Participants and data collection

The CBL course; "CBL Systems and Control" was designed to use the knowledge and methods of applied physics (AP) and mechanical engineering (ME) around the specified challenge: design and implement a real-time controller for a pick-and-place robot'. The hardware in used in the course was a robot arm set-up shown in Figure 1. The course included 30 second-year bachelor students. There were seven AP and 23 ME students who worked in teams. Each of the five teams consisted of six students. Data were collected from students (*n* = 12) and from the teacher team (*n* = 5).

Semi-structured interview questions were prepared considering the literature on factors that influence successful teamwork. In addition to the interview responses on the already existing conditions perceived as factors, participants also commented on how to address multidisciplinary teamwork in the course more effectively. Data also included students' individual reflection reports on their teamwork experiences. The reflection reports were collected at the end of the course.

Video recordings of team meetings were used to supplement the results of the interviews and the reflection reports.

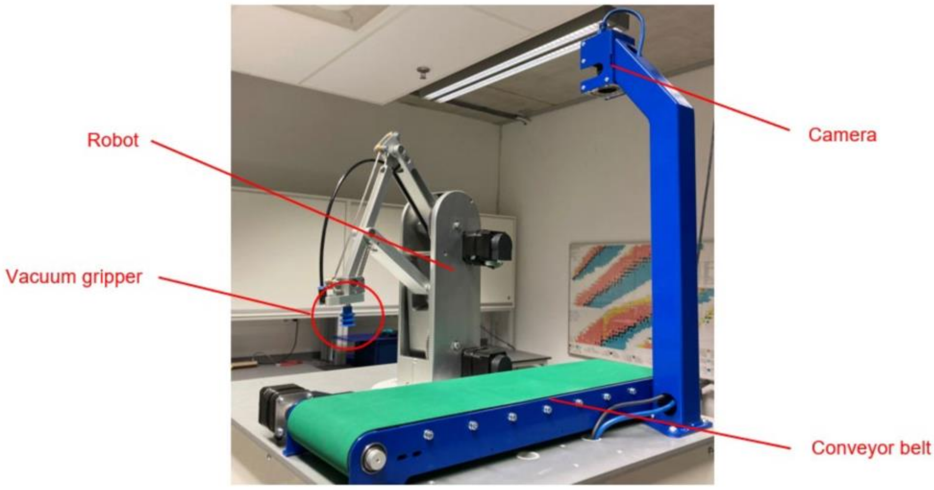

Fig. 1. Robot arm in the lab.

1.3 Data analysis

The qualitative analysis of the interview transcripts and the reflection reports revealed a codebook following a content analysis method [8]: 1) initial screening of data, 2) identifying themes and codes based on repetition and relatedness, and 3) finalizing the codebook with frequencies and percentages.

2 RESULTS

The results were sumarized in three categories: (a) individual factors (31%), (b) team factors (29%), and (c) contextual factors (40%).

For individual factors, findings revealed that *lack of pre-knowledge of control theory* (61%) acted as a barrier for multidisciplinary teamwork. ME students had to explain AP students about control theory in the first weeks of the course. Although the results indicated that *using online course materials* (17%); the lectures and videos on the course learning management system; Canvas was helpful in improving the necessary knowledge, the knowledge gap between AP and ME students were frequently addressed. An exemplary response was: *"AP students could catch up with the knowledge at the end of the project that let more ideas…Similar level of knowledge would have saved some time for teamwork."* The findings also revealed *prior experiences* (22%), team experience and experience in robotics as facilitators of multidisciplinary teamwork.

For the team factors, *communication* (41%) emerged as a facilitator of multidisciplinary teamwork. The video transcripts demonstrated team members' comfortably expressing their ideas and asking questions. *Exchange of disciplinary perspectives* (28%) between AP and ME students was suggested as another important facilitator of successful teamwork. One exemplary response was*: "…we were stuck in the methods part….and they (AP students) brought a different view to the project...".* Next, *making presentations* (16%) considering the presence of students from the other discipline facilitated teamwork.

The findings showed *the disciplinary connections of the design challenge* as the most significant contextual factor for successful multidisciplinary teamwork (54%). Results indicated that the design challenge, mainly drawing knowledge and methods from ME compared to AP was a barrier for teamwork. A teacher comment illustrated this point: *"I think the challenge being skewed to ME makes it tough in this case, to really guarantee that you can get the added benefits from both disciplines…"* Finally, *tutor guidance* (26%) is found to contribute by extending discussions where AP and ME students offered different insights.

3 SUMMARY

This work presents novelty by: a) presenting an example multidisciplinary CBL course and b) reporting suggestions on how to better promote multidisciplinary teamwork. An important conclusion is that although the disciplinary connections of the challenge task allowed for an exchange of disciplinary perspectives between AP and ME students, the challenge can benefit from a stronger connection to AP concepts. This suggestion is also related to the identified barrier; a gap on prior knowledge on control theory. The emergence of barriers to multidisciplinary teamwork, such as limited disciplinary connections and gaps in prior knowledge, can also be explained by the first piloting of a newly designed course. An improved understanding of the facilitators of and barriers to multidisciplinary teamwork can enhance the functioning of the teams and thus foster student learning in similar courses.

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PROFESSIONALISING TEACHERS IN GUIDING REFLECTION (SHORT CONCEPT PAPER)

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ABSTRACT

The contemporary knowledge society of the 21st century requires students, among other things, to have the ability to think analytically and reflectively. Research into the disappearance of technical employees from the technical labor market also shows it is important to guide students in their professional identity development, in which reflection of students is crucial. Various studies show however that educational programs and teachers experience difficulty with the effective use of reflection in education. In the project ‘Strengthening reflection in technical higher education programs’, six technical higher professional education programs of two Dutch higher education institutes are working on the improvement of reflection in their programs. Teachers from these teams are also trained in guiding and assessing reflection activities of students. In this current research, the following research questions will be answered:

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1. How do teachers guide students during reflection activities or conversations?
2. How do teachers assess students’ reflection activities?
3. Does the offered training contribute to an increase in skills of teachers with regard to guiding reflection activities of students?

A selection of teachers of the participating teams will be interviewed before and after the training. To assess teachers pedagogical and didactical knowledge and skills, video vignette interviews are used. Vignettes were designed to provide teachers with multiple authentic situations that are prototypical in their teaching context and which are depicted in video captions. Interview protocols were used to elicit teaching interventions and teachers’ rationales and thoughts behind these interventions in the depicted situations.

1 INTRODUCTION

1.1 Background

The labour market is transforming at such a fast speed, that education can hardly keep up with providing the actual knowledge that is needed for certain professions [1]. The present labour market is characterised by technological developments, complex challenges (or so called 'wicked problems'), flexibility and globalization [2]. Institutes for higher education are challenged to educate students in becoming professionals that do not only have sufficient knowledge and skills within a certain specific domain, but are also equipped with broader generic, often called 21st century skills [3]. Parallel to this movement, within these institutes there is an increased focus on personal learning trajectories of students with the aim to provide guidance from a wider perspective, for example by incorporating subjects such as "Bildung" or personal development [4]. Especially within the engineering, science, and technical sector, one of the main problems is the increased number of technical alumni that is not going to work in the sector they were actually educated for [5]. The reasons why students eventually do not choose for a job in this specific sector is not fully clear, but there seems to be an opportunity for providing improved guidance, to help students discover their potentials within the workplace and develop their professional identity. This means that students learn what their own qualities are, who they are, what kind of professional they would like to be, and how they would like to contribute to the labour market or society [2]. To achieve this with students and help them to become self-aware and self-directing professionals, education should stimulate the development of a reflective attitude [6].

1.2 Reflection (skills) and its use in education

The developments described above show, in a wide range, the importance of the use of reflection and the need for development of reflection skills in education. In addition, many authors argue that being able to reflect is a basic and essential skill for (future) professionals and, therefore, for current students [2]. To reflect or to stimulate a reflective attitude is, however, no sinecure. It is a skill that students really need to develop [9]. This means that educational programs should place reflection on the agenda of their curriculum, but also that they need to think about how they can guide the development of reflective skills throughout the study program from year one to year four.

At the same time, research shows that educational programs experience great difficulty in creating an effective learning environment for reflection [8]. Educational programs acknowledge the importance of reflection and use, for example, 'reflective practitioner' in the final goals of their program. However, the concrete design and execution of the concept of reflection differs between programs or is not always clear. Also, current reflection activities often take the form of writing assignments with questions like: 'describe what you learned from the assignment, what can you do better?'. Students often feel these kind of exercises are not relevant and motivating [6;8].

Engineering, science and technology programs experience even more difficulties because they often feel reflection is not easily adopted and implemented in their specific context [8]. Reflection is often designed in such a way that it requires good language skills, which is not always considered appropriate for students from engineering, science and technology programs. Many teachers in engineering, science and technology programs express the need to embed reflection in a concrete way in their programs and make use of reflection activities that suit their specific target group.

The project 'Strengthening reflection in technical higher education programs' addresses these issues; six technical programs from two Dutch institutes for higher education are working together with a project team for the duration of two school years on an improved vision and curriculum regarding the incorporation of reflection in their programs. In addition, efforts are made to improve reflection activities for students and professionalize teachers regarding the necessary guidance skills in order to help their students develop essential reflection skills.

1.3 Current study

The participating teachers of the above mentioned project are also trained in guiding reflection activities of their students. Alongside these training, research is being conducted that focuses on answering the following research questions:

1. How do teachers guide students during reflection activities or conversations?

2. How do teachers assess students' reflection activities?

3. Does the offered training contribute to an increase in guidance or assessment skills of teachers concerning reflection activities of students?Interviews with teachers will provide input for answering these research questions. Data collection is still ongoing at this moment. Therefore, the remainer of this short concept paper focuses on the design of this research.

2 METHODOLOGY

2.1 Participants

Participants come from two universities of applied sciences in the Netherlands. A random selection of four teachers of 3 participating teacher teams (Building & infrastructure, Information technology/ Electrical engineering and Fashion textile & technology) will be interviewed both before and after the training. The teachers voluntarily participated in the training and had different backgrounds in terms of experience with teaching, guidance of students, or the theme 'reflection'.

2.2 Data collection method

To assess these teachers' pedagogical and didactical knowledge and skills in terms of guiding students' reflections, video vignette interviews are used. Four video vignettes were designed to provide teachers with multiple authentic situations that are prototypical in their teaching context. Interview protocols were used to elicit teaching interventions and teachers' rationales and thoughts behind these interventions for the depicted situations. Video vignettes are considered a favourable method to capture the knowledge or beliefs that teachers employ, since they can cover multiple distinctive situations [7]. Moreover, direct and comparable assessments of teachers' knowledge and beliefs can be realised, since the interview protocol require each teacher to respond individually to each of the vignettes.

In developing the vignettes we focused on producing a set of hypothetical teaching situations that are prototypical and critical to teaching reflection skills in the context of science and engineering programs in a higher professional educational setting. In orderto cover multiple authentic situations in the particular teaching context at hand, the scripts for the vignettes were based on commonly occurring problems and prototypical topics with regard to students' reflections,. Each video vignette starts with a short description of the, containing information about a particular critical situation.During the interview, teachers were shown the video vignette one by one. After each vignette they were asked: 'How would you react to this situation?'; 'What would you do?' 'Why?'; 'What do you intend to promote in terms of student learning with your actions?'.

In order to gain insight into how teachers assess students' reflections, a selection of two excerpts from reflection reports was made. During the interview, teachers were asked: 'How would you characterize the quality of this reflection and why?; 'What feedback would you provide to this student and why?; Suppose this excerpt would be the starting point of a reflective dialogue with this student, what kind of in-depth reflection questions would you ask?'.

2.3 Procedure and intervention (training)

The first round of interviews is currently being conducted. After finalizing these interviews, the teacher teams will participate in three different workshops, focusing on guiding individual and group reflection and assessing reflection activities of students. After these training activities, the same teachers will be interviewed again, using the same interview protocol, video vignettes, and reflection report exerpts. Data will then be analysed to investigate whether teachers have extended their skillset in terms of guiding and assessing students' reflections.

3 ACKNOWLEDGMENTS

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FOSTERING UNIVERSITY NETWORKS AND ENTREPRENEURSHIP EDUCATION PROGRAMS: THE CASE OF THE ENTRENEW PROJECT AT IDEAS UPV

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ABSTRACT

A pan-European network of universities connected with a common goal and involving both students and professors can be a strong catalyst for the professional, economic and social development of the university environment that positively affects not only the university itself but also the other agents or actors in its ecosystem. It is also widely recognized that training and education in entrepreneurship constitutes a solid strategic tool for regional development in which both public and private institutions around the world have made large investments over the past years.

The European Project EntRenew in which the Universitat Politecnica de Valencia - Spain (UPV) participates from 2019 is working in facilitating the exchange, flow and co-creation of new knowledge, enabling professors to teach transdisciplinary studies through innovative methods and stimulate synergies between universities and entrepreneurial support systems throughout Europe.

Ideas-UPV, the entrepreneurial service at UPV has a large experience of 30 years promoting entrepreneurship among students and professors. It also participates in different European projects establishing networks and future collaboration opportunities. The design of entrepreneurship education programs aimed at higher education students is also a core area of the service, not only addressing business plans but also the development of entrepreneurial skills.

This work analyses the current results of the EntRenew program and how this and other initiatives of Ideas-UPV have had an impact on the creation of student entrepreneurial ecosystems, fostering cooperation between the actors and establishing connections to the university environments.

1 INTRODUCTION

Training and education in entrepreneurship are elements of vital importance for local development. For this reason, institutions have focused their efforts and investments on this area and in most cases they define themselves as entrepreneurial institutions.

One of the ways to promote this regional development and foster entrepreneurship is by working on European projects, creating networks of universities that collaborate in achieving a common goal, and taking advantage of the talent of their students and teachers. This will have a positive impact on the development of the university itself, as well as on the other agents of its local ecosystem.

Ideas-UPV, the service that has been in charge of the entrepreneurship activities of the UPV for 30 years, participates in different European projects establishing networks and future opportunities for collaboration.

An example of these projects is EntRENEW in which 5 european universities (Pôle Universitaire Léonard de Vinci, France. Halmstad University, Sweden. University of Vaasa, Finland. Leiden University, Netherlands and Universitat Politècnica de València, Spain) have been working since 2019.

2 THE ENTRENEW PROJECT

2.1 Overview

The EntRENEW Project and the sharing of their good practices and the co-creation of new knowledge, aims at promoting a dynamic interdisciplinary perspective that articulates the corporate, scientific, and pedagogical skills and knowledge in renewable energy and entrepreneurship. The project contributes to increasing the capacity of European students in their way to becoming effective entrepreneurs and leaders, enabling them to address the challenges of Europe's future sustainable prosperity and the transition of energy sectors towards decarbonisation (as part of the European Green Deal) [1].

The project answers three major needs:

- The need to train new skills and competences in future MA graduates in business and environmental/energy studies, bridging the knowledge gap in the current HE curricula to answer the demand by new energy businesses.
- The need to increase the use of new and innovative pedagogies in HE to enhance students' motivation.
- The need to enhance the collaboration between European students and the entrepreneurial community

2.2 Methodology

In order to achieve the ultimate goal of creating a blended-learning course on entrepreneurship in renewable energies an exhaustive analysis of the needs of each university was carried out. This work included interviewing students to build a proposal of the most appropriate pedagogical methodology that meet their expectations, while also adapting it to the academic requirements of every partner university.

After this, all the contents of the blended course were developed collaboratively among all the partner universities, sharing knowledge, available academic content, etc. The developed contents consist of videos, presentations for face-to-face classes, gamification, tasks and exercises. At the same time, the contents that the trainers will need to teach the course optimally in each of the universities have been prepared as well as the teacher's guide.

For the online part of the course and for all the gamification that has been created for it, a platform is being developed on which all the necessary content will be uploaded and from which the students will be able to enrol and take the course.

The next steps will be to conduct a pilot test of the course with a series of selected students in each of the universities, to obtain feedback on the content, the materials and the methodology of the course. After the appropriate improvements and the final validation, the EntRENEW course will be officially launched, integrating it into the study plans of all the universities participating in the project, and carrying out the appropriate dissemination actions to attract students to enrol in this course.

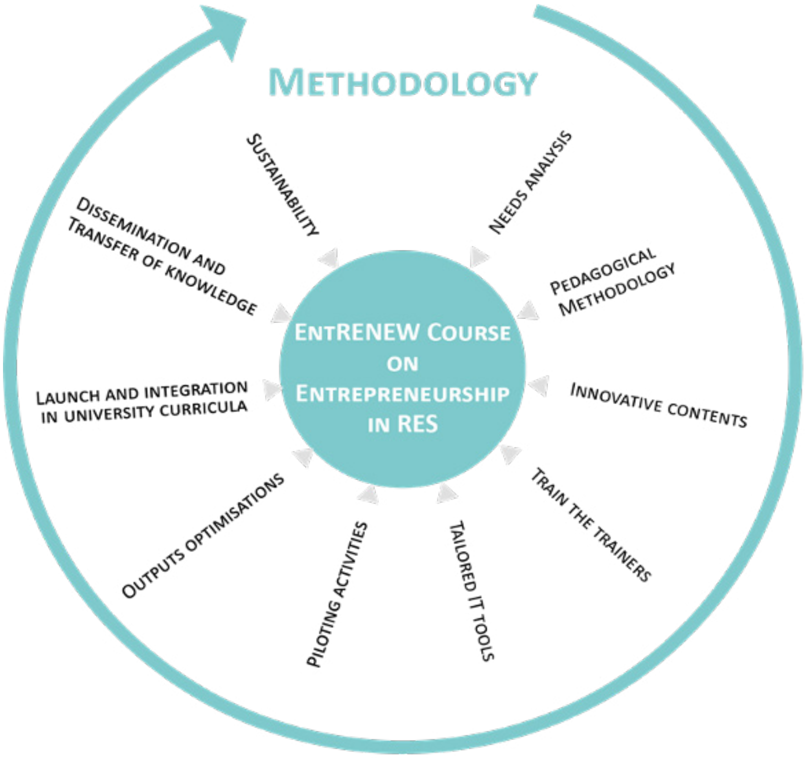

Figure 1. Phases of the implementation

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3 RESULTS

As a result of the work carried out by the universities participating in the project, sharing good practices and the co-creation of new knowledge, a blended-learning course on renewable energies entrepreneurship has been generated as a short term result. This course is divided in different modules and topics:

MODULE 1: Renewable Energy Systems
1. Introduction: Sustainability and the 2030 Agenda 2. The Basics of Energy
MODULE 2: Entrepreneurial ecosystem
1. Background Open Innovation 2. Vibrancy Of An Entrepreneurial Ecosystem 3. The Life Cycle Of The Small Firm 4. Local Entrepreneurial Ecosystems
MODULE 3: Business model innovation and ecosystems in renewable energy

1. Business Modelling (based on [2]) 1.1 Traditional business models Vs Sustainable Business Models 1.2 Card game for Sustainable Business Model (SBM) 1.3 Customer Segments 1.4 Value Proposition (based on [3]) 1.5 Revenue Streams + Cost Structure (cash flow analysis) 1.6 Channels 1.7 Competitive Advantage 1.8 Key Activities + Partnerships 1.9 Business model as source of innovation 1.10 Barriers for developing business models **2. Climate Impact** 2.1 Life Cycle Assessment & Measure reduction in carbon emissions **3. Validation** 3.1 Validation Plan 3.2 Minimum Valuable Product 3.3 Prototyping 3.4 Talking to humans **4. Talking to investors & stakeholders** 4.1 One Page 4.2 Elevator Pitch **5. Marketing** 5.1 Designing a marketing strategy
MODULE 4: Business model innovation and ecosystems in renewable energy
Assignment: EntRENEW Project

Table 1. Modules of the course developed in the project.

The long-term impact of the EntRENEW project will be to create a new generation of decision makers who will explore concrete entrepreneurial solutions in support of EU countries facing the important challenge of maintaining their social and economic performance and being more eco-responsible, especially in the energy sector.

4 ACKNOWLEDGMENTS

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THE IMPACT OF A STEM PARTNERSHIP ON TRANSFORMATIVE TEACHING AND LEARNING

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ABSTRACT

As educators committed to a transformative teaching and learning we need to actively engage with our new generation, promote critical thinking, and share knowledge and skills to promote sustainable developments in order to build that much needed Science Capital. At this moment the UK engineering industry is experiencing two main issues: i) a shortfall of 20,000 graduate engineers per year and ii) lack of female engineers. These two issues are a key challenge that must be addressed to guarantee a sustainable economy. To pursue these goals a STEM partnership between Glasgow Caledonian University (GCU), the Royal Navy and six Primary Schools was funded by the Royal Society Partnership Grants scheme. In this project GCU's students worked collaboratively with 250 primary pupils from age 8 to 11 on the design and manufacturing of a Luge start ramp. Different workshops related to design, manufacturing, mechanical properties, welding and beyond were delivered by the STEM partners, while the pupils provided ideas to enhance the ramp's design and teachers reinforced the topics prior and after each workshop. The

project enables the evaluation of aspects related to the impact of actively involving young pupils in an engineering real life problem, making them act as engineers, and their change in perception towards Engineering. Other aspects that will be analysed are the impact of positive role models not only on the pupils but on pupils' influencers (teachers and parents), as well as the inclusivity and diversity as part of the commitment to a transformative education.

1 INTRODUCTION

The UK engineering industry is facing a shortfall of 20,000 graduate engineers per year and lack of female engineers, issues that must be addressed to guarantee a sustainable economy [1-3]. However, to achieve a sustainable economy it is essential to invest in education in order to develop Human Capital in general [4] and more specific Scientific and Technical Human Capital (STHC) [5]; this is clear from the UN Sustainable Development Goals, outcome 4.7 which states that all learners should receive education to develop their knowledge and skills to promote sustainable developments [6]. On the other hand previous research has highlighted that the development of science capital should start at primary levels where sustainable approaches to primary science education are essential [7-8], together with the importance to develop meta-skills that include problem-solving, critical thinking, communication, creativity and leadership in order to thrive in the 21st century fast changing environment at economic and social levels [8], and all this is possible through a Transformative Education [9-10].

2 RATIONALE

One of the factors that aggravates skills shortage in engineering is the lack of role models [11] specially in deprived areas where the lack of facilities, lack of resources and lack of opportunities are amplified [12]. In order to stimulate and inspire new generation in the areas of Science Technology, Engineering and Maths (STEM) it is key to engage them with positive role models specially in underrepresented sectors where they are less likely to choose STEM subjects [13-16].

Glasgow Caledonian University have been ranked amongst the top 50 universities in the world for social impact and top 12 for gender equality and reducing inequalities [17]. As part of the commitment to the community and to increase the amount of girls in our engineering programmes our students are provided with the opportunity to be involved in different public engagement events, to not only introduce to the community the different aspects involved in engineering, but to act as role models to inspire the new generation. The opportunity to be involved in a collaborative project together with primary pupils will benefit univerisity students and primary pupils by allowing them to develop meta-skills through the participation and engagement in a real life engineering problem-solving activity with the help and support of all the STEM partners.

3 METHODOLOGY

A STEM partnership between Glasgow Caledonian University (GCU), the Royal Navy and six Primary Schools from varied demographic and SIMD (Scottish Index of Multiple Deprivation) was funded by the Royal Society Partnership Grants scheme. [18]. The Project entitled *The Olympic GB Luge team need a Luge starting ramp! Can pupils across Renfrewshire create the perfect design?*
The project entailed four GCU MEng mechanical engineering students being matched with 250 pupils from P4-P6 (ages 8-11) to Design and Manufacture the Luge Starting Ramp requested by the Royal Navy Luge Team .

The activity took place over a period of 10 months. Table 1 shows the activities led by each STEM partner involved.

Table 1. Activity delivered by the STEM partners involved and purpose

Partner	Activity	Purpose
GCU MEng Students	Workshops related to design, materials selection, material properties and welding.	Provide an understanding on factors that engineers need to consider during the design process with the aim that pupils could contribute on the enhancement of the ramp's design
Royal Navy Luge Team	Workshop related to Luge Sport and Winter Olympics	Awareness of Luge Sport and Winter Olympics. Development of competition skills
Royal Navy STEM Team	STEM workshops	Awarness of different types of engineering. Hands on activities in electrical circuits, coding, pneumatics, application of technology in submarines etc.
Teachers	Introduction and reinforcements	Optimal angle of the track to increase speed, effect of friction, testing materials, etc

The project was divided in 6 main stages as observed in Table 2

Table 2. Stages of the project

Stage	Description
1	Delivery of questionnaires to pupils, parents and teachers- before the project
2	Introduction of STEM partners to Primary Pupils- roles
3	Development of pupil's understanding in different topic-workshops- setting up challenges
4	Handover of the ramp- Visit to University-showcase the labs/workshops for the manufacturing of the ramp
5	Delivery of questionnaires to pupils, parents and teachers- after the project
6	Comparison and analysis of outcomes from questionnaires

4 RESULTS AND DISCUSSION

The STEM partnership provided the opportunity to bring positive role models to schools pupils, teachers and parents as part of a transformative education to build on meta-skills. The developed activities allowed pupils to work collaboratively, exchange knowledge, increase communication skills and apply critical thinking as part of the skills required for future career path ways, while observing further education at primary levels. A brief description of the impact on each participant is provided below.

4.1 Impact on Pupils

The project has allowed learners to develop their STEM skills whilst making links to further education and STEM careers. This is in agreement with previous research [14-15]

Pupil's quote: *"I have loved working with GCU students and the Royal Navy. Designing the luge for Team GB and getting the chance to try welding has been very cool."*

4.2. Impact on Teachers

The project has increased teacher confidence in teaching STEM as they have worked alongside STEM professionals from Glasgow Caledonian University and the Royal Navy. This collaborative and mutually beneficial approach has increased teachers' knowledge and engagement in the engineering element of STEM.

Teacher's quote: *"Every pupil has thoroughly enjoyed all aspects of the learning they have experienced. The unique opportunity to work with GCU and the Royal Navy has given pupils an insight of what it might be like to study STEM and to work in a STEM career in the future. It has certainly created a buzz around STEM in the classroom."*

4.3. Impact on Parents

Parents have commented on the fact that their children have the exciting opportunity to engage with universities whilst in primary school. This has allowed us to explore and tackle perceptions around university and highlight that a career in engineering in accessible whilst pupil engagement and interest increases in that field.

Parent's quote: *"My child hasn't stopped talking about all the class lessons/experiments and visits from GCU and the Royal Navy. I know when he has completed a task on the Luge project because he can't stop talking about it when he gets home!"*

4.4. Impact on MEng students

Students have mentioned how rewarding and satisfying the experience has been to be seen as role models to underrepresented sectors in general and to be able to engage with them by learning to use a simplistic language to communicate engineering concepts and provide the necessary information to interact with a young audience while keeping them engaged in the topic.

MEng student's quote: *"The STEM outreach program has impacted me on both a professional and personal level. Being able to impact the lives of young children is an incredible opportunity, and one in which I am proud to say I have been involved in. On a professional level, I have loved being involved in the outreach program. The positive experience and impact of the partnership and program has motivated me to pursue similar routes of STEM outreach and is something that I will endeavour to be involved in as I start my next chapter in engineering, post-graduation".*

5 CONCLUSIONS AND FURTHER WORK

- The value in outreach work between schools and university/industry cannot be underestimated as it widens learner perspective on engineering, and cultural capital whilst demonstrating the impact learners can make upon society through STEM skills
- Collaborative STEM projects allow everyone involved to develop/enhance meta-skills which will support learners to thrive in any environment (Social/educational/professional).
- This is an ongoing project and surveys to assess the quantitative impact before and after the project concludes will be conducted.

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ENGINEERING ETHICS EDUCATION FOR SYSTEMIC CHANGE: A CASE FOR SUB-SAHARAN AFRICA

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ABSTRACT

Unlike in the West, engineering practice in Sub-Saharan Africa remains mired in corruption, ethical malpractice, poor ethics governance and lack of effective leadership. This situation has, and continues to, negatively impact national infrastructure, health, education, and economies across Sub-Saharan African countries. Non-ethical engineering practices continue to occur despite the existence of national ethics legislation in Sub–Saharan African countries, and despite codes of ethics underpinning business operations in most public and private sector organisations that employ engineers. This is also despite the existence of codes of conduct and ethics prescribing professional engineering practice that have been developed, and are policed, by national engineering institutions and regulators. Increasingly, engineering education providers have incorporated engineering ethics education in their curricula. However, despite this, Sub-Saharan African engineering graduates transitioning into employment still face significant difficulties in dealing with the myriads of ethical dilemmas they meet in their professional practice. In this study we set out to establish the current state of engineering ethics education in Sub-Saharan Africa, and to assess the thoughts of engineering educators and researchers in the region on how engineering ethics education can be improved.

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1 INTRODUCTION

Throughout Sub-Saharan Africa, governments and ordinary people are increasingly becoming aware that unethical conduct by engineering practitioners has financial, social, and health and safety implications [1]. For instance, in 2016 an online news site linked some construction disasters that had taken place in Nigeria, Kenya and Ghana to unethical practices by the professionals responsible for implementing the construction works [2]. Examples cited by the publication include the collapse of a church building in Nigeria in 2014 that led to 115 deaths, and the collapse of a six-storey building in Kenya that resulted in three deaths. The publication concluded by suggesting that unethical practices are behind most engineering failures in Africa [2]. A 2010 study on building collapses in Nigeria suggests that approximately 40% of all building collapses are due to professional incompetence and fraudulent practices [3].

All the Sub-Saharan Africa countries that we looked at had codes of professional ethics that govern the professional practice of their engineers. These codes of professional ethics are comparable to Western codes of ethics, for example the IEEE Code of Ethics [4]. All these countries have legal frameworks that govern the conduct of professionals and they have institutions whose role is to enforce the legal requirements demanded for their professional practice. However, corruption and ethical misconduct are well entrenched, and often involve powerful individuals and organisations, which makes it difficult to resolve these issues.

Given the relative intractability of professional and ethical malpractice, a number of educators and researchers are exploring the possibility of ethics education as a tool to address the problem of ethical malpractrices in the long term. This includes Asheshi University College Ghana, whih was launched in 2002 with a mission to ‘educate a new generation of ethical entrepreneurial leaders’ [1].

In this study, we set out to explore from published works on engineering ethics education how the subject is currently being taught in higher education institutions in Sub-Saharan Africa.We also sought to establish from the identified published works what engineering ethics educators and researchers in Sub-Saharan Africa think should be done to improve engineering ethics education. We used the following research questions to frame our study:

1. How is engineering ethics education currently being delivered in Sub-Saharan Africa?
2. What do engineering ethics educators and researchers think should be done to improve the teaching of engineering ethics education in Sub-Saharan Africa?

2 METHODOLOGY

Guided by our two research questions, we carried out a semi-systematic literature review [5] to establish the current state of engineering education ethics research in Sub-Saharan Africa. We did this by carrying out searches in Google Scholar and Engineering Village. We identified two key search terms from our two research questions. These are “engineering ethics education” and “Sub-Saharan Africa”. We took a sample of nine English-speaking Sub-Saharan African countries covering West Africa (Nigeria, Ghana, Sierra Leone), East and Central Africa (Uganda, Kenya, Tanzania), and Southern Africa (South Africa, Zambia, Zimbabwe). To cover these countries, we used the following search string on both databases:

“engineering ethics education” AND (Africa OR Ghana OR Nigeria OR Sierra Leone OR South Africa OR Tanzania OR Kenya OR Uganda OR Zambia OR Zimbabwe)

Running the search string gave us 142 potential publications. We then weeded out those publications whose titles were not consistent with our research questions, giving us 37 publications. Reading through the abstracts of these 37 publications led us to whittle down the number to 12.

3 RESULTS

Table 1 lists the publications that were identified in this study, together with the total number of researchers that we identitifed in each country.Only three countries are represented as our search could not identify any publications from the other six countries.

Table 1. Engineering Ethics Education Publications identified in this study

Country	Number of Publications	Number of distinct authors
Nigeria	3	7
South Africa	6	11
Ghana	3	7

3.1 Nigeria

Reference [6] is a review of ethics teaching in a software engineering course at the University of America in Nigeria. The review concludes that regardless of whether ethics is taught as a standalone course or embedded in other modules:

- Industry partners should be invited to present guest lectures on the specific ethics relating to their industry

- Industry partners should support higher education institutions in aligning their curricula to current and professional ethical concerns and how these concerns could be addressed and implemented in the workplace.

The authors of the review also suggest that rather than restricting ethics education to a single dedicated course, usually in the final year,ethics education should be embedded in course modules throughout the degree programme, and this should lead to a dedicated ethics course in the final year focussing on current ethical issues within the discipline.

Reference [7] presents a survey of ethical practices in the Nigerian construction industry that was admistered to final year civil/structural engineering students at the University of Benin. In line with the curriculum, these students had undergone three months of industrial attachment in the construction industry each year from the first to the third year and six months industrial attachment during the fourth year.Findings from this survey collaborate an earlier study of practising construction industry professionals [3] which found that unethical professional practice was the norm within the Nigerian construction industry. 50% of the surveyed students believed that it was OK for engineers to have vested interests in the projects they were advising on, thereby suggesting that they found nothing amiss with some of the unethical practices in the industry. To address this situation, the authors suggest

- all practising engineers should go on reorientation programmes on ethical practices
- the existing curriculum should be reviewed to place an emphasis on ethics
- Nigerian society needs to be reorientated to undergo mindset changes.

3.2 South Africa

Reference [8] is an analysis of ethics education within software engineering programmes offered by South African universities of technology. The study revealed that coverage of engineering ethics within computing qualifications is insufficient, incomplete and superficial, and provides only limited opportunities for students to develop software engineering ethical competence [8]. Another study by the authors finds that the majority of software engineering educators (54.5%) are not aware of the prevailing ethics codes in the software engineering industry, and as a consequence, coverage of the codes in teaching is minimal, and lecturers often fail to apply the codes practically during their teaching [9].

A survey of engineering ethics educators at two South African universities also revealed that whilst ethics education was viewed as important, ethics educators had different understandings of what should be covered in ethics courses [10]. Few of the engineering programmes explicitly highlighted ethics in learning outcomes or assessment procedures, and educators felt that they did not have the skills to teach the subject. The authors of the study subsequently suggested that engineering ethics educators needed more support to master their subject. In another study, the same authors also advocated the repositioning of ethics within the engineering curriculum as a transdisciplinary area that provides context and rationale for the selection and practice of technical skills and knowledge developed in the discipline [11]. The authors suggest that such an approach will help to bring ethics from the periphery of curriculum design consideration to a position where ethics is viewed as the basis by which engineers make the necessary technical, mechanical and process choices in pursuance of their professional and ethical responsibilities and obligations. The authors believe that this strategy is best implemented by integrating ethics in engineerign education at the accreditation level to ensure that ethics is properly embedded within the curriculum.

Reference [12] makes the observation that in South Africa engineering programmes tend to teach ethics in an isolated module on "Professional Practice" which is mostly covered in the the final-year. The paper argues that ethics education could be improved by nurturing and discussing ethical behaviour throughout the undergraduate degree. However, the authors also indicate that the promotion of individualism within modern day society mitigates against ethics education, and suggest that a communitarian approach which emphasises the 'good for all' may provide a better learning environment. Such a proposal chimes in with proponents of ethics education approaches based on African communitarian philosophies such as ubuntuism [13].

3.3 Ghana

Reference [14] describes the architecture of engineering programmes at Asheshi University College Ghana. This architecture places an emphasis on ethics, leadership and civic engagement in addition to the typical science, mathematics and engineering courses found on traditional engineering programmes. This includes dedicated ethics courses, as well as a Code of Ethics and an Examination Honour Code.

First year students are also required to attend a not-for-credit seminar entitled 'Giving Voice to Values' where they learn ethical skills through role play and real case studies based on the experiences of the university's alumni [1]. The university believes that this focus on ethics and leadership will help to develop graduates who are more inclined to behave ethically in their professional roles. The effectiveness of this approach is still to be evaluated, however a study on the ethical attitudes of accountants carried out within the context of Ghana indicated that curricula that place an emphasis on ethics education have a positive effect on graduates' ethical behaviour and attitudes [15].

4 CONCLUSION AND FUTURE WORK

This study set out to identify research on engineering education ethics from countries in Sub-Saharan Africa. Nine countries in which English is an official language were identified. These countries ranged from West Africa, through Central and Eastern Africa down to Southern Africa. Most of the work identified in this study comes from South Africa, Nigeria and Ghana. This highlights the challenges of accessing published works from Sub-Saharan Africa focussing specifically on engineering education ethics, as is the case with this study, and more generally on engineering education research.

In our thinking, there are three possible reasons for this, the first one being the likelihood that Sub-Saharan African reseachers in engineering education, in general, and in engerering ethics education in particular, tend to target regional and local journals and conferences that are not covered by Google Scholar and other mainstream research databases. Another possibility might be that Sub-Saharan African researchers may be prioritising technical engineering research at the expense of engineering education research. A third possibility may be that most African higher education institutions prioritise education at the expense of research, and high teaching workloads preclude many academics from research and publication. From our own experiences, we believe that all three factors contribute to the lack of visible publication on engineering education ethics from Sub-Saharan Africa.

Given the limited number of publications identified in this study, we intend to identify and collaborate with engineering academics who teach on ethics course modules in the nine countries that we identified. The advent of social media platforms like WhatsApp and video conferencing tools like Zoom has made networking across Sub-Saharan Africa easier, as evidenced by the recent establishment of the Engineering Education Research Network-Africa (EERN-Africa). We intend to use these platforms, alongside EERN-Africa, to identify and connect with Sub-Saharan Africa academics teaching and researching on engineering education ethics.

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Evidence-Based Practice to the Forefront: A Case Study of Engineering Team Project-Based Learning in an Online Learning Environment

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ABSTRACT
Approaches such as problem and project-based learning (PBL) are the cornerstone of modern engineering curricula. With a growing need to move these student-centred active learning curricula to online and blended learning environments due to issues including increasing cohort sizes and limited budgets, it is essential that instructional designers in engineering education understand the impacts that these differing mediums may have on student collaboration. This study is the beginning of a body of work with the aim to develop effective teaching and learning strategies for team project-based learning in online and blended learning environments. This case study was carried out in an Irish university in 2021 in a first-year engineering module during the COVID-19 pandemic. The study followed an explanatory mixed methods design in which a questionnaire and semi-structured interviews were utilised to collect data. The research data was gathered in two phases. Phase 1 included a questionnaire with both closed- and open-ended questions (N=94). Phase 2 was based on semi-structured interviews (N=7). This paper will focus on the qualitative datasets, including the open-ended questions and interviews. After completing a thematic analysis, we identified six themes and eighteen sub-themes that affect students' perceptions of team project-based learning (PBL) in an online environment. Each of these themes are discussed within this paper. The paper concludes with an outline of future research plans for the ongoing project.

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1 INTRODUCTION

1.1 Overview

As a consequence of the COVID-19 pandemic and the growing need to deliver high-quality, student-centred engineering education to large and diverse student cohorts [1], interest in blended and online learning has increased significantly worldwide. Active and student-centred learning strategies such as problem and project-based learning (PBL) has been researched extensively in traditional on-campus environments; however, research on effective PBL implementation in online environments, especially in engineering is still emerging. With the rushed implementation of online and blended learning approaches during the COVID-19 pandemic, the need for a body of evidence-based pedagogical practices in PBL has been highlighted [2], [3]. In this paper, we argue that to begin developing evidence-based pedagogical guidance for engineering practitioners, researchers first need to explore students' perceptions of PBL in online environments. This process can identify both success and limitations perceived by the students in current strategies. These successes and limitations can then inform practitioner design decisions when implementing team PBL in online and blended learning environments.

1.2 Research Question

What factors affect 1st year students' perceptions of team PBL in an online environment?

2 METHODOLOGY

2.1 Overview:

This study was carried out at an Irish university over an academic semester in a first-year engineering module. The study follows an explanatory mixed methods design where quantitative and qualitative data were used to inform participant interviews. The quantitative data was gathered with the use of a student's attitude and satisfaction survey, Phase 1 (N=94). The qualitative data was gathered with the use of open-ended questions, Phase 1 continues, and a semi-structured interview, Phase 2 (N=7). In this paper, we report on the qualitative datasets and the results identified from the thematic analysis of this data.

2.2 Data Analysis

A six-phase inductive thematic analysis approach was undertaken to investigate both the open-ended questions and semi-structured interview datasets [4]. The main goal of the thematic analysis was to identify potential factors (Themes) affecting students' perceptions of team PBL in an online environment. All data from the open-ended questions and semi-structured interviews were uploaded to NVivo; however, the process was carried out with a mixture of both physical and digital documents to help identify all relevant codes, themes, and sub-themes.

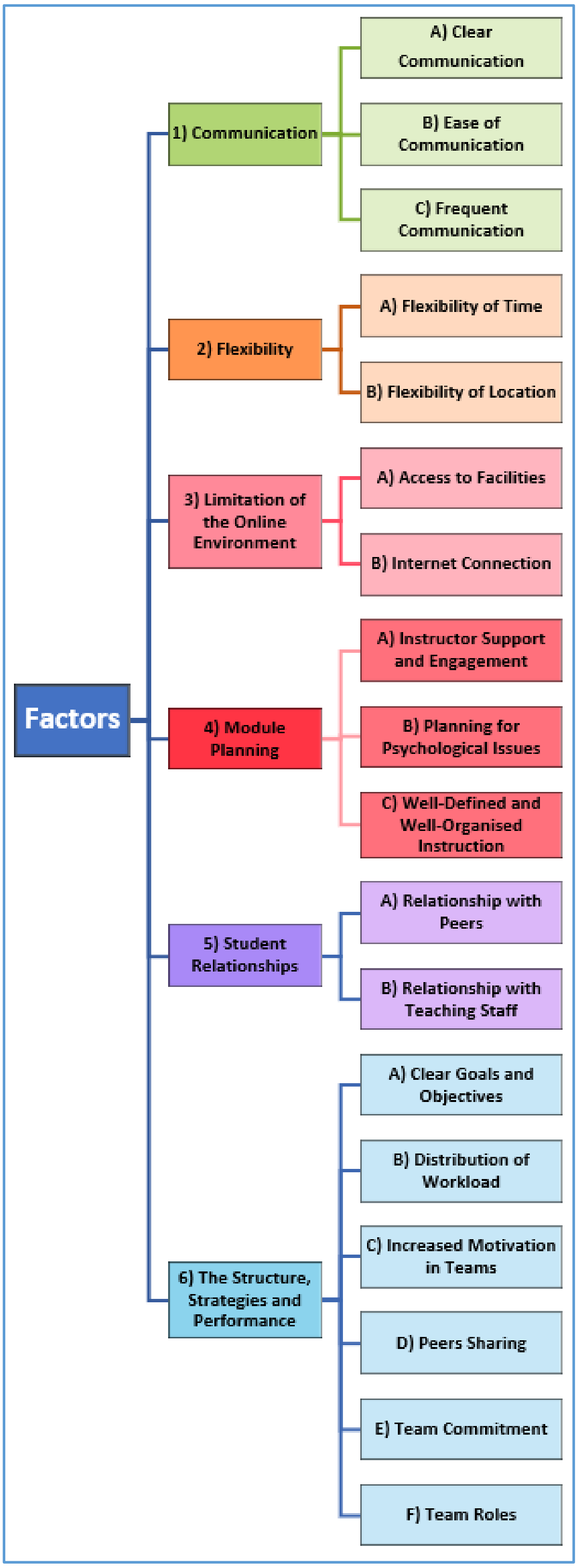

Fig. 1. Thematic Analysis Flow Diagram

3 RESULTS & DISCUSSION

3.1 Overview

Overall, the thematic analysis revealed that the participants demonstrated high satisfaction levels within their open-ended questions and interview responses within the module. However, we were able to identify several themes and sub-themes through the successes and limitations of the online format as perceived by students.

The following six themes and eighteen sub-themes, shown in Fig. 1, were identified to affect students' perceptions of team PBL in the online environment. The next section, 3.2, will discuss each theme and associated sub-themes in detail.

3.2 Themes and Sub-Themes

Theme 1: Communication (Student to Student and Student to Teacher): Communication was the second most common theme of discussion by students in both the open-ended questions and semi-structured interviews. It was clear from student responses that effective communication between student to student, student to teacher, teacher to student, teacher to teacher is essential for team PBL success within the online environment. Three sub-themes emerged from the data, including A) clear communication, B) ease of communication and C) frequency of communication. Although many comments were made referring to communication, students' main point of concern was the ease of communication. Students felt that their ability to communicate ideas with team members was limited in the online environment when compared to the traditional on-campus environment: (P.20) *"It is hard to fully explain and demonstrate ideas and concepts online, and I believe I would have a greater* *understanding by being explained there in person"*. Research suggests, many factors are shown to affect student performance in teams, while one of the most effective for improving it is the ease of communication between team members [5].

Theme 2: Flexibility of Online Environment: The increased flexibility of the online environment was seen as an improvement by many students. Two sub-themes under flexibility of the online environment emerged from the data, including A) flexibility of time and B) flexibility of location. One student stated how the increased flexibility was one of the benefits of working online: (P.19) *"I liked it in the sense I didn't have to actually set time aside to travel and meet the team". Increased flexibility is often highlighted to be a positive impact of online education*". Students, in general, perceive that online learning allows for more effective use of time than traditional on-campus courses [6], [7].

Theme 3: Limitation of the Online Environment: The students outlined two main limitations to teaching and learning in the online environment. These two limitations include A) access to on-campus facilities and B) poor internet connection. During the COVID-19 pandemic students were unable to access many of the on-campus facilities such as the university library, meeting rooms and workshops due to governmental restrictions. A few Students felt that limited access to the workshop impacted them negatively: (P. 27) *"we weren't able to go into the workshop […] mess around and create prototypes of the car […] we couldn't modify it in case something was wrong".* A lack of access to facilities in online engineering education is also shared in other publications [8]–[10]. Students also highlighted concerns around poor internet access: (P.23) "There are still drawbacks with online as not everyone can take a call or a live meeting due to internet issues". This concern is also shared by many other students working in online and blended learning environments [7], [11].

Theme 4: Module Planning: Three sub-themes were identified under the theme module planning. These sub-themes included A) instructor support and engagement, B) planning for psychological issues such as increased anxiety and decrease in motivation and lastly, C) well-defined and well-organised instruction. Most frequently, under this theme, students expressed the need for well-defined and well-organised instruction. When one student was asked to provide advice to the module leader planning a team-based project online he recommended: (P. 89) *"Always start on the right foot, start early and communicate roles effectively and clearly, and set deadlines and timelines for things to be finished at".* This also aligns with the finding of Ku et al.'s [12] publication on online collaborative learning. Ku et al.'s findings indicate that students expect instructors to provide a supportive collaborative learning environment and deliver well-defined and well-organised instruction for students.

Theme 5: Student Relationships: Two sub-themes emerged underneath the theme entitled student relationships. These sub-themes were A) relationship with peers and B) relationship with teaching staff. Students regarded making and maintaining good relationships with peers and staff member to be of high priority. Students had both positive and negative feelings towards building relationships in the online environment. Students felt that the team-based project gave them an opportunity to develop friendships that weren't usually possible in less collaborative modules: (P.1) *"it helped* *me to make friends and to communicate with my classmates in a way that hasn't been possible through online learning".* However, some students felt that the online environment in general made forming relationships with peers and teaching staff harder. This can be seen in the responses given by participant 21 and 27: (P.21) *"On campus also allows you to build a personal relationship and not just a professional one"* (P.27) *"I would have gotten to get know my group members better and been able to be more interactive with my teachers"*. Stenman [13] highlights that students perceive online courses as a negative experience when they feel a large transactional distance between instructors and their peers. She adds that online students view others as a number on a list rather than individuals, and this issue can influence whether a student will stay in or drop out of a course.

Theme 6: Team Structure, Strategies and Performance: Team structure, strategies and performance was the most common theme of discussion by students in both the open-ended questions and semi-structured interviews. Six sub-themes emerged from this theme included A) clear objectives and goals, B) distribution of workload, C) increased motivation in teams, D) peers sharing perspectives', experience, information and skills, E) team commitment and finally F) team roles. The most discussed sub-theme by student was peers sharing perspectives, experience, information and skills. The following comments highlight some of the sharing experienced by students: (P.48) *"everyone brings something else to the table and we had ideas that others came up with that I wouldn't have gotten myself"* (P. 1) *"I would have struggled with the maths and mechanics of the project had it not been for my teammates"*. This coincides with the findings presented by Volkov and Volkov [14] who found that students reported they attained deeper understanding through the sharing of students' skill sets while participating in teamwork.

4 CONCLUSION

4.1 Summary

Students' perceptions of courses influence the likelihood of success or failure when working online. It's reported that satisfied students are more likely to be successful in the online environment [15], [16]. This paper outlined multiple factors that instructional designers in engineering education need to consider that can affect students' perceptions of team PBL in online environments. Each of the factors (themes) outlined in the thematic analysis can be linked back to issues experienced by other practitioners in the field, and as such, solidifies the importance of planning for teaching and learning with theses factor in mind.

5 LIMITATIONS:

It should be noted that data for this paper was gathered during the COVID-19 pandemic and that students were experiencing many changes to everyday life in Ireland due to heavy governmental restrictions. This change in lifestyle may have affected students' responses during both the open-ended questions and interviews.

6 FUTURE RESEARCH

This conference paper is part of a larger body of research on team PBL within the online and blended learning environment. The project is conducted following an explanatory mixed methods approach were both qualitative and quantitative data is used to inform the results and discussion. The data for the project is gathered in two rounds, in the same module, one within the online environment (2021) and the second within the traditional on-campus environment (2022).

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ENGINEERING STUDENTS' MOTIVATION FOR LEARNING IN CHALLENGE-DRIVEN PROJECT COURSES: A QUALITATIVE PILOT STUDY

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ABSTRACT

This pilot study explores engineering students' motivation for learning and studying through the lens of Self-Determination Theory (SDT). Five postgraduate students from a research-intensive Swedish university participated in semi-structured qualitative interviews about their study experiences from different Challenge-Driven Education (CDE) courses. It adds to the limited, existing literature on CDE and is the first to study it from a purely motivational perspective. As this is a pilot study, the primary intent of the data analysis concerns the first two phases of Braun and Clarke's (2006) thematic analysis approach - familiarisation and immersion in the data and generating initial codes. A combination of inductive and deductive approaches to analysing the data were used, and preliminary motivational factors emerged from the interviews are illustrated according to the SDT concepts. A variety of motivations for learning and studying, such as innovation, real-world problem solving, contribution to the society, and trial for following master thesis projects, emerged from the data and positioned on the self-determination continuum in which different types of regulations are guiding students' behaviours simultaneously. Furthermore, autonomy in the choice of a project, feedback and assignment deadlines, and relationships within group work, enhanced or/and undermined the three psychological needs defined by SDT; autonomy, competence and relatedness. Preliminary findings are discussed in relation to the SDT literature, and practical applications are suggested for supporting the motivational needs of engineering students. Finally plans for a continuation of the study are discussed in light of this initial phase.

1 INTRODUCTION

There is emerging interest in learning approaches where students are collaboratively engaged across disciplines in open-ended projects that concerns complex real-world issues and interaction with various external stakeholders. Such learning approaches can for example be referred to as challenge-driven education 'CDE', challenge-based learning 'CBL, or problem- and project-based learning 'PPBL (e.g. [1], [2]). There have been attempts made to define some of these concepts (e.g. [3]), still there are large differences in how each of these concepts are being interpreted and implemented (e.g. [4]). There are also many implementations of such learning approaches that are not explicitly associated with any of these terms and concepts. These differences and the lack of definitional clarity do however not pose any barriers to exploring features and key concerns that these learning approaches have in common. One such feature is the opportunity in these learning approaches to enhance students' motivation for studying and learning.

In this pilot study, self-determination theory (SDT) [5]&[6] is used as a lens for exploring factors that facilitate or undermine the motivation for studying and learning among students engaged in these kinds of learning approaches (for simplicity hereafter referred to as challenge-driven education, CDE). A qualitative methodology has been used to investigate the following research questions:

(a) What are the motivational factors that guide students engaged in CDE?

(b) How do they relate to the SDT self-determination continuum?

(c) How are the needs for autonomy, competence, and relatedness, as defined by SDT, experienced and fulfilled among engineering students engaged in CDE?

2 METHODOLOGY

2.1 Participants

Five students in three different CDE courses were engaged on voluntary basis as a response to an invitation to participate in this study; three students in a course named Innovations for *Emerging Cities*, one student in the course *Ergonomics in Challenge-Driven Product Development*, and one student in the course *Innovation and Product Development*. The small number of participants is of course a limitation not allowing for data saturation. It should however be noticed that this is a pilot study with the purpose of enabling the researcher to practise the interviewing techniques and investigate the appropriateness of the interview questions as preparation a larger following main study.

2.2 Study design and Data analysis

Semi-structured interviews were constructed, conducted and analyzed in conformity with two methodological approaches: (1) thematic analysis, providing an inductive process, coding the content of the data in order to reveal emerging themes [7]. Specifically, the first two phases of Braun and Clark's [8] thematic analysis approach followed: (a) reading and familiarisation of the data; (b) taking note of items of potential interest which seemed relevant to the research questions; (c) coding; (2) theory-driven analysis [9], analyzing the data in a deductive process, relating the content to SDT concepts, observing arguments with SDT, enhanced by remarkable aspects portrayed by the pilot study's participants. The design of the interview protocol is informed by these approaches, which included both general questions regarding learning and studying motivation and specific questions relating to SDT constructs.

2.3 Interviews

In this pilot study, the coordination of the recruitment process was held by the first author and a co-author, four interviews were carried out by the first author, and one interview was conducted by both the first author and a co-author to strengthen the trustworthiness. The interviews took place online through Zoom agreed upon with the student. Each online interview lasted approximately 45-60 minutes, and all participants were interviewed in English. All interviews were audio/video recorded and transcribed verbatim for analysis.

3 FINDINGS

Two major categories emerged from the data. The first category gives a preliminary insight to the first research question — what are the motivational factors that guide CBL students in their studies? It focuses on motives that the students argued for studying a CBL course. Subsequently, answering the second research question, four motivational factors were identified and positioned progressively along the self-determination continuum [5]-[6], from the most extrinsically regulated behavior, to more self-determined behavior. The second category corresponded with the psychological needs described by SDT and with the third research question, examining how the needs for autonomy, competence, and relatedness are experienced and fulfilled by engineering students in different CBL courses. The categories and representative quotes are illustrated in Fig. 1.

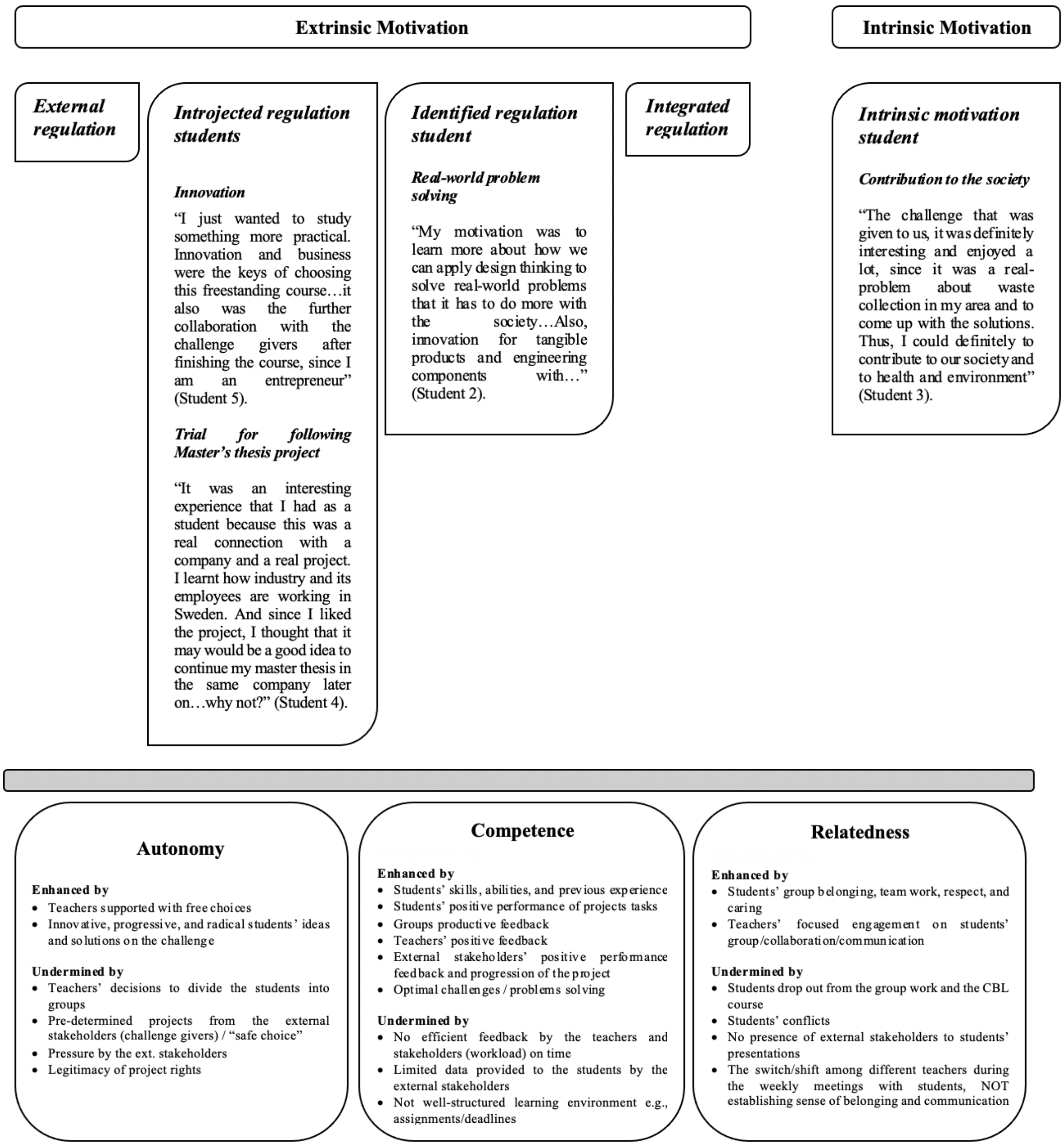

Fig. 1. Emerging categories and quotes, positioned along to the self-determination continuum [5]-[6], and in relation to the three psychological needs postulated by SDT

4 DISCUSSION

A variety of motivations for studying a CBL course emerged from the data. Innovation and further collaboration with the external stakeholders were motivations for studying CBL courses by an entrepreneur student. Additionally, a student who included a CBL course for his studies argued that it would be a good opportunity for doing a Master's thesis in the same company which collaborated with during the course. According to SDT, these externally regulated reasons for studying and learning fit the common definition of introjected regulation, depending on internal rewards of self-esteem for success [6].

Another student argued that the design thinking construct of the CBL course motivated to develop problem-solving skills for addressing societal challenges. The experiences shared demonstrate how design thinking, real world problem-solving skills and values of society are internalized to become intrinsically voice identifying with the value of the CBL course activities as an aim for itself, and thus can be positioned within the category of identified extrinsic regulation.

Last but not least, the contribution to society was a motive for a student who studied a CBL course. This student's behavior was facilitated by interest, enjoyment, and engaging of the challenge, and thus can be positioned within the category of intrinsic motivation.

Students related implicitly to all three psychological needs defined by SDT as particularly fundamental of the motivational process: autonomy, competence, and relatedness. Components of all three needs were mentioned as positive factors when enhanced, and negative factors when these needs were undermined.

With regard to autonomy, it is argued that when students experienced a sense of choice, they felt more autonomous, and facilitated their performance in the project tasks, resulting in an increased intrinsic motivation for studying and learning [6]. Whereas research has shown that, controlling teachers' and external stakeholders' behaviors (e.g., using pre-determined project challenges) are negatively related with students' autonomous motivation [10] and are related to an increased frustration of the basic needs across the educational process, and avoidance of challenges [11].

With regard to competence, students' perceptions are agreed with SDT that according to Niemiec & Ryan [12], students' competence supported by teachers' allowance to them to test and to expand their competences and skills; providing them with appropriate tools and performance feedback; offering optimal challenges that students understand, engage, value, and master; and necessary feedback which downplays evaluation promoting students' effectance, providing guides on how to master the learning tasks at hand. Howener, the findings agree with previous research that students and teachers' heavy workload on CBL courses negatively affect students' motivation [9]. Furthermore, according to SDT, when external policies of the external stakeholders [13] and teachers' experienced work overload [14] affect the educational process then negatively associated with both teachers' and students' autonomous motivation and perceived competence.

With regard to relatedness, the findings showed that relatedness was enhanced by students' sense of belonging and connection with teachers and external stakeholders, respect, and caring within their groups work, relating to the CBL courses' construct of team work to encourage them. Relatedness is also highly associated with students' perception of that the teachers genuinely respect and value them, with students besides to internalize and accept as their own the practices and values of those to whom they feel a sense of belonging. Whereas students who experienced a sense of disconnectedness or rejection by teachers or/and other external stakeholders would be argued in this pilot study, are more likely to move away from internalization and intrinsic motivation for learning and continue study [12].

5 CONCLUSIONS

The current pilot study provides a preliminary investigation of students' motivation for learning and studying in different CBL courses. Preliminary findings support the relevance of the SDT framework and lead to practical implications, suggesting not only 'what works' in CBL courses learning practices, but also why certain learning environment adjustments are important, and what motivational needs they serve. All motivational factors that students experienced and presented in this pilot study which undermined the three basic psychological needs should be taken into consideration and eliminated by teachers, CBL educational developers, and external stakeholders. Additionally, all factors that facilitated and enhanced the needs should continue to be flourished in CDE. The included real-world challenges of CDE should continue to bring students 'closer to the real world' [15] increasing motivation and engagement [16] by having an impact on students' lives [17]. However, it also needs to be agreed with the perspective of Ryan and Niemiec [18] that the direction of SDT is to broaden the idea that universities are just about developing skills and competences for some future employment. Instead, in this view they are about developing abilities and attitudes that include enjoyment, curiosity, interest, access to resources and data for transparency, confidence, and empowerment. When universities and teachers embrace such a vision, they can become liberators and help students develop critical thinking they need to use for the transformation of society to be more progressive, productive, and increase human wellness.

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KNOW-HOW TRANSFER IN AN ENTREPRENEURIAL ECOSYSTEM

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ABSTRACT

Universities have a very important role in entrepreneurial education. University students are not only trained in their specific areas, but they are also trained in entrepreneurial skills to lead teams and to develop leading innovations that will be applied into different markets.

Since 2012, the entrepreneurial ecosystem from Polytechnic University of Valencia (Spain), StartUPV, has implemented several education programs for its community, creating a whole learning roadmap with specific training for each stage of the startup. For instance: hypothesis validation, sales funnel, finance, etc. However, one of the main challenges was how to transfer the know-how generated by each startup to the entire ecosystem.

Beyond mentoring some projects altruistically, the need was detected to create a framework in which the entrepreneurs themselves could share their knowledge with the rest of their colleagues in the ecosystem. To this end, StartUPV Academies were created in 2015.

These sessions consist of small training pills, led by a member of one of the startups in the ecosystem, on a variety of topics: a new programming language, tips for creating marketing campaigns on social networks, how to negotiate with investors, etc.

More than 200 entrepreneurs have attended the StartUPV Academies, and an average of 8 sessions have been held per year. In this paper we analyze these programs, including the main conclusions of more than 5 years of implementation.

1 INTRODUCTION

One of the objectives of the UPV is to train its students in entrepreneurial skills at all levels. Specifically, for those projects that access the StartUPV incubator program, an itinerary has been created according to the degree of maturity of the company and the phase of the program in which it is located.

Throughout this itinerary, they receive training on business model generation[1], sales strategy, finances for entrepreneurs[2], business strategy[3], etc.

Moreover, to complement this training provided by the university, entrepreneurs have developed considerable expertise to share with the rest of their peers. This knowledge, enriched by their own entrepreneurial experience, is of enormous value for the growth of the ecosystem.

In this paper, we will present the main initiatives that have been launched in the StartUPV ecosystem to transfer this knowledge among the entrepreneurs who are part of it.

2 TRANSFERRING KNOWLEDGE IN AN ENTREPRENEURIAL ECOSYSTEM

Through the StartUPV program, an entrepreneurial value chain is created where the entrepreneurs themselves nurture each other, enriching the ecosystem as a consequence. In addition, StartUPV entrepreneurs are a reference for all students of the university, serving as an example through the experience gained in the adventure of undertaking business projects.

As part of this entrepreneurial ecosystem, entrepreneurial projects, startups, and companies benefit and take advantage of the institutional support, the services of the UPV, and the whole network of experts of IDEAS UPV.

However, the challenge lies in how to transfer knowledge among entrepreneurs of the ecosystem. For this reason, in 2015, the StartUPV Academies were introduced and, later, in 2016, the mentoring program. With these activities, entrepreneurs contribute other projects with their experience, increasing the value of the ecosystem itself.

2.1 StartUPV Academies – Universal transfer

As the ecosystem grew, the need was detected to find a formula where the entrepreneurs themselves could share their knowledge with the rest of the startups. To this end, StartUPV Academies were created, consisting of short training sessions on a very specific topic of interest to the ecosystem in general.

2.2 Mentoring program – Personalized transfer

The fact that more than 30 startups are housed in the same space means that knowledge is transferred in a natural way. The entrepreneurs themselves generate synergies between them and help each other altruistically.

The problem with this unstructured mentoring is that it does not reach all the teams equally, and the involvement of the parties is not equal. For this reason, StartUPV launched the mentoring program in 2016, in which we match senior entrepreneurs who act as mentors with junior entrepreneurs.

3 RESULTS

3.1 StartUPV Academies

Since 2015, a total of 37 StartUPV Academies have been held on the following topics:

Table 1. StartUPV Academies topics

Branding	Guerrilla LinkedIn; Leadership; How to create a community of FANS of your brand on Twitter.
Marketing & Communication	Growth Hacking; Inbound Marketing; Introduction to SEO; 2-sided user acquisition; Social Media Marketing; Marketing Automation and CRM; Sales Funnel Canvas; Media Relations and Press Releases; SEO for startups: tips to improve your online presence; HubSpot: How to boost your startup using the most powerful digital marketing tool on the market.
Investment & Funding	Crowdfunding; Capital increases: Finances for entrepreneurs; TechTransfer; Tips for applying for the Fundación Repsol Entrepreneurs Fund; Investment Tips.

Product	Machine design and product approval; Product development; Introduction to Meteor.
Legal & Talent	Data Protection Compliance; Legal mechanisms to attract and retain talent. Legal and tax implications; How to attract talent at the UPV; Choose a successful team; Phantom Shares; Attracting qualified personnel; How to interview in selection processes; Legal doubts against COVID-19; How to make customers pay; Structure of a contract. Essential clauses.
Misc.	Stress management; Bitcoins for dummies; Business model for accelerated development of patentable technologies.

3.2 Mentoring program

Since 2016, a total of 104 pairs of senior entrepreneurs with junior entrepreneurs have been created. From 2018 to 2021, a total of 542.5 mentoring hours have been held in 309 meetings.

4 SUMMARY

Knowledge transfer in an entrepreneurial ecosystem takes place naturally by the very nature of the space and the people who form it. In recent years, the StartUPV ecosystem has detected the need to structure this knowledge transfer in specific activities in order to reach more beneficiaries and maintain a medium-long term commitment.

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Teachers' and students' perceptions and practices in promoting a sense of community for blended education

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ABSTRACT

Blended learning is not a new concept, but has attracted increased interest among higher education institutions in preparing for future education. During the COVID-19 pandemic, many teachers have gained extensive experience with online and digital education. Yet, maintaining social engagement amongst and with students, while motivating them to actively participate in their learning, remains a momentous challenge for teachers working in a blended learning environment [1]. Poor social interactions cause a negative impact on the quality of blended learning [2], culminating in students feeling lonely, isolated, and losing motivation [3].

As such, a sense of community will be crucial, but may be difficult to achieve due to limited physical classroom time. This study addresses students' and teachers'

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viewpoints, and seeks to answer the question: *What are the perceptions and practices of students and teachers regarding promoting a sense of community in a blended learning environment?*

A qualitative methodology is utilized, including non-participant observation, document analysis, and interviews for data collection and analysis. Firstly, the findings of this study enhance our understanding of teachers' perceptions, practices, and challenges for cultivating SoC. Secondly, this study provides information for professional development of teachers that carry out blended education. Finally, we hope this study can support higher education institutions in preparing and reshaping for the future.

1 INTRODUCTION

1.1 Blended learning challenges

Blended learning (BL) has gained considerable attention in higher education for more than two decades [2]. Research suggests that BL has the potential to increase learning flexibility, accommodate individual needs, and improve student results [4, 5]. Combining the advantages of online education, while still including face-to-face contact, BL has attracted increased interest among universities in preparing for education post-COVID-19. However, teaching during the pandemic revealed that maintaining social connections with students and motivating them to learn was difficult [1]. This confirms previous research indicating that poor social interactions can lead to students' feelings of loneliness, isolation, and motivation loss [1, 3]. In this situation, a sense of community (SoC) is essential, representing ‘a feeling that members have of belonging, a feeling that members matter to one another and to the group, and a shared faith that members' needs will be met through their commitment to be together’ [6, 7].

SoC has a beneficial effect on learning. However, it can pose certain challenges in a blended environment. Hence, this study aims to investigate students' and teachers' perceptions and practices in promoting SoC, to gain insights on how to support students and teachers for a quality BL in higher education. More specifically, this study seeks to answer the following question:

What are the perceptions and practices of students and teachers regarding promoting SoC in a blended learning environment?

1.2 Theoretical background

Blended learning

Alongside ongoing debates regarding the best definition of BL, two definitions from Graham [8] and Garrison and Kanuka [9] are most frequently cited in various literature. Graham [8] considers BL as a mix of traditional face to face (F2F) and online learning. Similarly, Garrison and Kanuka [9] acknowledge that the essential components of BL are F2F and online instruction or learning, and they further emphasize the importance of a '*thoughtful integration*.'

Sense of community in Blended learning

Despite BL's potential to improve the pedagogical richness and learning outcomes, some researchers have contended that it can be a double-edged sword if the social aspect in BL is overlooked. Learning is most effective when a strong sense of community exists [7]. Evidence suggests that SoC is associated with increased perceived learning, academic success, as well as students' well-being [7, 10].

SoC conducive to learning is important for the educational process, but it may be difficult to achieve, notably when physical classroom time decreases in BL. It is recommended for teachers to explicitly integrate SoC into both synchronous and asynchronous environments. To assist teachers in this area, Rovai [11] identified two critical variables to esthablish a strong SoC in BL: *connectedness* and *learning*. The connectedness refers to 'connectedness, cohesion, spirit, trust, and interdependence', while the learning focuses on the extent to which students impart educational goals and benefits through interaction with peers and teachers. Studies have further revealed that in order to build a strong SoC, three presences in BL are beneficial, namely: social and cognitive presence by students, and teaching presence [12-15].

- The ability of the students to project themselves socially and emotionally, as 'real' persons to develop inter-personal relationships in a trustworthy environment, is known as **Social Presence** [16]. Social presence contributes to the dimension of 'being connected' of SoC.
- Simply having good social relationships would not be sufficient for academic success. Interactive activities need to be structured and directed towards intellectual engagement. For this, **Cognitive Presence** becomes imperative. Cognitive presence is conceptualized as the extent to which the students are able to construct and confirm meaning through sustained reflections and discourse [17]. Cognitive presence focuses on the learning aspect of SoC.
- Teaching presence is the instruction, facilitation, and direction of students' social and cognitive presence for the purpose of realizing personally meaningful and educationally worthwhile learning outcomes [18]. Teaching presence is usually under the leadership of teachers and it is intertwined with social and cognitive presence to create a deep and meaningful learning experience for students [18, 19].

2 METHODOLOGY

2.1 Research framework

An effective SoC that encourages connectedness and learning is fostered by well-designed and organized interactive activities spearheaded by teachers. These activities are characterized as social, cognitive, and teaching presence. In this sense, the three presences serve as this study's interpretive lens, analyzing students' and teachers' perceptions of SoC-promoting activities (see the Figure 1).

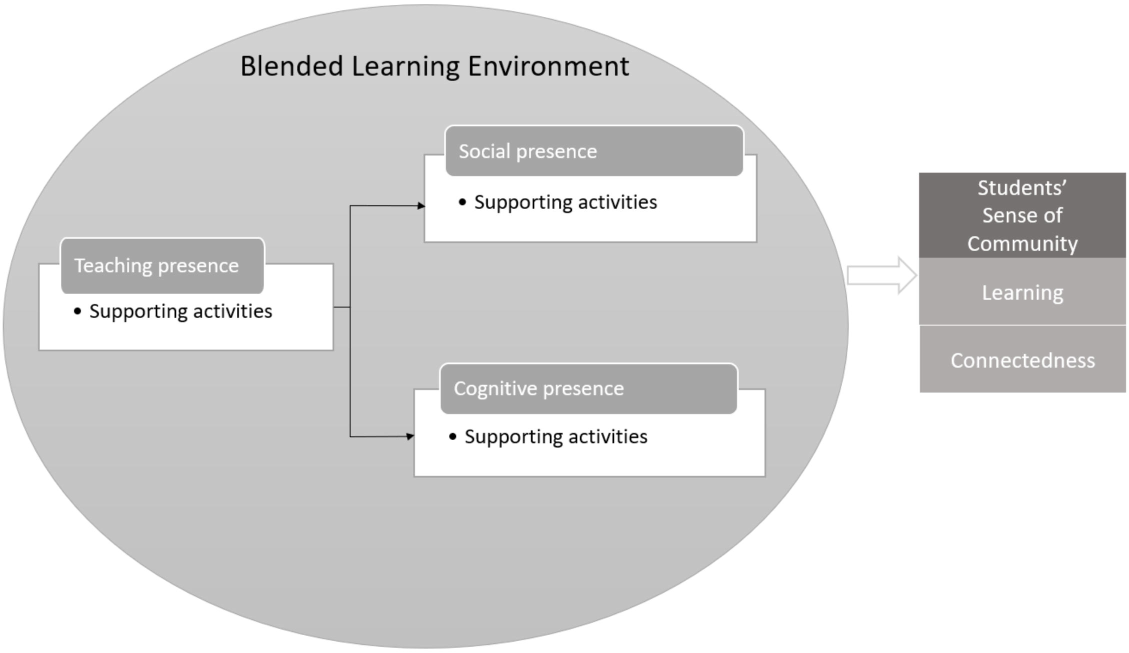

Fig. 1. Conceptual framework

2.2 Data collection and analysis

The university's ethics committee approved this study prior to data collection. Each participant was provided with a consent form and an information sheet regarding this study's aims, potential risks, and the option to withdraw from this study at any time. A blended course at one university was included in this study. This course was chosen as a sample for this study because it was developed over several years and complies with the requirements for a blended course as 'a thoughtful integration' of the F2F and online components [8, 9]. Additionally, the teacher of this course would like to investigate ways to improve students' SoC and interactivity, which would allow for a more in-depth examination of the course. The data collection spanned two phases: observation and document analysis were performed first, which provided input, directions, and knowledge to inform the interview questions in phase two, enabling a exploration of the participants' perceptions and practices on SoC.

- First, nine observation including both online and F2F sessions were scheduled at the beginning, middle, and end of the course, to explore SoC at various stages of the course.
- Secondly, this study obtained permission from teachers to access their courses via the learning management system (LMS). It scanned the course contents, assignments, and assessments and discovered specific course elements influencing students' SoC.
- Finally, one-on-one interviews with teachers and a group interview including five students have been conducted. The interview with the teacher provided

their perspective on their roles, teaching practices and their challenges in promoting SoC in BL. Interviews with students also revealed activities that would have contributed to SoC but were not supported by teachers.

The interview transcripts and the observation and document review notes served as the content analysis sources. The study generated two sets of codes to identify significant themes that would explain the perspectives of students and teachers on SoC. It utlized the pre-defined codes using the three presence categories and indicators [20]; while it established emergent codes by scanning obtained data to generate discoveries.

3 RESULTS

Although the study is still ongoing and the results are not yet fully available, preliminary findings indicate that specific pedagogical methods, practices, and tools that promote SoC in the BL environment can already be identified:

- A high-quality BL course requires teachers to consider students' social, emotional, and intellectual needs. A safe and open culture can be established by allowing students to express themselves without fear of repercussions.
- While it is easier to establish social bonds at the start of a course in a face-to-face session through icebreaker activities, teachers and students must work together to maintain them throughout the entire course.
- Personalize a BL course by including relevant personal stories, experiences, and examples. A video introduction with audio and video feedback are viable methods for boosting social presence. This strategy may encourage students to communicate their thoughts, feelings, and difficulties.
- Convert a static BL course into an active one with multiple opportunities for student engagement. Asynchronous activities (e.g., self-study and individual assignments) provide students with greater flexibility and control over their learning; on the other hand, synchronous activities encourage immediate personal engagement and more responsive exchanges (e.g., brainstorming, discussion, and live polling).
- Create an environment conducive to collaboration and encourage students to assist one another. It necessitates a shift in teachers' roles ‘from sage on the stage to guide on the side’ [21] by allowing students to assist one another first and then stepping in when necessary.

Additionally, this study shows that many universities are now required to offer hybrid education to allow corona-infected students to participate in online education. However, catering to online and on-campus students simultaneously is not easy; activities that should take place on campus (e.g., group projects) are forced to be moved online, raising concerns about the university’s educational quality. It is important to stress that hybrid education is not synonymous with blended education. Universities should transition from emergency remote teaching to quality education by making well-considered decisions about which activities should take place online while others are better supported by F2F instruction.

4 CONCLUSION

Quality blended learning requires that students have a strong sense of community in order to keep them engaged and motivated throughout the learning process. Teachers play a crucial role in this process by imparting knowledge and fostering a safe and productive learning environment for students.

Furthermore, we hope that the study's future findings will identify the barriers teachers face and the support they require to develop a high-quality BL. We anticipate that this study will shed light on future professional development opportunities in blended education at HEIs.

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ONLINE VS IN PERSON: FLIPPED CLASSROOM APPROACHES TO A 3rd YEAR ELECTRICAL AND ELECTRONIC ENGINEERING PROJECT MANAGEMENT MODULE

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ABSTRACT

Managing Engineering Projects is a 3rd Year module of the 4-year MEng in Electrical and Electronic Engineering with Management degree. Its purpose is to provide students with innovation and project management skills in the context of engineering practice.

The format was modified during the 2020-21 academic year to include more elements of student-centred learning to increase engagement given the online delivery format due to Covid. The module comprised 10 x 2-hour weekly sessions. Students were sent the material for each of the sessions ahead of time, with the first hour being devoted to discussing relevant aspects or issues raised by the students. The second hour focused on a related case study or activity, where students were allocated to break out rooms on Teams for group work, then coming together for some general discussion and conclusions. Alternatively, guest industrial speakers would share their professional experiences to illustrate the theory covered in the first hour. There was also an opportunity for questions and general project management discussion.

The module was delivered in person this academic year, retaining the same flipped classroom format, case studies and industrial speakers.

This paper compares the feedback and insights gathered through questionnaires from the online and in-person cohorts. Initial evidence shows that both groups found the flipped classroom, practical group work, and guest talks more engaging than traditional lectures. However, the in-person cohort showed higher rates of attendance and students were more engaged in group activities.

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1 INTRODUCTION

1.1 Background to the module

The “Managing Engineering Projects” module was designed and taught for the first time in the spring term (January to March) of 2019. It is offered to 3rd Year students on the Management Stream of our MEng Electrical and Electronic course.

The module comprised 10x2-hour sessions with 1 hour of traditional lecturing, or passive learning, and 1 hour where an industrial speaker would illustrate the material covered in the lecture, or the cohort would work in groups on a case study or management challenges.

The format was modified during the spring term 2021 to include more elements of student-centred learning [1] to increase engagement, given the online delivery format due to Covid. Using a flipped classroom, students were sent the material for each of the topics ahead of time, with the first hour being devoted to discussing relevant aspects or issues raised by the students. The second hour remained unchanged.

The module was delivered in person this spring term, retaining the same flipped classroom format, case studies and industrial speakers [2].

This paper compares the feedback and insights gathered via questionnaires as well as levels of engagement from the online (Group 1) and in-person (Group 2) cohorts.

2 METHODOLOGY

2.1 Student sample details

Two groups were sampled for this paper; Group 1 who experienced the module through online delivery in 2021 and Group 2 who attended face to face in 2022.

Table 1. Details of student sample

Group	Cohort	Delivery method	Cohort size	Attendance and engagement
1	2021	Online	49	69.39%
2	2022	In person	17	88.23%

2.2 Questionnaires

Both cohorts of students were asked to complete a 16-question questionnaire (see Appendix) anonymously. Only Questions 3 and 4 were considered for this paper.

Table 2. Questions 3 and 4

Q3. Class format - which format do you find most suitable for the way in which you learn?
Q4. Class format- please explain the rationale for your selection in Q3

2.2.1 Question 3

The purpose of Q3 was to establish which learning format was best suited to the respondent’s learning style. The responses included the options available in pre-Covid times (face to face, online pre-recorded and live discussions, a combination) and the most widely approach applied during Covid and the various lockdowns: online live. Respondents also had the opportunity to add their own method under the "Other" reply.

2.2.2 Question 4

Q4 was free text to allow respondents to elaborate on their answers for Q3. These replies gave great insights into their attitude and motivation towards learning in the context of the pandemic.

2.2.3 Level of engagement

The level of engagement was obtained by calculating the number of students who attended more than 50% of the classes as a proportion of the total number of students.

This threshold was selected as it is the minimum number of sessions students can attend and still have the knowledge necessary to successfully complete the coursework.

3 RESULTS AND DISCUSSION

3.1 Results

3.1.1 *Question 3*

Group 1 showed a clear preference for traditional lectures (46.1%) while Group 2 was equally divided amongst flipped classroom, traditional lectures, and a combination of both. The percentage for flipped classroom, however, remained almost constant, moving from 30.8% to 33.3%.

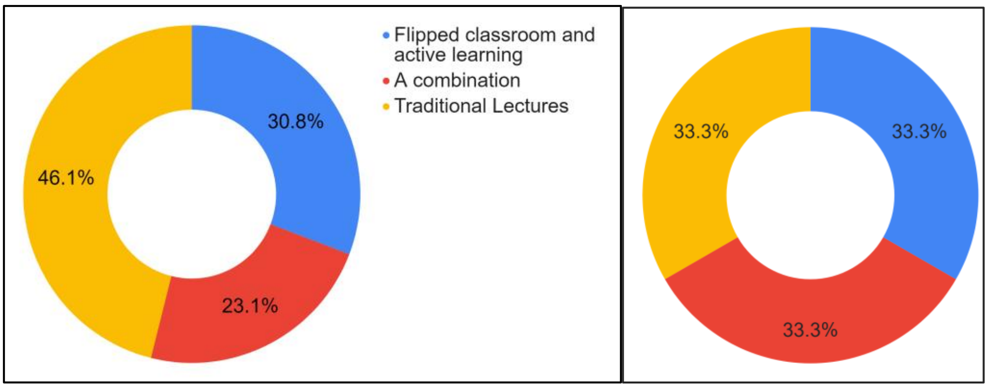

Fig 1: Q3 results for Groups 1 and 2

3.1.2 *Question 4*

Group 1 provided feedback with opinions on both passive and active learning camps:

"If the course consists of only traditional lectures, it can be boring, and I switch off. However, sometimes, it is useful to have the material explained by the lecturer"

"I like to view the content first and then have time to do further research after."

"I would maintain an element of pre-lecture preparation through case study readings"

Group 2 were more in favour of active learning, as the results show:

"This [flipped classroom] would help us gain information and exchange ideas more effectively for learning."

“It`s more interactive which is also suits the nature of the content being delivered”

“The pre-recorded videos are useful for learning new information as everyone learns at a different pace. However online discussions don't have good participation and should be face to face”

Fig 2: Group 2 students applying material from flipped classroom to a case study

3.1.3 Level of engagement

The results are quite disparate, with Group 1 scoring 69.39% and Group 2 88.23%. The reasons for this difference have been included the Discussion section.

3.2 Discussion

Group 1 were in the last term of their 2nd year during the first lockdown in March 2020, and had to adapt to online learning, exams, presentations, and assessments very quickly. Unfortunately, most of the following academic year was delivered online as well, resulting in students spending many hours in front of their screens listening to traditional lectures [3]. The level of uncertainty at the time meant that many academics made only slight changes to the material and the delivery since there was the expectation of a return to normal by October 2021.

After 2 terms of online learning, students attended online classes live but switched off their cameras, to do something unrelated while the class was on in the background. Other students took a “binge watching” approach to their learning by missing live sessions and then watching several sessions, one after the other.

This “screen fatigue” and the requirement to prepare material ahead of the class explain the level of engagement for this cohort being 69.39% vs 83.23% for Group 2.

Group 2 on the other hand, were in Year 1 when lockdown started and completed Year 2, the most demanding in the course, online. They had missed the social aspect of learning and were keen to return to campus and face to face teaching. Hence the important level of engagement.

There was consensus in the value of and appreciation for the industrial speakers, as they gave insights into potential career paths.

In conclusion, two separate cohorts enrolled on the same module had quite different experiences: online and face to face. Group 1 was less interested in a flipped-classroom approach since it involved preparatory work and online discussions, which students find intimidating. Group 2, in contrast, was more interested in active learning as the discussions were face to face and more productive.

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Appendix

Questionnaire

Q1. Course delivery - which format do you find most suitable for the way which you learn?
Q2. Course delivery - please explain the rationale for your selection in Q1
Q3. Class format - which format do you find most suitable for the way in which you learn?
Q4. Class format- please explain the rationale for your selection in Q3
Q5. How did you find working on practical examples, case studies and group discussions? For example, deployment of Covid vaccine to remote locations, organising Hackathon, Europa Foods, etc.
Q6. Guest industrial speakers - what is your opinion?
Q7. Industrial speakers - what would you keep and why?
Q8. Industrial speakers - what would you change and why? what alternatives would you propose?
Q9. Assessment - cw1 essay on a project management topic
Q10. Assessment cw1- what would you keep and why?
Q11. Assessment cw 1 - what would you change and why? what alternatives would you propose?
Q12. Assessment - cw2 "Turning your 2nd Year EERover into an educational toy" group project
Q13. Cw2 deliverables - group project (Video and Q&A session)
Q14. Cw2 deliverables - group project deliverables (Report)
Q15. Assessment cw2- what would you keep and why?
Q16. Assessment cw 2- what would you change and why? what alternatives would you propose?

A META-ANALYSIS OF THE EFFECT OF PEER FEEDBACK ON ACADEMIC ACHIEVEMENT IN THE STEM FIELDS OF HIGHER EDUCATION

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ABSTRACT

Recently, there has been a significant increase in the use of peer feedback in higher education. However, the evidence of the effect of peer feedback on students' academic achievement does not seem conclusive and, to our knowledge, there has not yet been a meta-analysis of the effect of peer feedback on general academic achievement in the STEM fields of higher education. Therefore, we conducted a meta-analysis to determine whether peer feedback is beneficial to STEM higher education students' academic achievement. The final data set for the meta-analysis consisted of 286 effect sizes from 90 independent samples in 75 studies, with a total of over 14,000 participants. All effect sizes were calculated as Cohen's *d* values. A random-effects model used to synthesise the effect sizes indicated a significant positive summary effect size (d = .421, SE = .037, 95% CI = .350, .493, p = .000). The variance of the true effect sizes (T^2) was .069. The Q_w value of 644.167 was significant (p = .000) and the I^2 value of 88.512 was high. Therefore, in order to identify the source of the between-study heterogeneity, moderator analyses were conducted to evaluate the influence of various methodological quality characteristics and peer feedback intervention characteristics on the effect of a peer feedback intervention. The results of this study will provide researchers, policy makers and practitioners with the information they need to decide whether or not to use peer feedback and to be able to design peer feedback interventions for maximal effectiveness.

1 INTRODUCTION

There has been a significant increase in the use of peer feedback in higher education. Peer feedback involves students providing their peers with feedback on their draft work and/or receiving feedback on their own draft work, followed by revising their work based on their peers' work and/or based on the feedback they received [1]. Research on the effect of peer feedback on academic achievement in the STEM fields of higher education found a positive effect (e.g. [2], [3]), a negative effect (e.g. [4], [5]), no effect (e.g. [6], [7]) or a limited effect (e.g. [8]). To come to a consensus on the effect of peer feedback on academic achievement in the STEM fields of higher education, this research used meta-analytic methods to synthesise the available literature to answer the following research questions:

1. What is the effect of a peer feedback intervention on the academic achievement of students in the STEM fields of higher education?
2. How do the peer feedback intervention characteristics moderate the effect of a peer feedback intervention on the academic achievement of students in the STEM fields of higher education?

2 METHODOLOGY

The data collection was based on [9] and was conducted in four steps.

2.1 Determination of Inclusion Criteria

To be included in the meta-analysis, studies should have have:

1. Been published as an English-language article in a peer-reviewed journal
2. Been conducted in the context of a course in STEM higher education
3. Involved the implementation of a formative peer feedback intervention
4. Been designed with a control condition and an intervention condition
5. Included at least 15 participants in each condition
6. Reported quantitative measures of students' academic achievement as the outcome measure

2.2 Search for Literature

To find articles for inclusion in the meta-analysis, three approaches were used: 1) searching through existing meta-analyses on peer feedback, 2) searching through electronic databases, and 3) backward and forward searching using the references and citations of the articles shortlisted from the first two approaches.

First, the articles included in the meta-analysis of the effect of peer feedback on academic writing by [10] were considered. Second, for the search through databases, four databases were selected (ERIC, PsycINFO, Web of Science and Scopus). A search string was created using the keywords 'peer feedback', 'STEM' and 'higher education', along with synonyms for these keywords. Third, once articles were shortlisted from the meta-analysis by [10] and the database search results, all English-language journal articles were identified from: 1) the reference lists of these articles, and 2) the citations of these articles found on Web of Science, Scopus, ResearchGate and Google Scholar.

2.3 Identification of Studies

This search for literature resulted in a total of 6,935 unique results. The titles and abstracts of these articles were put through a preliminary screening to determine whether the articles satisfied the second and third inclusion criteria, with articles not satisfying either or both of these criteria being excluded. The full manuscripts of the remaining 1,419 articles were sought, and the full manuscripts of the 1,330 articles that could be obtained were then put through a thorough screening using the second, third, fourth, fifth and sixth inclusion criteria. During this screening, 92 articles were selected for data extraction.

2.4 Data Extraction from Studies

An extensive data extraction form was created to obtain the data from the selected articles. Data from all articles was extracted and coded by two researchers. The two researchers' codes were compared to ensure reliability of coding procedures and decisions. Any discrepancies in the codes were discussed by the two researchers until a consensus was reached. Also, any doubts were clarified through discussion with a third researcher and/or a statistics expert. Some of the articles contained data for multiple effect sizes, resulting in a total of 367 effect sizes from the 92 articles.

3 DATA ANALYSIS

The data analysis was based on [11], using Comprehensive Meta-Analysis.

3.1 Summary Effect Size

In the case of studies with a pre-test post-test design, the pre-test results were compared with the post-test results. In the case of studies with a controlled trial design, the post-test results for the control group were compared with the post-test results for the intervention condition. In the few cases where a pre-test was conducted just before the peer feedback activity, the difference between the pre-test and post-test results for the control group was compared with the difference between the pre-test and post-test results for the intervention group. The individual effect sizes were computed as Cohen's *d* values.

Ultimately, of the 367 effect sizes, 30 could not be calculated and were excluded from the meta-analysis. Moreover, some of the effect sizes were not included in our final analyses, e.g., to include only mutually exclusive effect sizes within articles, to exclude articles that reported the same study and same effect size(s) as another article, and to exclude articles with extreme effect sizes. In order to avoid inflating the sample size, an overall effect size was computed for each study, and each study contributed only this one overall effect size to the meta-analysis. The final data set for the meta-analysis consisted of 286 effect sizes from 90 independent samples in 75 studies, with a total of over 14,000 participants.

A random-effects model was used to compute the summary effect size. Using the model, the summary effect size (*d*) as well as the standard error (*SE*), 95% confidence interval (*CI*) and significance (*p*) of the summary effect size were computed. For the summary effect size, significance was set at $p < .05$.

3.2 Between-Study Heterogeneity of the True Effect Sizes

To check for the between-study heterogeneity of the true effect sizes, the variance of the true effect sizes between studies (T^2) was computed. In addition, a measure of whether the observed variance was significantly different from that expected from within-study variance alone (Q_w) and a measure of the proportion of the observed variance that was from the variance of the true effect sizes (I^2) were computed. For the Q_w value, significance was set at $p < .05$. For the I^2 value, 25%, 50% and 75% were considered low, moderate and high heterogeneity, respectively [12]. If the Q_w value was significant and the I^2 value was high, moderator analyses would be justified [12].

3.3 Moderating Effects of Methodological Quality Characteristics

Methodological quality characteristics could have a moderating effect on the effectiveness of a peer feedback intervention. If the moderating effect is significant, caution should be exercised when combining studies with different attributes of the characteristic. Therefore, a series of moderator analyses were conducted to check for the moderating effect of pre-selected methodological quality characteristics.

3.4 Moderating Effects of Peer Feedback Intervention Characteristics

Peer feedback intervention characteristics could also have a moderating effect on the effectiveness of a peer feedback intervention. If the moderating effect is significant, it could help to explain the between-study heterogeneity of the true effect sizes. Therefore, a series of moderator analyses were conducted to check for the moderating effect of pre-selected peer feedback intervention characteristics.

A mixed-effects model was used to conduct each moderator analysis independently of the other moderator analyses. Using the model, a measure of whether the observed variance across the attributes of the characteristic was significantly different from that expected from within-study variance alone (Q_b) was computed. For the Q_b value, significance was set at $p < .01$.

4 RESULTS

4.1 Summary Effect Size

The meta-analysis revealed a significant positive summary effect size of peer feedback on academic achievement ($n = 286$, $k = 75$, $d = .421$, $SE = .037$, $CI = .350$, $.493$, $p = .000$), representing a medium effect size [13].

4.2 Between-Study Heterogeneity of the True Effect Sizes

The variance of the true effect sizes (T^2) was .069. The Q_w value of 644.167 was significant ($p = .000$), indicating that the true effect sizes in the primary studies were not the same, while the I^2 value of 88.512 was high, indicating that the proportion of true variance to observed variance was high. Since the Q_w value was significant and the I^2 value was high, moderator analyses were conducted to attempt to identify the source of the between-study heterogeneity.

4.3 Moderating Effects of Methodological Quality Characteristics

Moderator analyses were conducted to check for the moderating effect of the research design used in the study, the type of allocation used to create groups, the equivalence between the groups created and the blinding of the assessor(s) to the condition of the participants. For each of the analyses, the Q_b value was not significant. Since there was no evidence that the methodological quality characteristics had a moderating effect, it was deemed appropriate to combine studies with different attributes of the characteristics in a single meta-analysis.

4.4 Moderating Effects of Peer Feedback Intervention Characteristics

Moderator analyses were also conducted to check for the moderating effect of a range of peer feedback intervention characteristics, with respect to the nature of the task subjected to peer feedback, the nature of the peer feedback itself, the logistics of the peer feedback activity, the support for the peer feedback activity and the grading associated with the peer feedback activity. For each of the analyses, the Q_b value was not significant.

5 CONCLUSION

The meta-analysis showed that peer feedback is beneficial for improving academic achievement in the STEM fields of higher education. Therefore, it is recommended that peer feedback be incorporated in courses, where possible and appropriate.

It was hoped that the results of this study would provide the data needed to be able to design peer feedback interventions for maximal effectiveness. The way a peer feedback intervention is implemented can vary widely, and it can be presumed that the way in which it is implemented can influence the extent to which a peer feedback intervention is effective. While the moderator analyses in this study did not show a significant moderating effect of any of the peer feedback intervention characteristics tested, it does not rule out the possibility that (at least some of) these characteristics can make a difference. As explained by [14], moderator analyses are often insignificant and insignificant findings do not always mean that the characteristic does not have an influence on the effect. Therefore, it is recommended that, when designing a peer feedback activity, consideration is given to which design characteristics are likely to increase students' participation in the activity, elicit feedback of high quantity and quality and improve students' use of and learning from the feedback they provide and receive. It is also recommended that further research be conducted to increase the knowledge on how a peer feedback intervention can be designed for maximal effectiveness.

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Exploring usage of summative peer assessments in engineering education

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ABSTRACT

Summative peer assessment is an assessment method where the one's work is typically graded by several other anonymous peers using predefined criteria. The value of summative peer assessments in higher education stems from the fact that they can provide scalability in assessment for large enrollment classes for a variety of different assessment types. The main disadvantages of using summative peer assessments are questionable validity and reliability. In this paper, the first results of using summative peer assessments in a large enrollment professional skills course at the University of Zagreb, Faculty of Electrical Engineering and Computing are reported and discussed. The main research question of this work is how well, given specific conditions of the conducted summative peer assessments, do assignment credits assigned by peers correlate with assignment credits assigned by course lecturers. Data were obtained from four summative peer assessments through the course. A random sample of 50 submitted works per peer assessment was evaluated by course lecturers and corresponding assignment credits were compared to assignment credits awarded by students. Data analysis results suggest a moderate to high correlation between several measures of assignment credits awarded by peers and lecturers.

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1 INTRODUCTION

Peer assessment is "*an arrangement in which individuals consider the amount, level, value, worth, quality or success of the products or outcomes of learning of peers of similar status*" [1]. Peer assessments can be either summative or formative in their nature [2]. The main goal of formative peer assessments is to to provide the author of the submitted work with feedback to help them plan their learning [2], while the main goal of summative peer assessments, also known as *peer grading* [3] or *peer marking* [4], is to assign grades or assignment credits to the author of the assignment.

Research results suggest formative peer assessments, in which students typically get feedback on their assignments through textual comments has a positive influence on learning outcomes related to the assignment as well as on other factors including learning strategies, academic mindset [5], [6], and motivation for learning [7]. When using peer assessments in a summative context, the psychometric properties of validity and reliability of peer assessments are a major concern since they depend on students' ability to produce valid and reliable evaluations of peers' work. While students tend to perceive peer assessments as beneficial, some students express a dislike of awarding a grade to their peers [8]. A meta-analysis of peer assessment research revealed the average Pearson's correlation coefficient between peer and teacher ratings of 0.63 [9]. Research has also indicated that quality of peer assessments' psychometric properties can be improved by training and experience of peer assessors. Student attitudes towards peer assessment are also positively influenced by training and experience [10], although some authors suggest peer grading can undermine effects of peer feedback [11].

This short paper contributes to the body of related research by reporting the first results of a research exploring the correlation between teachers' and students' ratings on a summative peer assessment conducted among the first-year undergraduate engineering students in a professional skills course called *Communication skills*. The assignment credits assigned by students (peers) were compared with those assigned by course lecturers to investigate how valid peers' credits are if they are used in summative context under conditions described in the paper.

2 METHODOLOGY

2.1 Context

This research was conducted in context of a first-year course *Communication skills* at the University of Zagreb, Faculty of Electrical Engineering and Computing. Around 700 students are enrolled in the course every year. Trough the semester, students have a total of six summative peer assessments in which the following assignments are assessed: (1) writing a formal email message according to an individualized scenario, (2) writing a cover letter and a narrative resume for a job application, (3) capturing a photograph, (4) capturing a video, (5) creating a slideshow presentation with narration, (6) creating a two-minute video presentation with audio narration and subtitles. The assignment credits a student finally receives are based on peers' ratings of the submitted assignment (~65%). A student can achieve the remaining assignment credits (~35%) by submitting ratings of five peers' assignments. Following the advice in published research [12], students are, aside from a small amount of assignment credits (external motivation), provided with a clear and understandable evaluational framework and they have a guarantee of anonymity in the peer assessment process. To submit their ratings students use an online form (Moodle *Quiz* type activity) with a set of evaluation questions which are available to them in advance. Questions typically have four offered answers to each question, for example:

> *Is there a paragraph (part of text) that states who the e-mail sender is and what is their role? Is that part of the text clear?*
>
> *a. No, that part of the text does not exist.*
>
> *b. Yes, that part of the text exists, but it is completely unclear.*
>
> *c. Yes, that part of the text exists and is written somewhat clearly.*
>
> *d. Yes, that part of the text exists and is written quite clearly.*

The evaluation form for each assignment contains questions that can roughly be divided into two categories: subjective questions like the above example, where the difference or exact criteria for answers b) and c) might vary between students, and objective questions like *Does the submitted work have subtitles?*, where the answers or answer criteria are close to indisputable. Answers to some of the objective questions (for example the presence of subtitles in a video file) are assessed automatically using software support. In order to discourage students from submitting invalid or unreliable assessments, students are warned that each of such attempts will results in losing all assignment credit for that complete assignment. This rule is enforced only on objective question are automatically removed from further processing.

2.2 Data

Data presented in this paper was collected during the academic year of 2020/2021 in four out of six summative peer assessments (all except (3) capturing a photograph, (4) capturing a video). In each of the peer assessments, ratings submitted by students are screened for inconsistencies in objective questions and assessments by their authors are removed form further processing. Additionally, about 5% to 10% of submitted works with highest standard deviation of assignment credits assigned through peer assessment are screened by lecturers. The assignment credits for each submitted work are afterwards awarded either by course lecturers or by averaging the assignment credits of the remaining peer assessments.

In order to investigate the relationship between assignment credits assigned by peers and those assigned by course lecturers, 50 randomly selected works for four peer assessments have been evaluated and assigned credits by both peers and course lecturers.

3 RESULTS

Results of the analysis of correlation between the lecturers' assignment credits and assignment credits awarded by by peers measured as (1) average value of peers' assignment credits, (2) average value of peers' assignment credits without minimal and maximal credits value, and (3) median value of peers' assignment credits, are presented in Table 1. The correlation coefficients (Pearson's *r*) are based on assessment of 50 submitted works for each peer assessment and are all significant above the p = 0.001 level. The average values (M) of lecturer's and peers' assignment credits are also given in the table for each of the peer assessments.

Table 1. Correlation between lecturers' assignment credits and other measures

Peer assessment	Lecturer's assignment credits	Peers' assignment credits	Peers' assignment credits without max and min	Median peers' assignment credits
(1) E-mail message	M = 81.92%	M = 85.63% r = 0.564	M = 86.52% r = 0.576	M = 86.60% r = 0.574
(2) Resume and cover letter	M = 91.52%	M = 88.47% r = 0.813	M = 89.87% r = 0.811	M = 89.90% r = 0.812
(3) Slideshow	M = 89.12%	M = 90.98% r = 0.686	M = 91.37% r = 0.708	M = 91.44% r = 0.705
(5) Video presentation	M = 88.45%	M = 89.01% r = 0.812	M = 90.24% r = 0.775	M = 87.99% r = 0.824

M – mean, *r* – Pearson's *r*

The overall results of peer assessments regarding the achieved assignment credits are relatively high, between 85.3% and 91.44% of the total assignment value. This can likely be attributed to the availability of evaluation criteria in advance helping students know what exactly is expected from them.

The three measures of calculating total assignment credits from peers' assignment credits have shown a strong correlation with assignment credits awarded by course lecturers. Overall, it seems that the average value of peers' assignment credits without maximal and minimal values best correlates with lecturers' assignment credits. The correlation values range from 0.564 to 0.824 indicating a strong correlation. The obtained results are encouraging regarding the potential of summative peer assessments in the described context. It is interesting that the correlation coefficients are the highest for the video presentation assignment, in which there are several objective questions, but also for the resume and cover letter assignment, where most evaluation questions are rather subjective in their nature.

4 CONCLUSIONS AND FUTURE WORK

In this paper the first results of a comparison between lecturers' and peers' assessments of students' work in a professional skills for engineers course are described. The obtained results suggest a moderate to strong correlation between peers' and lecturers' grades under given conditions and provide some support for claims about validity and reliability of this kind of assessments. Questions that remain and should be addressed in a follow-up in-depth investigation include how the relative ratio of subjective to objective questions affects the correlation of assignment credits, how high is the inter-rater reliability of course lecturers' assignment credits, and whether different assignment credit calculation models can be used, for example, to identify students whose evaluations are most similar to lecturers' and achieve a higher correlation by assigning a greater weight to their evaluations.

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MACROETHICAL DEVELOPMENT IN CIVIL AND ARCHITECTURAL ENGINEERING EDUCATION

(SHORT)

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ABSTRACT

This short research paper presents the early stage of an ongoing project in engineering ethics education. Given the impact of civil and architectural engineering and the profession's obligation to uphold public welfare and trust, students must understand macroethics, engineering's responsibilities to the human, natural, and built environment. The Bachelor's curriculum plays a key role in developing ethical responsibility, as a site of professional socialization and the only institutionalized training most engineers receive. Students are also exposed to ethics, values, and the societal impacts of engineering via informal learning before and during their university experience. The present project is designed to explore how civil and architectural engineering students make meaning of their societal responsibilities by examining their conceptualisation of the impact of engineering and the factors that influenced it. This study employs a constructivist grounded theory (CGT) approach and draws on interviews with Bachelor's civil and architectural engineering students in Belgium and the United Kingdom. Data collection and analysis are ongoing simultaneously with the aim of generating a novel theoretical model of macroethical development. This short paper introduces the theoretical and methodological approach of the study, anticipated outcomes, and next steps.

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1 INTRODUCTION

1.1 Engineering Ethics Education

In charting the future of engineering education, Sheppard and colleagues point out that “engineering inevitably means intervening in the world,” and therefore “all engineering projects carry with them responsibility for the effects of those interventions” [1] (p. 9). They call for powerful learning opportunities, so engineers understand “that social and ethical connections are as important, if not more so, as electrical and mechanical ones” (p. 9). However, the integration of ethics in engineering education has lagged behind recognition of its necessity by both industry professionals (e.g., [2]) and accreditation bodies (e.g., [3]). An understanding of the process through which students develop their professional and societal responsibility can inform engineering education and improve the ethical impact of engineering practice.

1.2 Contribution and Significance

Extant theories of moral development (e.g., [4]) have limited application to engineering and to populations of diverse university students. In particular, existing theory tends to emphasize individuals’ decisions and actions without accounting for the environment in which those decisions are made or the sociocultural mediators of their agency, and this approach reflects microethics. Engineering practice, however, is increasingly recognising the importance of macroethics, the broader responsibilities of the engineering profession within organizational and societal contexts with respect to issues such as climate change, artificial intelligence, and social inequality [5]. Finelli et al. developed a conceptual framework of ethical development during university based on an input-environment-output model for studying students’ outcomes [6]. The framework posits that inputs (student characteristics) and the environment (inside and outside the classroom) inform students’ ethical development. Although the framework provides a helpful starting point for understanding the broad components that shape ethics education, it is conceptualised as quality (level of students’ involvement) and quantity (variety of experience and amount of time students invest) and has a microethical emphasis, as evidenced by how ethical development was measured in the student survey. Additionally, prior work aggregates engineering fields, but engineering is not monolithic with each discipline having a distinct culture, degree-specific outcomes, and relevant ethical issues [7]. As a result, it is instructive to disaggregate engineering to provide a more nuanced understanding of macroethical development. This study focuses on civil and architectural engineering due to its unique work at the nexus of the human and built environment.

2 METHODOLOGY

2.1 Study Design

This research employs a constructivist grounded theory approach (CGT) [8] to address the research question: How do civil and architectural engineering students develop their macroethical responsibility through their university experience? CGT is a qualitative systematic process for collecting and analysing data to generate new theory. The overarching perspective in this study is constructivism, which postulates that people construct knowledge based on their experiences. Instead of seeking an absolute truth, constructivism acknowledges that social and cultural factors mediate individuals’ ability to make meaning of their experience and knowledge.

2.2 Data Collection

The study takes a cross-sectional approach to include participants at every level of their Bachelor’s studies in civil and architectural engineering. The data collection and analysis occur in parallel until saturation is reached; around 30 individuals is common in CGT [9]. Participants are recruited via email invitations through the civil and architectural engineering programmes at one institution in the United Kingdom and one in Belgium. Intensive, semi-structured interviews [8] suitable to the need for flexibility to elicit the participants’ authentic perspectives and co-construct meaning through their experience, lasting approximately an hour, will follow.

2.3 Data Analysis

The analysis follows the coding procedure of CGT [8]. The overarching process is the constant comparative method and is defined by initial and focused coding. Initial coding stays close to the data to develop emergent understandings of actions and processes within the transcripts. It takes an incident-by-incident approach in which the unit of analysis focuses on critical incidents that can be compared within the interview. Focused coding involves synthesizing and sharpening the initial codes based on what is most relevant and significant in the data. The resulting more conceptual codes will reflect tentative attempts toward theory building. Given the interplay between data collection and analysis, theoretical sampling will occur in parallel, using emerging theory to select participants to fill crucial holes in the data and refine ideas.

Sensitizing concepts serve as guideposts in grounded theory to draw attention to potentially important aspects of the phenomenon under investigation. **Agency**, conceptualized here as the “socioculturally mediated capacity to act” [10] (p. 112). Engineering ethics education is often framed as developing individual moral agency [11]. However, a narrow focus on individual agency neglects environmental factors that enable and hamper agency, and as a result, practicing engineers often perceive their agency is limited in the face of ethical dilemmas [12]. Ethics training of future engineers should reflect agency in the macroethical perspective. **Engagement** has an important role in learning and student achievement. Drawing on Lawson and Lawson’s sociocultural framework [13], this research synthesizes engagement as a meta-construct with affective, cognitive, and behavioural components. This conceptualisation of engagement aligns with the affective, cognitive, and behavioural considerations in ethics while also integrating experiences inside and outside the classroom to reflect the multiple avenues through which students engage and develop an understanding of ethics. **Emotion** is inextricably connected to ethical decision making and risk evaluation in engineering [14]. However, engineering ethics education gives limited attention to emotion [15].

3 EXPECTED OUTCOME

3.1 Next Steps

Interviews were conducted with eight architectural engineering students at one university in Belgium in May 2022. Data analysis is ongoing and preliminary findings indicate minimal, if any, framing of ethics in the curriculum but each student pointed to a course or a professor who integrated notions of responsibility and impact. Since engineering is ubiquitous in the world around us, student expressed a background awareness of these concepts, but it was not until they were formally discussed in the classroom that students began to contextualize and internalize them. One participant described a single mention of responsibility by a professor as a “domino effect” after which he began to see responsibility throughout his understanding of architectural engineering. Students also expressed feeling anxiety and pressure related to their future responsibilities given the impact of engineering on human lives and the built environment. Data collection will continue with students in the United Kingdom in September and October 2022.

3.2 Theoretical Model Development

This research will develop a theoretical model of civil and architectural engineering students’ macroethical development with the aim of addressing how agency and engagement can be fostered in the classroom and how informal outside of the classroom can be leveraged.

4 SUMMARY AND ACKNOWLEDGMENTS

This study is designed to explore civil and architectural engineering students’ conceptualisations of societal responsibility and the impact of engineering. The aim is to contribute a novel theoretical model of macroethical development with implications for engineering educators, administrators, and policymakers seeking to prepare students for the sociotechnical realities of engineering practice and the ethical expectations of the profession.

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The teaching involvement of the users, the units and the whole UPC measured through the Moodle indicators of the virtual platform Atenea. An extension proposal of Atenea's BI platform

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ABSTRACT

Atenea is the Moodle virtual platform of the Universitat Politècnica de Catalunya (UPC) with about 31000 users and 5000 active subjects from 16 school centers. Atenea indicators give information on the teaching activity of the users and centers. This is specially relevant when teaching is online, as was the case in the Covid-19 period. The UPC already has a Atenea's Bussines Intelligent platform (BI), which has recently been launched. In this 1st phase the Institute of Science of Education (ICE) has actively participated in the design of the application. Currently it shows basic indicators over a period of time where one can filter or compare by centers or type of users. The paper presents this design and make a proposal for the extension of the BI, for the future, with respect to: 1) the inclusion of some key indicators for measuring the subjects' activity, 2) a proposal for cross-referencing data with academic performance.

1 INTRODUCTION

1.1 Teaching at the UPC

The teaching and learning development at the Universitat Politècnica de Catalunya (UPC) take place phase to phase at the schools, in classrooms or laboratories. Like most universities, the UPC also has a virtual learning environment to facilitate access to content, resources, documentation and to deliver digital tasks. The UPC has a unique Moodle virtual platform, named Atenea, which manages about 5000 courses and has 31000 registered users in the various school centres and Faculties (total 16), about 3000 are teachers. The regulation of training, learning opportunities, educational technology adoption, updating, and recycling of the knowledge of lecturers is managed by the Institut de Ciències de l'Educació de la UPC (ICE-UPC) [1].

1.2 Backgroun of Moodle indicators at the UPC

ICE is also responsible for training lecturers and managers in the use of learning management systems that are based on Moodle. In July 2019, ICE-UPC began the extraction and initial analysis of Atenea indicators. These practices and tests during over a period of two years gave us an insight into how to gain the maximum benefit from these indicators. Atenea's corporate business intelligence indicators (BI) for the UPC are currently being designed with advice from ICE, and right now a first limited version is already accessible for all the community [2,3].

During the period Covid-19 (from March to June 2020), lecturers were trained by ICE with online teaching and the use of Moodle tools, so the Ateneas platform use was extensive [4,5]. That background with the use of virtual techniques will surely enrich the traditional teaching, where a continuated evaluation across virtual platform will arise. For this reason it is important to study the virtual indicators that provide important information regarding the type of teaching activity—such as online continuated evaluation, the level of teaching activity for a given subject (even including assignments that were completed per user in a subject).

2 METHODOLOGY

2.1 Global key indicators

Atenea's BI, right now is designed that gives a global UPC useful information during a fixed period of time[2,3]. The indicators viewed are classified in:

1) Sessions/Users: Logged in sessions, logged in users, active users.
2) Activities/resources: Created (by teachers), Read (by students).
3) Qualifications: Input of grades and visits to rating grid

Graphs of the evolution of time are displayed where the unit of time can be chosen (hour / day / week / month). In addition, it can be filtered and compared over time by groups (Teachers (PDI) / administratives or estudents), units (school centers or departments), degrees (Degrees or Masters) and in some cases, by type of activities or resources. Finally, the relative weight of the indicator by groups, units and degrees throughout the period can be compared in bar charts. See examples in Fig. 1.

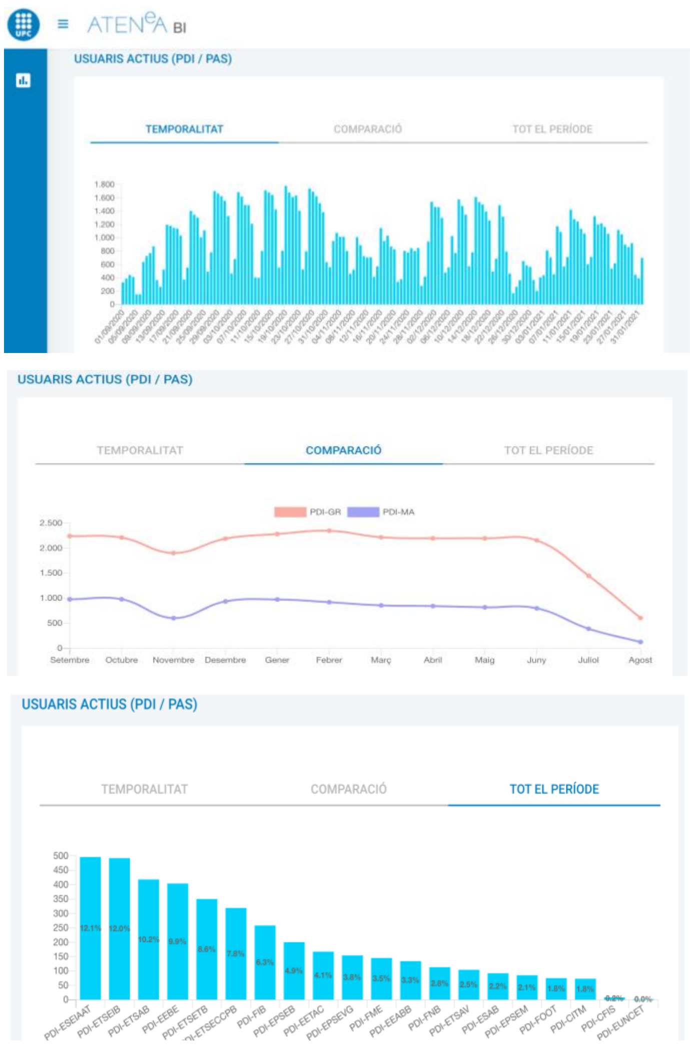


Figure 1. The Atenea's BI platform. Different displays during the academic year 2020-21.

2.2 Key indicators for measuring the online teaching activity

One useful teaching key indicator is the *Level of activity* of a subject during a term [2]. The subjects are classified according to the level of activity: low, medium, hight. We defined the level of activity depending on the number of actions by user in mean value. The reference values were taken from a 'normal' period of teaching (before covid-19 pandemics, for instance). The division was done, so that 66% of the subjects are medium activity and the rest are equally divided between high and low activity levels (see Fig. 2 like the application to a real example).

This is a good indicator to measure activity within a subject but to properly characterize the use of Moodle resources should be added:

- an indicator of *Intensity of use* for each resource / activity duly standardized similar to how it is done with the level of activity, and

- an indicator of the *Variety of use* of resources / activities used that simply counts the different number of resources/activities used.

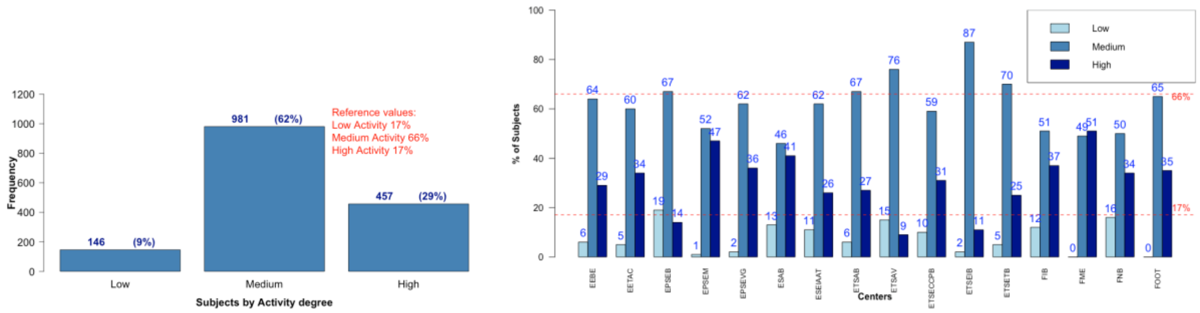


Figure 2. Left: Number (and %) of UPC's subjects during Q2-2020 term classified according to the level of activity and the reference values before Covid-19. Right: Comparison of the level of activity between UPC School Centres.

3 RESULTS

3.1 Proposal of extension of Atenea BI

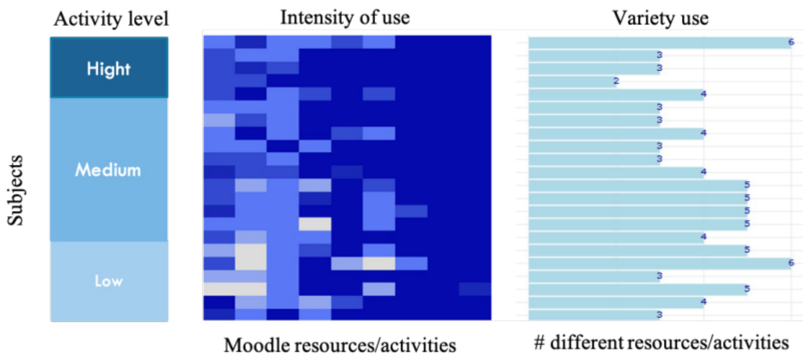
Thinking in terms of measuring and compare the subjects activity in a period of time seems natural to perform a heat map of the activity of all the subjects. A proposal of this is to use the 3 indicators in section 2.2 : *Activity level, Intensity of use* and the *Variety of use*.

A display proposal of a **heat map Atenea's activity of a center** is shown in Fig. 3, where the subjects activity of a unit is measured during a semester: each row is a different subject and in each column are ploted the three indicators. In this case the subjects are ordered with respect to the *Activity level* of subjects (see left row). The central colum of *Intensity of use* is ploted like a matrix where rows are the subjects and columns correspond to each type of Moodle resources/activities (files, tasks, quizzes,…), in addition the color of cell, gradated from white to blue, depends on the intensity of use, for instance measured from 0 to 5. The Variety of use is plotted directly like the frequency of different resources used.

An extension of this idea can be applied to see the **heat map of activity of the UPC centres,** changing subjects by school centres.

The heat map would be useful to cross-referencing data with academic performance, for instance with the percentage of non presented students. Is the engagement of students bigger when the indicators of activity of a subject are big?

Figure 3. Proposal of heat map of activity of a unit during a semester. Every row is a unit's subject



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DIGITAL DOCUMENTATION AND PLANNING OF STUDENT PROJECTS IN ENGINEERING AND PRODUCT DESIGN USING E-PORTFOLIOS

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Conference Key Areas: *Curriculum Development, Digitalisation and Hybrid models*
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ABSTRACT

The use of e-portfolios is very rare among academic teaching on engineering design and product design especially in Germany. Written exams and reports are not always suitable to evaluate competencies and skills of students gained through such projects. A wide range of competencies is required and a variety of results (sketches, 3D-CAD-models, real prototypes, user feedback, etc.) are generated, that cannot be adequately represented in a written exam or report. We see the use of e-portfolios as a solution to this problem. Our goal is to enable the documentation and planning of the entire product design process using e-portfolios for student projects in a course on product design - and thus also include the production and assembly of the individual parts until the real final product.

This short-paper will detail the necessary preparations and changes in content and organization to a course on product design and how the students are introduced to the use of e-portfolios. We develop a three-step process, that supports i) the preparation of e-portfolios (in advance to the course), ii) the design of individual e-portfolios (during the course) and iii) the evaluation at the end of the course.

The main findings of this work are seen in a provided recommendation on structure and design of an e-portfolio based course on product design (integrating required and useful software-tools and manufacturing machine interfaces) as well as the identified specific requirements of students and lecturers that need to be fulfilled to successfully implement e-portfolios.

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1 INTRODUCTION

The existence of e-portfolios and their use in the academic world are known and tested for many years [1]. In Germany however, e-portfolios are hardly used in academic teaching especially in MINT subjects [2]. Therefore we started to explore how to implement these personal, user centered online spaces to store data and project progress from student projects at our university. We use the open source e-porfolio software Mahara in a course on project-based product design within the bachelor's program on Sustainable Engineering to test and evaluate the use of e-portfolios as a digital option to document and grade student projects.

Until springtime 2022 students had to prove their acquired skills by a seminar paper at the end of the semester. From now on we plan to implement e-portfolios as a tool for documentation, reflection, and presentation of the acquired skills. The creation of an individual e-portfolio by each student as proof of the acquired skills will replace the seminar paper as the examination method.

This short paper is structured as follows. Section 2 details the necessary preparations and changes in content and organization to the existing course on product design. Section 2.2 will explain, how the students are introduced to the use of e-portfolios. Section 3 describes the evaluation of the changes implemented in the course and provides the results as well as conclusions and an outlook for the future of the project.

2 PREPARATIONS AND CHANGES TO IMPLEMENT E-PORTFOLIOS

To successfully implement e-portfolios as a new examination method and a new form of documenting and planning student projects in an existing course on project-based product design, changes to the course have to be made. These are detailed in the following sections.

2.1 Content and organizational changes to the course

The course on project-based product design for bachelor students used to test the use of e-portfolios during this research project is a mandatory course of the bachelor program on Sustainable Engineering at our university of applied sciences in Germany [3]. This is the only course focusing on product design in the curriculum of the bachelor program. In addition, there is no separate course in the students' curriculum that focuses on the fundamentals of project management. Therefore, we merged those two topics and designed a course that both satisfies the demands on product design education and provides an adequate first experience of project management for the students [4]. The students face a challenge to plan, design and build a first prototype of a wooden product for children (age: 3+) or a useful wooden product for teenagers (up to 16 years) [5]. They are free to decide on the target group for their product.

The course includes two 90-minute slots in the weekly curriculum over 14 weeks during each summer semester. The course is structured in two main parts, each spanning the entire semester and ends with a written seminar paper.

The first part is the theoretical part. It is assigned to the first 90-minute slot each week and includes seven lectures and five workshops that provide the content on relevant aspects of project management and product design, which are seen to be essential for the students and the success of their design projects.

The second and practical part is assigned to the second 90-minute slot each week. During these time slots, the laboratory for creative prototyping is open to all students to discuss their projects and designs with colleagues, the lecturer as well as the lab engineer. Furthermore, the students can get to know the available manufacturing machines and tools in the lab, take part in safety training and (usually rather later in the project) manufacture and assemble their prototypes.

These parts had to be shortened to make room for the workshops described in section 2.2. Therefore the lectures where shortened a little and the workshops on relevant aspects of project management were reduced to four. This makes room for a 60 minute time slot for the introduction of e-portfolios each week. Enough time to support the students with their task on planning and documenting their project as well as to answer their questions and collect feedback.

In preparation for the course and the added use of e-portfolios an e-portfolio system within the universitys network infrastructure was set up. We use the open source software Mahara combined with the learning platform moodle to provide the necessary infrastructure to digitalize the course and make everything accessible for students and staff members of the university. Within the moodle platform we set up a digital version of the mandatory safety instructions for the laboratory including a test to provide proof and documentation for further traceability. All operating instructions and safety instructions for the machinery within the laboratory like CNC carving machines, milling machines and different power tools are combined to an e-portfolio within the Mahara system. The necessary URLs for the different browser based design and manufacturing software tools to be used for the realization of the projects are also provided via a moodle course.

The legal aspects of a new examination method in the form of e-portfolios are also checked and discussed with the responsible people at the university.At the moment exists no final decision on this subject but a change of the general examination regulations to allow the use of e-portfolios seems inevitable. Our test within the research project is not affected by this.

2.2 Introducing students to e-portfolios

To introduce e-portfolios to the students we use weekly workshops and example portfolios as a source for inspiration. These weekly workshops are always led by the same person of the research team and supported by the others regarding student questions and technical issues with the system. The workshops are designed with a constant development of complexity and entitlement in mind. They provide the students with the necessary competencies to create their own e-portfolios out of their project task. Example portfolios show the students a selection of possible layout strategies and stored data (e.g. sketches, 3D-CAD-models, time schedules, etc.). The example portfolios also outline the requirements of the lecturer regarding the contents of the e-portfolios. These have to be fulfilled by each student to get the e-portfolio graded.

3 RESULTS AND CONCLUSIONS

The regular evaluation of the project progress, the feedback from the students and the lecturer as well as the evaluation of the e-portfolios created by the students provide the information, if e-portfolios are a sufficient way to digitalize the documentation and planning of student projects. At the current time only the first student group of the course and the corresponding e-portfolio work can be evaluated. After some problems with the user authorization and the setup of the Mahara system the received feedback is consistently positive.

We found, that the use of e-portfolios has different advantages compared to written seminar papers. They allow parallel working on the design project and the exam and thus allow the students to safe time and effort at the end of the semester as well as optimize their available time to work on the project itself and the documentation. E-portfolios additionally allow a creative and free design of the documentation and support the reflection and cooperation skills of the students via the peer to peer and tutor feedback within the portfolio software. The global availability of the e-portfolio via the internet and the opportunity to share it easily with a selected audience are significant benefits. Students can proof their acquired skills to future employers based on data and facts instead of plain conversations. E-portfolios also provide a better understanding of relatively complicated projects or unstructured ideas.

The final e-portfolios of the projects done by the first student group lead to the conclusion, that e-portfolios are a suitable way to document and plan engineering related projects within university courses. The variety of opportunities and the added creativity have a positive impact on the quality of the students work. However, it must be mentioned that there is still room for improvement with regard to the possibilities for project panning and project management within the e-portfolio software (e.g. milestone planning).

Further the lecturer will reflect his own seminary based on the course proceeding, the e-portfolios of the students and their evaluation of the course. This comprehensive critical analysis is very important to further develop portfolio work and to increase common knowledge in the field of e-learning by sharing the experiences with others.

4 ACKNOWLEDGMENTS

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FACTORS OF EFFECTIVE INTERDISCIPLINARY ONLINE TEAM LEARNING

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Conference Key Areas: *Student Engagement. Building Communities and Coordination*
Keywords: *interdisciplinary, team learning, psychological safety, virtual*

ABSTRACT

The pandemic has forced higher education to radically change the teaching format from face-to-face mode into virtual or hybrid format. Also, intensive courses, workshops and seminars have been conducted totally or partly online. These formats include lots of students` team work in order to succeed. Starting to work virtually with strangers might be difficult for students. Our paper presents how we developed and conducted two interdisciplinary team learning projects during the academic year 2021-2022 and the results we got. Our projects were implemented in the BSc degree programs of engineering, business administration and nursing at two Finnish UAS and at two foreign partner universities. After the courses we collected qualitative data from students´ learning diaries and other reflections and performed content analysis which revealed that there are supportive and hindering factors for virtual team work and they should be considered while designing the learning experiences.

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1 INTRODUCTION

At this time with the pandemic, the learning curve for virtual cooperation has been dramatic, for both companies and public organizations, including universities and other educational institutes. The digital transformation combined with a pandemic has both forced and allowed us to work and learn on distance. We have witnessed a dramatic growth of meetings in virtual platforms within the two past years (2020-2022) and those platforms have become everyday tools in studying as well. Our students are now used to work both alone and together virtually, but what type of factors are affecting their collaboration in the virtual context?

Previous research gives consistent hints that getting along with each other is essential in groups, in terms of both performance and well-being. The term used for this is cohesion, which is also related to concepts such as involvement, coordination, communication and trust [1]. To successfully continue working together virtually, these factors must be considered.

Also, we need to underline the importance of common understanding and shared interpretation. Unshared understanding is often regarded as hindering collaboration and communication, but on the other hand, versatile knowledge based on various disciplines is needed especially in contexts where the aim is to innovate and create new ideas and solutions. An argument can be made that in order to have both shared and opposing views in a team, coordination must be wisely used, in order to understand the different phases of cooperation: when innovating you need to accept various views without confrontation, and when making decisions you need common acceptance among team members. This is an interesting paradox as both convergence and divergence are needed in order to produce good team performance.

Psychological safety is an old concept [2] but during the last decades it has been further developed, researched and applied to different team work situations and learning by e.g. Edmondson [3]. Psychological safety (PS) is a “condition in which person feels included, safe to learn, safe to contribute and safe to challenge the status quo without fear of being embarrassed, marginalized or punished in some way [4]. Psychological safety has been found, e.g., to facilitate team learning [5].

In this paper, we aim to shed light on the topic of how to support cohesion and psychological safety in virtual student teams in order to achieve good team learning performance. We describe preliminary findings from our teaching experiments which were two interdisciplinary intensive courses, which we have planned and executed at two universities of applied sciences in Finland together with two partner universities abroad.

2 METHODOLOGY AND DATA COLLECTION

The first course implementation (hybrid version) was organized in autumn 2021 simultaneously both in Finland and in one location close to the western border of China. There was a time difference between the locations which had to be considered in the course implementation. This course consisted of students´ pre-work online and one face-to-face intensive week at two campus locations and at two touristic destinations. During the intensive week, the multicultural group of students from different BSc engineering disciplines (mechanical, material and environmental engineering) learned different waste management and energy related issues and how to use a multi-criterion decision-making tool (MCD). This tool was then used by the student teams in the touristic sites for solving the team project task which was suggesting a suitable waste to energy solution for the touristic location. The task solution was based on interview data and other data collected by the students on the sites. This data was then processed with the MCD. In the end of the week each multinational team presented their suggestion for the site given to the team. During the week one part of the activities, lectures and teamwork were performed online and another part onsite face-to-face.

The latter course implementation (online version) took place only in Finland during the spring 2022 at one Finnish university of applied sciences. In this implementation, there were students from three different disciplines, namely engineering, nursing and international business BSc students. These students worked in international, interdisciplinary teams of 4-6 students for an intensive week. They were given a problem from a client organization and the teams worked with the problem, innovating solutions to be presented at the end of the week. The students were working only online all the time.

Our preliminary analysis is based on content analysis of written student reflections given after each course implementation. The interpretation of these reflections has aimed to understand what type of meanings the participants have attached with their experiences of virtual teamwork and learning. The reflections have been qualitatively analysed by reading them and analysing how and to what extent their perceptions differ. By comparing similarities and differences, different categories of description have been formed and reflections with similar meanings grouped in the same category.

2.1 Supportive factors

When analysing the different categories, we were able to distinguish two main categories: those elements which *supported the cooperation* and other elements *hindering the collaboration*. Then, we looked at the differences between the different disciplines in terms of how they perceived supportive factors of teamwork in virtual context (see Table 1).

We can notice from the comments that all students mention *respect, listening, sharing ideas, encouragement and having different visions* as supportive factors for virtual team work. All of them are factors describing psychological safety according to the previous research. Students also mention having fun and joy to be important supportive factors in virtual team work and learning. This is perhaps something teachers easily forget when they are planning the learning experiences?

Table 1. Supportive factors experienced in virtual context according to the study field

Engineering	**Nursing**	**International business**
-sharing the same goal -respect -encouragement -having fun -inspiring each other -group thinking -agreeable personality types *"Different point of view combined creates good results"*	-focusing on the task -open mindedness -respect -understanding -needing something from each other -listening skills -sharing ideas -making things together -being professional *"We all needed something from each other, they all knew from their field, we made them all together"*	-equal effort -energy and passion -having different visions -coordination efforts such as time management and solving misunderstandings -communication -fun -being professional -encouragement *"My observation is that the team must move forward together somehow"*

2.2 Hindering factors

In Table 2 we can see which factors students perceived to be hindering their virtual teamwork. Our results show that *communication* was the most frequently mentioned factor that was hindering the effective virtual teamwork and learning. The communication problems were caused by many reasons. Students mentioned the following ones: unreliable virtual technology, poor English language skills and communication problems caused by the time zone differences. They also perceived difficulties to communicate in such a manner that the students from other disciplines would understand their message. In addition, they mentioned comprehension problems caused by the language and terminology used and the way of presenting ideas etc. Although students had some training for team development and diversity issues, it seems that not all teams were able to apply this knowledge in practice in their teams.

Table 2. Hindering factors experienced in virtual context according to the study field

Engineering	Nursing	International business
- communication - Internet connection - difficulty in understanding each other - language barrier - difficulties to agree - coping with different personalities - time management - thinking outside the box *"We had difficulties to communicate: express our ideas and being understood by the foreign team members"*	- time difference - understanding different personalities - communication - responsibilities taken were not equally shared -misunderstandings -hard to work with different disciplines as ideas are so different *"Due to different fields some people were very familiar with certain stages but because others are not familiar it would take more time."*	- understanding each other - the lack of communications or difficulties in communicating properly - having a lot of different perspectives, opinions and priorities -problems with some members not being involved in discussions -different levels of expertise *" It can be frustrating if some study field students are not used to doing tasks like this."*

3 CONCLUSIONS

Students mentioned that the teachers should have forced them to communicate more with each other. When planning especially the hybrid course the teachers decided beforehand that the students were free to use any virtual communication tools. After reading about the communication problems in the reflections and comments in the students` learning diaries and feedback formulas we have to conclude that perhaps it was a mistake to leave the communication issues for the students to organise by themselves only.

There might have been some psychological safety issues meaning that not all students felt safe enough to ask "dumb" questions from their virtual team members while being afraid of losing their face. As cameras were not used much in the students´ virtual team meetings the gestures and body language could not be seen, and this might have caused some of the communication problems too.

Based on both theoretical and empirical analysis, in order to create psychological safety the teacher should design the educational situation so that following four elements are present: *openness* (tell who you are, let people get to know you), *direct talk* (dare to raise the problems and also difficult issues into discussion), *credibility* (be consistent, no nonsense, take responsibility of your sayings) and the most important one *approval* (listen, everybody has a value, dare to reveal /tell about your own failures etc.). These elements form collective trust needed.

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TWO APPLICATIONS FOR TEACHING TELECOMMUNICATION ENGINEERING STUDENTS THE ATMOSPHERIC EFFECTS ON THE OPTICAL CHANNELS. APPLICATIONS IN ASTRONOMY, MECHANICAL ENGINEERING AND TELECOMMUNICATIONS

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Conference Key Areas: *Physics and Engineering Education, Virtual and Remote Labs*
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ABSTRACT

Atmospheric turbulence is one of the limiting phenomena in interesting applications and fields such of optical telecommunications and Observational Astronomy. Both Telecommunication and Aerospace Engineering students may encounter those

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applications in their professional careers, thus, there is the necessity to introduce this phenomenon and its impact on those fields at the academic formation stage.

In order to teach students of the principles and effects of the atmospheric turbulence in optical propagation, and to illustrate how to solve these problems, two different applications written in MATLAB© were developed.

In this communication both applications and the theoretical background are presented, and the designed activity for Telecommunication Engineers is shown. Results obtained by students and their experience performing the activity are also presented.

1 INTRODUCTION

The atmospheric variations due to fluctuation of the different meteorological parameters (pressure and temperature) affects the refractive index of air, thus modifying the propagation of optical signals throught the atmosphere.
Those variations on the trajectory of the signal have a great impact in Optical Telecommunications and Observational Astronomy, among other fields. Being aware of the growing interest of the optical telecommunications market, and the necessitity of improvement of Adaptive Optics technologies, aiming the necessity of enlarge the recruitment of new engineers, and the fact that, typically, atmospheric turbulence is poorly analyzed in the academic formation of such future engineers, a MATLAB®-based application has been developed, in parallel with a computational workshop that has been designed in order to introduce this topic to Telecommunication Engineering students.

This communication summarizes the basis of this application and the future implementation of the said workshop.

2 METHODOLOGY

2.1 Physical basis

To simulate the effect of the atmospheric variability and turbulence on the propagation of a light beam, wto basic theories are considered. First, the simulation of the atmospheric turbulence is done by means of the so-called Kolmogorov's theory of atmospheric turbulence.
On the other hand, the diffraction theory of light provides the theoretical mathematical basis for describing the propagation of an optical signal (usually a two-dimensional signal which propagates in the third dimension). As is deeply described in the existing literature, diffraction is, by definition, the deflection of waves around the corners of an obstacle or through the aperture in the region of a geometrical shadow of the obstacle. Thanks to Huygens principle, the diffracting object or slit effectively becomes a secondary source of the propagating wave. This framework is useful for describing two-dimensional light sources and the propagation of its corresponding radiation between different planes.
The combination of both theories allows to the simulation of the propagation of a light beam throught atmospheric turbulent layers, hence, allowing the simulation and evaluation of the harmful effects that the beam suffers. Figure 1 shows a schematization of the process that is implemented in the next subsection based on this two mathematical and physical frameworks. Both mathematical descriptions are

widely exposed on the existing literature. The interested reader is referred to [1], [2], [3] and [4].

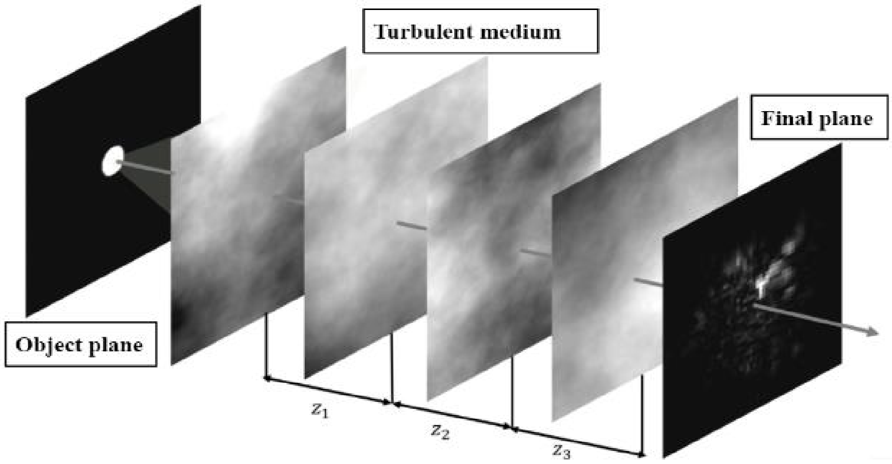

Fig. 1. Propagation of an optical signal through a turbulent medium. First, an emitting object in 2D is defined (in this example, a circular emitting source). Later, the different phases screens corresponding to several turbulent planes are generated at the corresponding distances $\mathbf{z_i}$ from the original plane (the object plane). Finally, the resulting amplitude in the final plane is obtained. This working scheme is valid for both the analysis of the effects of the turbulence on the optical quality of an astronomical observation and for the case of a communication between an optical emitter and its corresponding receiver.

2.2 The application

Applying the above-exposed theories, an application written in MATLAB® was developed.

The software presents two different options for simulations:

- Astronomical observation. This option allows the user to simulate an astronomical observation from a ground-based telescope under different meteorological conditions. Furthermore, this option permits to analyze the wavefront distortion due to turbulence and to implement a correction using Adaptive Optics. See Figure 2.
- Satellite communications. This option permits the simulation of the optical link between a ground station and a satellite, and to analyze the effects of the bad meteorological conditions to such communication. See Figure 3.

3 RESULTS

The application developed for this work is capable of provide interesting computational results for engineering in the fields of Adaptive Optics and Free Space Optical Communications.

As an example, the following figures show the main capabilities/possibilities of analysis of the developed code.

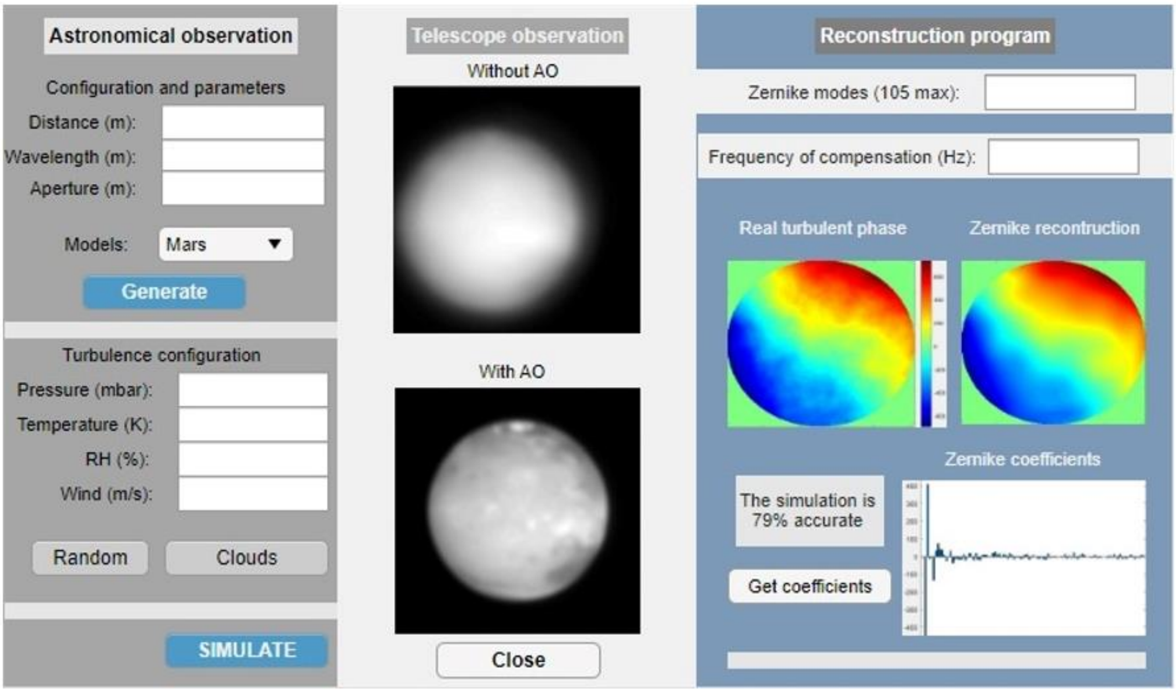

Fig. 2. Main window of the Adaptive Optics application. The software allows to simulate a situation without the implementation of Adaptive Optics and also a solution implementing Adaptive Optics. The program also represents the distorted wavefront.

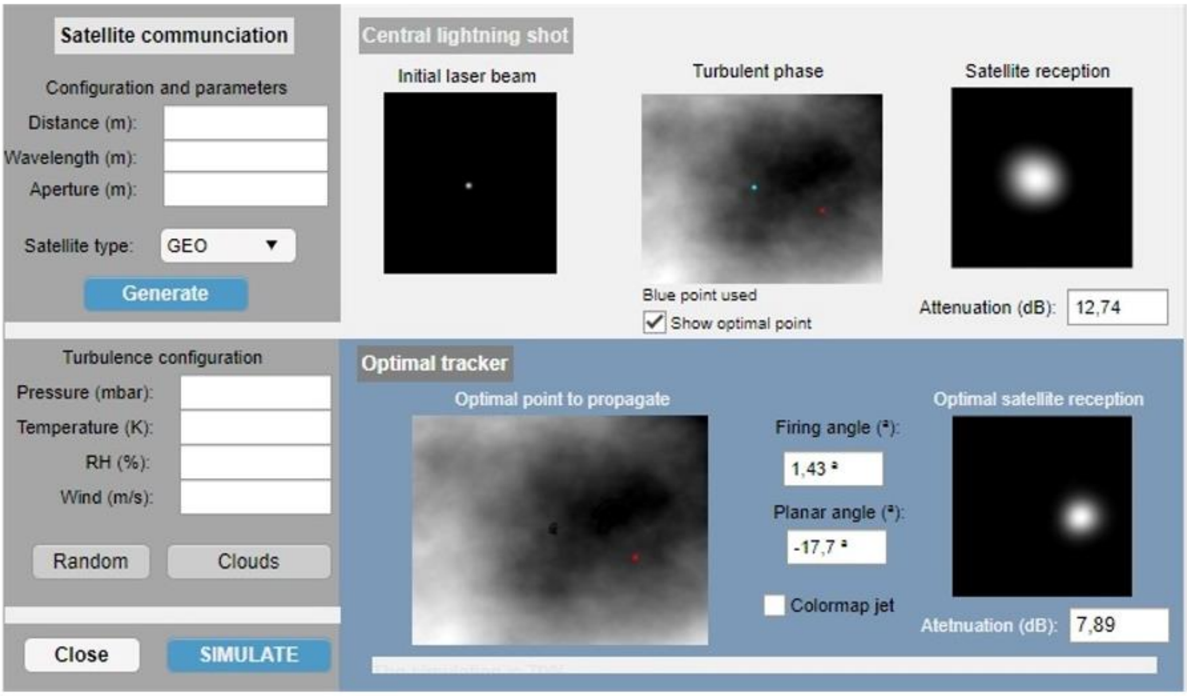

Fig. 3. Main window of the Optical Communication application. The software allows to evaluate the loss on the signal introduced by the atmospheric tubulence. Furthermore, the application prmitts the estimation of the optimal path for the propagation of the optical signal.

4 SUMMARY AND ACKNOWLEDGMENTS

Using the software presented in this paper, which has been developed during a student final degree project, two different workshops has been designed. First, a workshop to set up the basis of Adaptive Optics and design of such kind of systems for Ground-based telescopes has been designed. Second, a workshop introducing the Optical Communications basis and atmospheric turbulence influence in the optical channel has been written. Both workshops are going to be performed in next months, with the participation of Telecommunication and Aeroespace Engineering students. A future work will present the early results obtained with the software and the students' feedback.

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EDUCATING ENTREPRENEURIAL ENGINEERS - TO BE CONTEXT-AWARE OR GENERIC?

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Conference Key Areas: *Curriculum development, Entrepreneurship education*
Keywords: *context-awareness, engineering, entrepreneurship, education*

ABSTRACT

Entrepreneurship education (EE) is high on the agenda of governments and universities globally. With the new forms of entrepreneurship, there has been a surge of specific training programs and materials, e.g. ones dedicated to social entrepreneurship as well as for science & technology-based entrepreneurship.

Parallel to this division of EE into subsegments, tools and methods such as the Business Model Canvas (BMC), Lean Start-Up and Customer Development methods, or Disciplined Entrepreneurship by MIT have spread to be used by EE practitioners globally.

With the increasing globalization, virtualization, and mobility of learners, EE courses have learners differing in 1) their cultural context that reflects in their values and beliefs, 2) their educational and professional background, and 3) in the area - market and industry - where they aim to start their business. E.g., the process of entrepreneurship is likely to differ in dynamics when going into medical technology vs. mobile gaming, yet some aspects may be mutual to both businesses.

Thus, EE education is facing a dilemma: How unified and non-context specific should the approach of the educator be to deliver EE in scale and keep the EE program manageable vs. how much to focus on the individuals or teams and their specific context.

The paper draws its conclusions based on the quantitative survey done among 60 entrepreneurship educators globally in February-March 2022. The global respondent pool consisted of educators diverse in the context they come from, institutions and faculties they work at, and the type of entrepreneurs they have trained. The data analysis is based on descriptive statistics based on the assessments done by the respondents on 4- or 5-step Likert scales on perceived current EE practices and the perceived importance of different factors in successfully context-aware EE. The core taxonomy used to elaborate on context is the PESTEL-analysis of the environment, consisting of Political, Economical, Social, Technological, Ecological and Legal factors.

The results indicate that the economical-technological consideration is weighted in today´s EE generally speaking, whereas the truly context-aware EE would balance that leaning to economical and technological matters with more factors, especially the one of social context. Another takeaway to participants is a set of proposed EE designs that deal with the contradicting forces.

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1 INTRODUCTION

1.1 The meaning(s) of context

Context is a construct both wide and widely used in research and development across disciplines. In business and industrial research, context can mean a specific set of environmental variables in which an organization operates (external context) but also the characteristics or a category of the organization under study (internal context). In addition, contexts can be studied either as the possession of specific characteristics of an individual or of a community. Individuals are likely to interpret their surroundings differently because of their differing habits, routines, and intelligence. Parallel to that individual interpretation, however, we identify ourselves not only as individuals but as parts of social systems we link to [1]. In practice, since these two scopes are inbuilt and interdependent. What we perceive as our context (our habits, experiences, values, etc.) has been and continuously is affected by other individuals and institutions around us – the schools we go to, courses we take as well as companies and markets we operate in. Institutions such as Higher Education Institutions (HEIs) engaged in business, engineering, and entrepreneurship education act as a context relevant for this study. Likewise, industries and companies offer specific contexts to which individuals and entrepreneurial teams adapt.

Since engineering is fundamentally built on science-backed findings in natural sciences, technology-related views and skills have the potential to be less context-dependent than more culturally bounded functions in business activity, such as HRM or marketing. In other words, “technology travels well”. In the same vein, it can be argued that in technology-based entrepreneurship the market opportunity and competition are global, whereas in cultural and service-based industries the scope is more likely to be local or regional. Despite a potential lowering of contextual boundaries, the context has still been claimed in research to play an important role in issues such as innovation, inter-organizational learning, and entrepreneurial actions.

For the scope of this study, we synthesize the prior research on context stating that 1) context is both situational as well as a prevailing condition that in its part explains, directs, and delimits action, 2) context is both an individual as a social/institutional construct, and 3) context is present – consciously or subconsciously – in multiple areas of entrepreneurship and engineering (education) research and practice.

1.2 Context and context-awareness as factors affecting educational practice

Following the ideas of the previous section, understanding the concept of context is a solid starting point for analysis of how context(s) affect education. Adaptive

context-aware learning environments (ACALEs) are expected to detect learners' context and adapt learning contents to match the context identified to make education more relevant to learners [2]. Context-aware systems understand the situational needs and offer at the right time the relevant information.
Learning context consists not only of individual learners with differing contexts but also of the social fabric they jointly create and to which also the educators pertain. The concept of learning spaces consisting of physical, social, cognitive, and virtual environments captures in a wider meaning the context for education.
Also, the context that an educator brings into a learning space moderates the learning process. Some studies like conclude that the "teacher effect" outweighs the effect of the methods used in learning efficiency and student achievement [3]. It has become imperative that educators in the modern world with characterized by increased mobility of people, immigration, refugee crisis, etc. acquire competencies in the diversity of contexts present. Does this apply also to subsegments of education in engineering and education – and their combination?

1.3 Context and context-awareness in entrepreneurship

A big part of the entrepreneurship education within HEIs' entrepreneurial courses and incubation/acceleration programs focuses on students in business and science /technology majors. Companies born in these environments are so-called *born globals.* These companies conduct international business at or near the founding of the firm. Events in recent decades – primarily globalization and the emergence of key technologies – have facilitated the rise of born globals.
As a result of the opportunities and role models offered by successful young but global entrepreneurs, EE has embraced methodologies suited to the goals of growth and internationalization. Methods such as Customer Development, Lean Start-up, Business Model Canvas, Design Thinking, and MIT's Disciplined Entrepreneurship have spread to entrepreneurial programs across continents, universities, and faculties. This trend depicts EE as a rather context-independent phenomenon. However, entrepreneurship as an activity has been described as a context-laden and context-bounded phenomenon worth studying with the context in focus [4]. There are studies on the impact of regional, technological and institutional context on EE. This paper adds to the body of knowledge on context-aware entrepreneurship education, with a focus on the technology element of context.

2 METHODOLOGY

The research method of this paper is a quantitative one based on a survey directed to scholars who had published within the last 4 years in the regional and local conferences on entrepreneurship education (EE) and/or were known by the researcher team to act as entrepreneurship educators. Some of the respondents had written their studies based on EE within Schools of Engineering, but the organizational background of respondents or research focus outside the "entrepreneurship education" definition was not a selection criterion. The survey link was sent to some 250 respondents, in addition to which the receivers were requested to spread the link to their EE network. The assumption on the response rate is some 20 %. Data were collected in February-March of 2022, as a cross-sectional explorative study aimed at identifying the interesting areas for further studies with larger data sets and a qualitative approach focusing on the root causes for the findings reported in this paper.Demographically the respondent pool was heterogeneous, 43.3% of the respondents were females and ages were distributed to 5%/20-30 years, 21.7%/31-40 years, 40%/41-50 years, 20% /51-60 years/ and 13.3%/over 60 years). Present educational contexts were: in North America 20%, Mid- and South America 1.7%, Europe 60%, Africa 1.7%, and Oceania16.7%, thus Mid- South America and Africa are underrepresented. On average respondents had acted 12 years as an entrepreneurship educator. The learning spaces of respondents were described by 28.3% as monocultural, 46.7% as somewhat multicultural, 7% as quite multicultural, and by3% as very multicultural. Due to a relatively small dataset gathered at the time of writing this paper, the results are presented with descriptive statistics, further papers are targeted to contain more data and analyses on statistical significance.

3 RESULTS

3.1 On current practices of context-aware entrepreneurship education

First, the respondents' views of the general context-awareness practiced in entrepreneurship education were screened, after which it could be mirrored in the respondents' self-perceived view on their context-awareness in EE.

	Is very rarely context-aware	Is sometimes context-aware	Is often context-aware	Is very often context-aware	Is always context-aware
Entrepreneuship education…	6,8%	37,3%	30,5%	20,3%	5,1%

Table 1. Q: "How well do you perceive contextual issues are taken into account in Entrepreneur education generally speaking?"

	I am not context-aware	I am sometimes context-aware	I am often context-aware	I am always context-aware
In my Entrepreneurship education…	1,8%	17,5%	71,9%	8,8%

Table 2. Q: "How would you describe your context-awareness in Entrepreneurship Education?"

As a comparison of Tables 1 and 2, it can be stated that the study attracted EE practitioners with higher context-awareness than their average EE peers. This may *lead to overinterpretation of findings, but also the findings may act as a model for more context-aware (if that is needed, see section 3.2.) EE of the future.*

3.2 Is context in entrepreneurship education technology-sensitive?

A common way to describe a context/operational environment made of elements is the PESTEL-analysis, made of political, economic, social, technological, ecological, and legal factors. Our findings (Tables 3-5) propose that a) different PESTEL areas of context enjoy varying perceived importance in successful EE, b) the current practices highlight the importance of context as a technical-economic system, and c) the context-aware teachers (our sample) perceive themselves to be context-aware in a more balanced way across PESTEL-factors, but still d) they put even more weight into economic-technological context than they perceive to be common in EE.

	Very unimportant	Quite unimportant	Not important nor unimportant	Quite Important	Very important
Political context	5,2%	12,1%	17,2%	39,6%	25,9%
Economical context	1,7%	1,7%	3,5%	31 %	62,1%
Sociological context	3,4%	1,7%	8,6%	46,6%	39,7%
Technological context	1,7%	1,8%	8,8%	33,3%	54,4%
Environmental/ ecological context	3,4%	5,2%	19 %	25,9%	46,5%
Legal context	1,7%	5,2%	13,8%	44,8%	34,5%

Table 3. Q: "How would you rate the importance of contextual issues for a successful entrepreneurship education?"

	Never taken into account	Sometimes taken into account	Often taken into account	Always taken into account
Political context	10,1%	42,4%	39 %	8,5%
Economical context	0 %	17 %	52,5%	30,5%
Sociological context	1,7%	37,3%	55,9%	5,1%
Technological context	0 %	23,7%	42,4%	33,9%
Environmental/ ecological context	1,7%	42,4%	44,1%	11,8%
Legal context	5,3%	38,6%	45,6%	10,5%

Table 4. Q: "Which contextual elements do you perceive are taken into account in Entrepreneurship education generally speaking?"

	Never taken into account	Sometimes taken into account	Often taken into account	Always taken into account
Political context	10,2%	35,6%	37,3%	16,9%
Economical context	0 %	6,8%	45,8%	47,4%
Sociological context	1,7%	18,6%	47,5%	32,2%
Technological context	1,7%	19 %	36,2%	43,1%
Environmental/ecological context	6,8%	22 %	45,8%	25,4%
Legal context	5,1%	35,6%	28,8%	30,5%

Table 5. Q: "Which contextual elements do YOU take into account in YOUR Entrepreneurship education?"

One interesting finding is the weak focus on legal matters as compared to technological/economical factors. If the legislation was able to reflect the prevailing trends in business and technology, the legal considerations would match in importance a) technology areas such as artificial intelligence, cybersecurity, and robotics would follow, and b) business trends and models such as marketing automation, platform businesses, etc. As this is not the case in our data, we conclude that the technological/economical context keeps developing and changing at a higher clock speed than other areas of PESTEL affecting EE.

4 SUMMARY AND ACKNOWLEDGMENTS

We conclude our findings by stating that context still matters, despite the "global village" of mixing cultures and the fast-spreading of novel technologies across the world. The technological context still is a powerful contextual moderator. We suggest the research community pay attention to technological context and adapt the prevalent models to the degrees of technology sophisticatedness and intensity.

We aim at adding with our future work to add to the knowledge pool on the subject through qualitative research. We also encourage research on the technological context and studying that phenomenon via the constituents that make it: What are the differentiators between different technological contexts relevant to be taken into account in engineering-based entrepreneurship: Infrastructure, skill levels, availability of technology suppliers, technology levels of potential customers?

Due to the limited size of the sample, the generalizability of the results is limited, especially in African and Mid-/South-American contexts. Despite that shortcoming, our aim at exploratory research that would help to understand the phenomenon under study better and indicate areas for further study was reached.
Acknowledgments for this study's achievements belong to Dr. Alexandros Koukaris from the University of Peloponnese in Greece for joint data collection and analysis.

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SMART PRODUCTS, ENGINEERING AND SERVICES – AN EXAMPLE OF MODERN ENGINEERING EDUCATION

(2 spaces)

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Conference Key Areas: *Curriculum Development, Engineering Skills*
Keywords: *Agile development, flipped classroom, smart systems, rapid manufacturing, condition monitoring*

ABSTRACT

As digitization and Industry 4.0 progress, the need for smart products and innovative business models increases. This contribution presents the underlying novel concept of the collaborative course “Smart Products, Engineering and Services”. The objective is to enable students of mechanical engineering to develop and work with smart products, and to derive possible business models for their use. A combination of traditional lectures, flipped classroom exercises and a development project characterizes the unique character of the course. The presented topics range from the basics of sensing machine elements, intelligent mechatronic systems and the use of artificial intelligence in the latter. Further, it comprises product development methods such as agile development, V&V methods and the usage of rapid

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manufacturing technologies. The flipped classroom exercises serve as preparation for the project work and allow students to gain practical experience with additive manufacturing processes as well as cyber-physical systems. As part of the project work, students develop a smart product which must complete the control task of balancing a body on vertically excited surface by minimizing the bodies movement. For this purpose, the kinematics, the controller, and the usage of a force-measuring ball bearing as a sensing machine element are predetermined. Missing components must be designed and manufactured in a Makerspace using 3D printing or laser cutting and the developed controller must be implemented. The smart product is finally tested on a specially developed test rig.

1 INTRODUCTION

Nowadays, an engineer will not be performing the same task throughout his work life. In our fast-paced world, quickly learning and transmitting newly acquired knowledge to team members has become much more important (Castaneda & Cuellar, 2020). It is paramount to know and understand technologies such as AI, Big Data, rapid prototyping etc. in order to grasp the potential and the development implications for new products. Equally important is the ability to manage a team through an environment with limited resources in time, material, and availability of production capacities. Especially with regard to time, rapid prototyping can be leveraged to achieve quick transitions from concept to prototype, thereby accelerating development speed. The new Master's course Smart Products, Engineering and Services (SPES) is held for the first time in 2022. The concept is a response to the growing need for highly versatile engineers that not only dominate their own domain, but in addition show expertise in neighbouring areas. The topics of the lectures range from the basics of smart mechatronic systems and smart machine elements over rapid manufacturing technologies and agile development methods to the application of smart systems for e.g. condition monitoring. Furthermore the lecture covers market analyses and business models in order to discuss and analyse the economic potential of smart products and services. Accompanying the lectures, Flipped-classroom exercises and a complex mechatronic development project subsequently to the lectures are performed in groups of five. The flipped-classroom exercises topics expand the concepts presented in the lectures and facilitate the application of theoretical knowledge throughout the development project. The project itself assists students in the transition from theory-driven university to the industry.

2 METHODOLOGY

The teaching concept integrates the idea of deepening theoretical knowledge gained within the lectures into two student-centered teaching approaches. After conveying the key knowledge in compact lectures during the first five weeks, SPES aims at breaking through the simplifications of a purely theoretical course and confronts students with problematics that arise when working on an engineering problem. Prior to the project work the students can participate in the flipped-classroom exercises as a team. The format incentivises students to prepare their works individually and present their findings shortly. This enhances communication and presentation skills. As a motivation, a successful participation improves the student's final grade by earning a small bonus. The flipped classroom is a method to teach problem solving skills for more complex tasks. Developed by Bergmann and Sams (2012) for schools and adapted for higher education it flips the traditional way of teaching and learning. Instead of learning the basics in face-to-face classes and reinforcing what they have learned by solving assignments at home, students prepare for a lesson by learning the basics individually. In the lesson itself, the students solve tasks together or discuss the learning content (Werner et al., 2018). Cho et al. (2021) list studies that found various advantages and disadvantages of using flipped classrooms in mechanical engineering teaching. It is shown that the flipped classroom leads to a higher learning success, as long as the number of participants is not too large, or is managed appropriately. With approximately 25 students, the number of students is similar to the size of a school class and is therefore suitable for the Flipped Classroom.The final project phase is accompanied by a limited number of optional helpdesks where students can seek counsel regarding engineering topics. This teaches them to self-identify their weak spots and carefully choose on what questions they need aid. The final grade is based on the written exam at the end of the project phase as well as the evaluation of a written project elaboration and an oral colloquium of the project results.The results of exercises and project work are included into the curriculum to iteratively improve the course for future terms. Doing so the work of participants has a direct influence on the orientation of SPES and aligns the discussed topics to the need of students and the industry.

3 RESULTS

The concept of SPES is based on a review on state-of-the-art teaching methods. Ten lectures convey the basics for the successful realization of a smart product. Lectures about business models, market analysis and acceptance, innovation management, and concepts for generating ideas give an overview to get in touch with methods and the jargon of economics. Additionally, eight lectures cover a wide range of interesting methodologies in growing R&D areas. Core ideas transmitted are implications and methods for developing products in a fast-paced world leveraging available technologies such as rapid prototyping, AI methods, and Big Data. Even most recent research results are introduced to the auditory in order to enable innovative smart products utilizing current research trends were possible, (Reichwein et al., 2020). Up-to-date norms are discussed in the context of the classical V-model for product development as well as agile development.

3.1 Flipped Classroom exercise

The flipped classroom concept encourages students to deepen their knowledge and to train teaching and presentation skills. First, the individual student teams are given a list of tasks, of which they individually choose two tasks, complete them and teach their insights to the other teams within the flipped classroom environment. Research associates as well as student tutors are providing expert knowledge and supervision during the preparation of the tasks as well as the flipped classroom lectures, to ensure a sufficient quality of the lectures. Necessary fundamentals are taught through traditional lectures as well as supplementary material available online (catalogs, tutorials, scientific articles, etc.). The exercises are intended to deepen the content of the lectures and to prepare students for the practical project phase. Different tasks for every group vary from exercises in the field of 3D printing or programming microcontrollers and on the other hand of a theoretical nature, in which the current state of research is analyzed and discussed. The students have 3 weeks to complete the assignment. For the practical tasks, the Makerspace is available as a place to elaborate the solution. The results are presented by each group to all students and discussed in short presentations. Particularly good or interesting results extend the content of the lectures in subsequent years and enable students to actively contribute to the continuous improvement of the lectures quality as well as the coverage of state-of-the-art topics. The presented topics of the first term varied from rapid manufacturing techniques up to trends in artificial intelligence.

3.2 Project phase

Following the flipped classroom units, the participants develop a smart product, representing a balancing system, which will be field tested in the course of a final presentation. The test environment is a damped two mass oscillator, which represents a quarter car and is shown in figure 1. The students will design parts of the kinematic and manufacture the system using FFF and SLA printers, as well as a laser cutter. For assembly and post processing an open Makerspace including all necessary tools is accessible to the participants. To conduct the control task, the teams have to develop a control strategy, calculate the control parameters and implement the control system using an autonomous calculation unit. The smart product consists of the developed kinematic, predefined sensors and actuators and the controller which is designed and implement by the students. Sensors are available in the form of displacement and acceleration sensors as well as a sensing rolling bearing as sensing machine element. The sensor data serves as input for the control system as well as for data analysis and the use of artificial intelligence to e.g. predict future behaviour of the test rig.

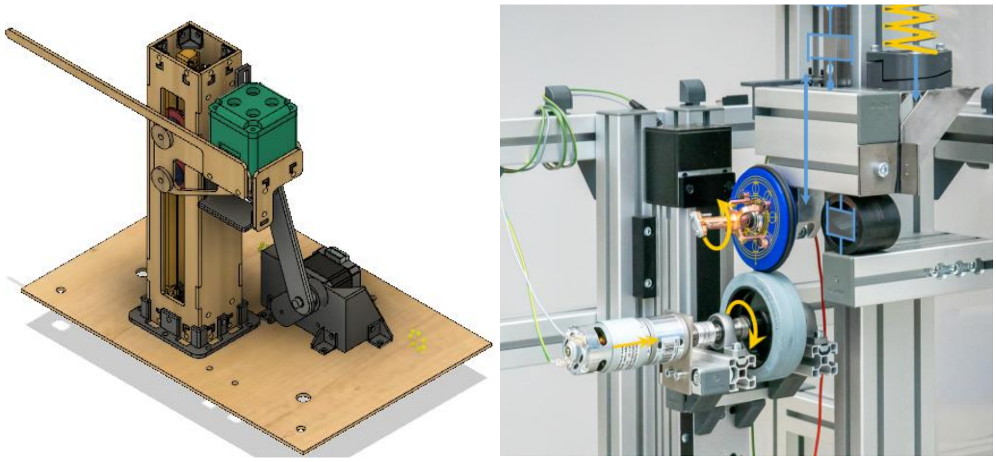

Fig. 1. Left: A developed smart system, right: Propulsion system of the test rig

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MONITORING STUDENT ENGAGEMENT AND LEARNING IN A VIRTUAL LEARNING ENVIRONMENT USING BADGES

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ABSTRACT

A monitoring system embedded into a virtual learning environment (VLE) can assess student progress to ensure no student is left behind. This is significant to support student engagement and learning in a blended transferrable skills and research methods module delivered to over 1,200 students from 15 different postgraduate engineering and business courses at a UK university. Therefore, this short paper addresses the question, *"How can a monitoring system for student progress be implemented in the VLE?"*, through a reflexive evaluation of a monitoring system that recognises individual student's weekly progress using a series of badges. A badge is awarded to a student when they have successfully completed or passed a set of required learning activities, and it enables students to self-monitor their progress. As a work in progress, this short paper presents a way to implement a monitoring system using badges in a large class VLE, along with an initial discussion about the challenges for implementing this system and the use of this system to prompt interventions. Further research will advance this short paper by examining the impact of badges to motivate student engagement and learning.

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1 INTRODUCTION

Virtual learning environments (VLEs) have enabled engineering educators to gather vast data with which to track and evaluate student engagement, learning, and progress. This data can be used to monitor student engagement, learning, and progress as a foundation for interventions to re-engage students, improve student learning, and encourage student retention [1]. Yet how to design a monitoring system is a key concern. Furthermore, it is necessary to consider how data is gathered to monitor students and communicated to students so they can self-monitor their progress. Therefore, this short paper answers the question, *"How can a monitoring system for student progress be implemented in the VLE?"*

This research concerns the experience of the authors to design a monitoring system to evaluate the progress of over 1,200 postgraduate students from 15 unique engineering and business courses enrolled in a transferrable skills and research methods module at a UK university. Of these students, there are 270 from two courses completing the module for credit. While all students enrolled on the VLE of the module are accounted for in the monitoring system, the research scope is specific to students participating in the module for credit. This blended module is delivered with a strong online component due to the high student-to-teacher ratio since the teaching team consists of four academics, including the authors.

Badges embedded in the design of the module VLE can aid engineering educators to monitor student engagement, learning, and progress in a way that is practical and to scale. This work in progress provides insight into the experience of implementing this monitoring system to support engineering educators to innovate their own VLE to assess student progress in online learning. Further work to evaluate the impact of badges on student engagement and learning will occur at a later stage.

2 METHODOLOGY FOR MONITORING ONLINE LEARNING

Embedded in the VLE of the module is the 'monitoring system' comprising of 20 badges, achieved by students on a weekly basis by completing or passing a series of virtual activities (such as group forums, reflective questionnaires, and quizzes). Badges are a form of gamification that motivate students to engage in learning [2]. These tokens are a visual indication of progress that students can self-monitor on their VLE profile. Badges facilitate individuation with each student responsible for their own learning with the aim of achieving all badges [3]. These badges constructively align with the module content in preparation for students' module assessments. Students enrolled on the module for credit achieve badges as 'continual assessment' to promote continued engagement with asynchronous learning [4]. This means a student can earn up to 20% of their module mark by achieving 20 badges (1 badge = 1% of module mark).

The monitoring system is an accumulation of four monitoring points that check student progress during the module and are aligned with assessment dates or term breaks to fit within the student learning journey. One cycle of the monitoring system is illustrated in Figure 1, below. First, a student must complete or pass a set of activities available each week on the VLE. An activity is marked complete when all components have been answered, such as a questionnaire, or passed when a minimum mark has been achieved, as in a quiz. On successfully completing or passing these activities, students earn a badge for that session. Second, students must earn a set of badges to pass a monitoring point. Third, students who do not earn all badges for the monitoring point are sent an email. A student's course leader is also notified by email of students who have missed the monitoring point. Finally, students can continue accessing additional weekly sessions and their activities to achieve further badges regardless of whether a prior monitoring point is complete or not.

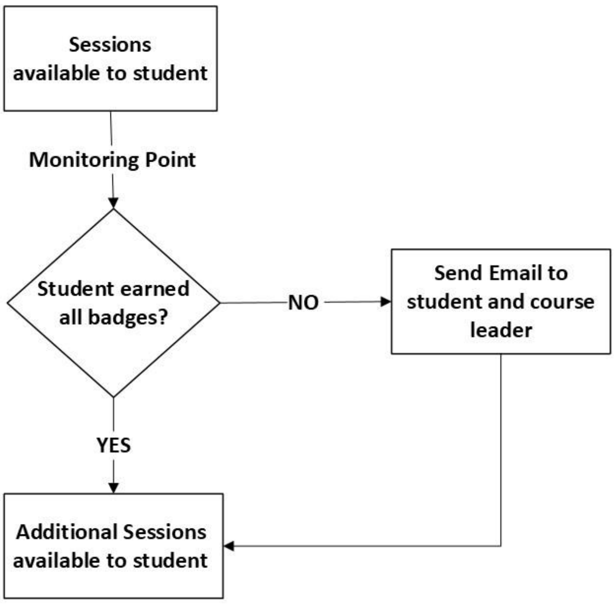

Figure 1. One cycle of the monitoring system (Student completes virtual activities in each session to earn a badge and for each monitoring point a student needs to earn 4-6 badges, depending on the monitoring point)

The monitoring system is overseen by the teaching team who are responsible for embedding the monitoring system in the design of the module, technical deployment of the badges on the VLE, analysing badge attainment, and communicating notifications of non-engagement to students and their course leader at each monitoring point. The authors' initial findings of the monitoring system are presented as a work in progress focusing on two themes: challenges to embed a monitoring system and interventions to support student engagement and learning. These findings are based on reflexive interrogations on the use of the monitoring system. Future work will evaluate the impact of badges on student engagement and learning.

3 INITIAL FINDINGS

3.1 Challenges to embed a monitoring system in the curriculum design of a large class VLE

An initial challenge to implement a monitoring system was the lack of technical ability to design activities. For instance, early session activities focused on a topic or skill rather than in combination due to a lack of technical skills to design complex activities. This resulted in a high number of online activities created for each badge. Some students who were overwhelmed by the number of activities needed to pass a monitoring point resolved this by rapidly clicking through activities. A VLE that includes a high number of activities, or similarly too many materials and links, can compromise deep learning as it undermines the learning experience [5]. Therefore, to avoid surface learning, the team later designed complex virtual activities that included multiple components that weave together many topics or skills to reduce the overall number of activities in remaining sessions. Hence, to implement a monitoring system on a VLE, it's important that module design is informed by technical expertise to create virtual activities that, once completed or passed, form the qualifications needed to achieve a badge.

The team also experienced an additional consequence of the high number of activities used to monitor student engagement and learning: data overload. The teaching team did not have the time and necessary resources available to analyse the extensive data that was captured through monitoring activity completion or marks, so it was difficult to enact strategic decisions to adapt content or delivery of online learning to respond to gaps or barriers in student engagement and/or learning. Therefore, it is important the design of a monitoring system considers the amount of data it will generate and the extent this data is useful for pedagogic decision-making. Hence, construction of a monitoring system must be based on quality rather than quantity of data.

Monitoring points enabled the teaching team to evaluate the extent of an individual's progress to complete or pass learning activities during the module. Yet an issue in using a monitoring point for several badges, rather than a weekly deadline for each badge, is that students achieved a series of badges at the last-minute as evidenced in data captured on when a badge was achieved. While a deadline for each badge was avoided to enable flexibility for students, as some students would be unable to achieve a badge during the week due to conflicts with intensive one-week-block module teaching, it may have compromised the quality of learning. This is significant since the transferrable skills and research methods taught in the module have long-term implications on students' dissertation and professional success. Therefore, further work is needed to evaluate how students perceive monitoring points and how changes to temporal structures of monitoring, such as a deadline to achieve a badge, would impact student progress.

3.2 Interventions in a monitoring system to support student engagement and learning

A benefit of a monitoring system that can assess student progress is that this information is quantifiable for dissemination to course leaders who can follow-up directly with their students who are not progressing in the module. For instance, at each monitoring point a list of students who did not complete the required badges were identified for each course. This list of students was emailed to the relevant course leader with students categorised as 'incomplete progress' or 'minimal to no progress.' The latter category concerned students who missed the majority or all badges for the monitoring point. This categorisation enabled the team to communicate to course leaders if there were students who may require further support, such as a wellbeing check-in, due to a consistent lack of engagement and learning over a series of weeks. This was a beneficial practice for improving the learning community in which an individual student is supported by a network of staff who are aware of, and knowledgeable about, the student and their circumstances [6]. Yet, further work is needed since it is not clear the extent course leaders did follow-up with these students or the extent course leaders found the communication about the monitoring point helpful.

Students who did not complete a monitoring point received a personal email about their module progress. The email had two key messages. First, the importance of achieving badges as these constructively aligned with the module's summative assessment (as well as counting towards continual assessment). This emphasised the significance of attaining badges as part of learning in addition to engagement. Second, since a lack of progress, learning, and engagement can be due to poor wellbeing, guidance on how to access wellbeing support was included. Many students immediately responded to this email intervention by contacting the teaching team to raise concerns and questions related to their learning experience. As part of an ongoing evaluation of the monitoring system, additional analysis on how the email intervention improved student engagement and learning is needed. For instance, how quickly students began to re-engage with the learning activities following the email intervention.

4 CONCLUSION

In evaluating the monitoring system embedded into the VLE of a module delivered to over 1,200 students, there are two key considerations for practice. First, engineering educators keen to embed a monitoring system using badges must consider the quantity and quality of activities, as well as the timing of badge achievement, to avoid surface learning. It's also important that engineering educators are provided technical skills training so they can design and implement their own monitoring system. Second, collecting information about student progress in the module can be communicated to students and course leaders to enhance student engagement and learning.

This short paper shares reflexive evaluations by a teaching team to oversee a monitoring system of student progress for a transferrable skills and research methods module. Suggestions for future work to advance this short paper include evaluating the impact of badges to motivate engagement and learning, as well as the impact of the email intervention to re-engage students to learn. Further research would also benefit from evaluating the impact of other forms of gamification beyond badges that can be used to monitor student progress.

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Innovation Strategies to Develop Specific Professional Skills on Photovoltaic Systems Engineering

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ABSTRACT

This work describes experiences learned in teaching photovoltaic (PV) courses in Engineering Master Degrees at the UPC. These PV courses are included as elective courses in the Master of Energy Engineering included in the international master programs: Environomical Pathways for Sustainable Energy Systems (SELECT) and Renewable Energy (RENE) and in the Master Degree in Electronic Engineering at the Universitat Politècnica de Catalunya (UPC) in Barcelona, Spain.

These Master Degrees are aligned with the objectives of the European SET plan and the objectives of KIC InnoEnergy in the field of renewable energies and aim at delivering education for high competency and quality engineering skills in the field. The content of these programmes is focused to the renewable technologies concept of “learning by doing”, so combining deep theory knowledge (top-down approach) with internship in industry co-advisored by the university and the industry (bottom-up approach) in an international environment.

1 INTRODUCTION

1.1 Contents of the courses.

The courses are focused in PV as a renewable energy source to its use as an energy service including social and environmental dimensions in order to help students to make value judgments. The duration of both courses is one semester: 15 weeks- 5 ECTS, and the courses include stand-alone and grid connected applications of PV systems considering both technical and economic criteria to select the most appropriate electrical equipment for a given application and solutions for a smart control and fault detection in the generation systems in order to optimize the generation of energy and costs. Professional software tools are presented in order to help the students in the design, evaluation and analysis of the behaviour of the whole system. Contents are technical and self-contained.

1.2 Engineering skills.

The courses are focused on technical skills required for engineers in the field of PV applications. Moreover, from a transversal point of view, an special effort is done to enhance training the students in soft skills such as communication, economics, business administration and, very specially, to promote the orientation to innovation and the entrepreneurship spirit by means again, of the “learning by doing” concept.

2 METHODOLOGY

2.1 Teaching methods.

The teaching methodologies are as follows: Lectures and conferences, knowledge exposed by lecturers or guest speakers and participatory sessions including collective resolution of exercises, debates and group dynamics. Classroom presentations of activities, individually or in small groups, are also included.

Homework: Resolution of short exercises, writing reports on technical issues that include the approach, results and conclusions, individually or in groups.

Project-based learning: Throughout the semester, students organized in groups must carry out a real PV project design that is described in the next section.

Participatory sessions: Learning based on participation in the collective resolution of exercises, as well as discussions and group dynamics, with the teacher and other students in the classroom.

2.2 Project design.

An important part of the course is the sizing, design and planning of a PV project for a specific application. Students groups are required to study the irradiance and temperature profiles at the PV system location throughout the year and select the size of the PV array to meet the specified power demand in the selected application. Then, students must select : The PV modules, batteries, inverters if any, charge regulators and the rest of electronic equipament present in these systems taking into account the application requirements, loads present in the system, consumption profiles, cost of the whole system and its reliability.

The sizing and design of the PV system is carried out with the help of professional simulation tools that include characteristics and parameters of commercial elements of each of the parts of the PV system. For this purpose, students work with PV-SOL [1-2] and PVsyst [3-4].

The final results obtained in the projects are presented by the students for analysis and discussion with the teacher and other students in the classroom.

3 RESULTS AND DISCUSSION

At the end of the autumn semester of the 2021-2022 academic year, a survey was conducted of the students of the course corresponding to the master's degree in energy: SELECT and RENE. A total of 36 students out of 51 enrolled responded to the survey.

The results obtained are shown in table 1. The students value between 1 and 5 the degree of satisfaction of each section, with 5 being the maximum score. As it can be seen in the table, the students have highly valued the simulation tools used in the course in the development of group projects. Moreover, the development of these projects, the group work and the methodology presented in this communication and used throughout the course have also been very positively valued by the students.

Table 1. Sample of questions from the survey. The results show the degree of satisfaction of the students between 1 (min) and 5 (max) in each question.

Question	1	2	3	4	5	Average value (out of 5)
I found the contents of the subject interesting	0%	0%	21.05%	28.94%	50%	4.28
I am satisfied about the course and the skills acquired	0%	0%	15.78%	39.47%	44.73%	4.28
The teacher presents the contents clearly and the methodology used is appropriate	0%	0%	15.78%	31.57%	52.63%	4.36
Working in groups to solve the proposed projects has helped me learn	0%	0%	23.68%	15.78%	60.52%	4.36

The simulation tools used in the course are useful for the design of PV systems	0%	0%	13.15%	15.78%	71.05%	4.57

The students in this course have different profiles. Some enter with a degree in energy engineering, others instead come from degrees in mechanical, electrical or electronic engineering. This facilitates an interdisciplinary vision in the development of projects and facilitates the improvement of both technical skills and soft skills, valued with an average value of 4.28 out of 5 by the students. Throughout the course, the students have appreciated that the members of their group respect their disciplinary experience and are willing to learn from it. In addition, there is a change in the way students perceive the willingness of their groupmates to work incorporating skills not associated with their disciplines during the course.

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COPING IN PANDEMIC TIMES: *BRICOLAGE* EMPLOYED BY FIRST-GENERATION ENGINEERING STUDENTS

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ABSTRACT

First-generation students have been a focus in higher education research over the past ten years. However, limited attention has been paid to engineering students who are the first in their generation to enter university. The paper reports on data collected as part of a longitudinal study of first-generation engineering students at a South African university during the early stages of the pandemic. First-generation students, who already face multiple difficulties in their educational journey, were confronted with a juxtaposition during the lockdown. As engineering students, they are inducted into technical approaches to problem-solving via systematic and analytical exploration. Levi-Srauss contrasts this notion of the ingenieur, grounded in the Enlightenment belief in the superiority of rational scientific reasoning, with the bricoleur, who finds solutions by “doing things with whatever is at hand”. With the lockdown period being less amenable to structured problem-solving, students often had to resort to more improvised approaches to accommodate their studies and their shifted precarious everyday routines. The study not only adds to literature on first-generation engineering students, but also provides insight into the ways in which these students cope with obstacles over which they have little control. In the process

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a picture of resilient agency emerges that challenges a narrow deficit view of students with limited resources.

1 INTRODUCTION

Much has been published over the past two years about students' experiences during the period of online and blended learning enforced by the COVID-19 pandemic. In this paper our focus is on how a specific group of first-generation students negotiated their engineering studies during this time.

1.1 First-generation students

The concept of first-generation students is useful to identify students who experience multiple intersecting disadvantages in their educational journey [1]. Challenges often include a lack of role models and pressure from communities of origin to succeed. Many students are unfamiliar with "what counts" in higher education. These students frequently face financial challenges, and for some, their prior educational trajectories did not prepare them adequately for higher education. Although attention to first-generation student experiences has increased in various higher education fields over the past 10 years, less attention has been paid to experiences from the global South, and specifically experiences of engineering students. It is also important to extend research foci beyond notions of deficiency and scarcity [2]. It is thus worthwhile to conduct research that sheds light on learning experiences in ways that avoid simply conflating accounts of first-generation students with those of poverty [3].

1.2 Precarity

In discussing these challenges, we adopt Butler's [4] distinction between 'precarity' and 'precariousnessas'. Precariousness describes the vulnerable human condition of innate interdependency we all share, whereas precarity refers to the politically induced condition in which certain populations suffer from failing social and economic networks of support and thereby become differently exposed to threats.

The events unfolding as a result of the global pandemic constitute an appropriate moment to reconsider what we think we know about vulnerability, precariousness and precarity. In a radically unequal society, such as South Africa, widely diverging social experiences are concerning realities, and first-generation students become disproportionately vulnerable as precarity accelerates..

1.3 *Ingenieur* vs *bricoleur*

In his influential publication, The Savage Mind [5], Levi-Srauss distinguishes two ways to relate to the world, that of the *ingenieur* and that of the *bricoleur*. These two figures approach problems differently: the *ingenieur* is rooted in the Enlightenment tradition of the historical French engineer – a belief in the superiority of the rational scientific reasoning process. *Bricolage* is a French loanword that refers to the creation of an artefact or solution to a problem, using a diverse range of objects or options that are readily available, "doing things with whatever is at hand" [5].

How do first-generation engineering students make sense of precarious changes in physical space? How do they navigate restricted identities back home where being a student intersects with being a child, a sibling, a caretaker? How do they manage challenging engineering studies online, often faced with almost intractable digital access problems? How do they make meaning out of digital sources to assemble technical knowledge and skills?

2 METHODOLOGY

2.1 The study

A group of 17 first-generation engineering students from four departments (chemical, civil and electrical engineering) at the university of Cape Town is participating in a longitudinal study to track their educational journey and path into initial employment. Students are interviewed annually in semi-structured interviews that are transcribed. This paper reports on the 2020 anonymised interviews that took place 3 months into the initial hard lockdown period at the start of the pandemic, an environment of accelerated precarity for these already vulnerable students.

2.2 Conceptual framework for analysis

Transcribed interviews were coded according to a set of categories developed from scholarly literature on the characteristics of *bricolage*: *bricolage* involves “making-do” [6] with whatever is at hand. It represents an “integration of conceptualisation and realisation” [7]. In *bricolage*, *repertoires* are independent elements that take on different meaning in association with other elements [7]. Coutu [8] argues that the *bricoleur’s* familiarity with their own environment helps to orient them to draw on that which is recognisable, using a way of practical reasoning or “science of the concrete” [5]. Finally, *bricoleurs* are marked by resourceful resilience [8].

3 RESULTS

3.1 Making do with what is at hand

The bricoleur takes stock of the context, the problem faced and then uses what is at hand to make do. Velani’s physical circumstances are less precarious than some of his peers, but he too faces resource challenges that impact greatly on his ability to work at his engineering studies: for him, internet access. He has to initiate requests that rely on the goodwill of distant family members. This leaves him feeling conflicted, and yet he acts: “If I have a test or an assignment… anything that is online, I have to go to another space... I have relatives around the area, even though it’s not close relatives, but I do go to them and ask them for some space so that I can just do my tests, because they do have network… But the disadvantage of that is that … I have to go there and use their space. I don’t know how they feel about that…. They still say they are okay with that but you can't really know… I think I'm disruptive to them and their living space.”

3.2 Practical reasoning: “science of the concrete”

At the start of the lockdown Mlungisi relocates from a campus residence to an informal settlement just outside Cape Town sharing a small shack with his two brothers. The single room dwelling is divided in two: his older brother has his own space with a small section where they can prepare food. The other two brothers share the second partition; this is where Mlungisi also has to study. He needs to improvise: “At the beginning, I thought there was no workspace since it’s … very small … there is a table which is very small, but at least I can study on top of it… I tried to move some things… against the walls of the shack. So yes, I tried to make some space for me to study, just to study…” Mlungisi’s improvised study consists of assembling elements from his environment according to simple rules (a small table in a limited shared space). Improvisation makes adaptation to challenges possible, often in a way that integrates thought and action – moments of conception and realisation become indistinguishable in disordered or unpredictable environments [7].

Mlungisi explains that they have electricity in their shack, and qualifies “and it is legal” (illegal electricity connections are common in the informal settlements where extension cables are run from the few legal provisions). They also have running water, possibly an irregular connection – Mlungisi’s brother “made a plan to have some water… he had pipes, so we do have water… I think it’s good water. I hope so.” However, for sanitation they have to rely on shared community facilities: “… around the area there are loos … some like municipal kind of things that are outside… so that’s where we can go… many people go there and it’s poor hygiene, but we have to because there is no other option”.

3.3 Repertoires: independent elements that take on different characteristics

Students have to repurpose resources they are familiar with and use these in new ways. An example is the way students adapt the use of WhatsApp groups during the early part of the hard lockdown. Classmates were displaced and sent home from campus that provided at least a modicum of equity in the WiFi access students shared in residences and on campus. WhatsApp, that once served exclusively as a means of social contact with friends, becomes a *repertoire* [7] to facilitate tutoring and contact with lecturers. Far from being a perfect replacement, the social media platform is reimagined to allow tutors to respond and clarify student queries. Matteo describes the way he has to go about getting feedback on a mathematics query: “…[with classroom] learning, you can kind of ask a direct question, you know, as the lecturer’s going through the notes, you can just point to a specific section on the page. Whereas if you [now] need to ask a lecturer [for clarification], you need to… take a screenshot, draw on it, indicate what, and then try and ask your question…”

3.4 Familiarity with own environment, drawing on what is recognisable

A rapidly changing environment can lead to feelings of being overwhelmed, resulting in paralysis or inaction, but Coutu [8] argues that the *bricoleur’s* familiarity with their own environment helps to orient them as they draw on that which is recognisable, using a way of practical reasoning or “science of the concrete” [5]. Students find various ways to try and impose structure on their days after being thrust into almost feature-less days. For Mlungisi, this means trying to stay warm during the cold rainy Cape Town winter nights and sticking to a similar timetable that he used before: “… during the evenings it’s very cold. During the mornings, it’s also really cold. So, I usually study during the day… I try to wake up at six o’clock … then try to study… I try… to make my learning as close as possible to the way I did at [university], to motivate myself".

For other students it makes more sense to use the night hours to work: Jerome works "… mostly during the night when it's really quiet because during the day it's really [noisy] in the house. The kids are running around and making noise". For others, like Luyanda, nights are used for study because data costs are slightly lower in off-peak hours: "I'm just using the data that [the university] gave us… it's not really enough… when the day data is finished, I tend to work in the night. But then, in the night there are not a lot of hours to work, because it's from midnight to 5AM and then it [the data] stops working".

3.5 Resilience, self-efficacy: "I am always an optimist"

In spite of challenging circumstances faced by these first-generation students, they respond in ways that demonstrate the remarkable resilience of the *bricoleur* [8]. Zinhle draws on past experience that saw her succeed through her school years: "…it's really a tight space and there's a lot of us [11 people in a small home], and during the day we are all awake and busy. I don't have a special place where I study… I just cope because this is where I lived when I was in high school, so some[how] I've found a way to make things work".

Mia draws on inner resources and a sense of self-sufficiency: "… many times, I would be like, I can't do this… Why did I decided to study this? And then it was always a case of, I can do this. If other people can do it, why can't I do it? And that always got me through it… And I am always an optimist. That's one thing. Even through this coronavirus… I am like, no, it's okay… at the end of the day… you have to realise whatever decision you make, you're going to have to deal with it.

Bakari even manages to keep thinking and planning a small business venture (temporarily on hold during the lockdown): "It's an agricultural-based project… we managed to get funding. We did a pilot phase of the project… last year. Now, we want to… start growing and selling microgreens in Kenya".

4 SUMMARY

Students enter engineering studies from a diversity of backgrounds. Our study contributes to the limited literature on first-generation engineering students with insights into ways in which these students cope with the stark realities of accelerated precarity brought about by a pandemic raging in a developing country context. Scholars emphasise that there is no such thing as pure *bricolage*, and that in real-life individuals function somewhere between the ends of the *bricoleur* and *ingenieur* [7] as context demands. Faced with situations over which they have limited control, and where their engineering training cannot provide neat, systematic solutions, these students nevertheless act as *bricoleurs*, exercise agency and draw on resilience to continue to study. Mlungisi explains: "I try by all means… to be very, very creative… One of the reasons why I don't give up is because I have a family. I have myself, I'm thinking ahead. What about my community in the future? If I give up, many things will fall down in my life... So, I don't give up; I try to endure".

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PRELIMINARY INVESTIGATION OF A CFD-ASSISTED VIRTUAL REALITY EXPERIENCE IN ENGINEERING EDUCATION

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ABSTRACT

Virtual reality has become a significant asset to diversify tools in the support of engineering education and training. The cognitive and behavioral advantages of virtual reality (VR) can help lecturers reduce entry barriers to concepts that students struggle with. Computational fluid dynamics (CFD) simulations are imperative tools intensively utilized in the design and analysis of chemical engineering problems. Although CFD simulation tools can be directly applied in engineering education, they bring several challenges in the implementation and operation for both students and lecturers. In this study, to tackle these challenges, we developed the "Virtual Garage" as a task-centered educational VR application with CFD simulations. The Virtual Garage is composed of a holistic immersive experience to educate students through a real-life engineering problem solved with CFD simulation data using a VR headset. The prototype is tested by graduate students (n=24). Participants assessed usability, user experience, task load and cybersickness via standard questionnaires together with self-reported questions and a semi-structured interview. Preliminary results reflect that the Virtual Garage is well-received by participants. We identify features that can further enhance the usability and user experience.

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1 INTRODUCTION

Computational fluid dynamics (CFD) simulations are heavily applied in engineering design and analysis to solve engineering problems in a time cost effective fashion. Educational use of CFD simulations may be challenging due to expert-centric user experience in conventional simulation environments, which requires complex skills to perform CFD simulations and interpret obtained results to make justifiable decisions. Learning in conventional simulation environments often happens by learning-by-doing on 2D desktop settings. Such environments do not comprise any assistance except help options relevant to the usability of the tool. These conventional simulation environments have been criticized by educational scientists and were found less efficient than that of traditional instructional designs [1].

Utilization of virtual reality in support of immersive learning has been a hot topic in engineering education. Immersive virtual reality learning environments may reduce the entry barrier to complex learning subjects including CFD simulations. These environments can positively trigger cognitive skills with advanced interactions and easy-to-access technical content, as well as behavioral aspects of learning such as attracting and motivating students. This might open gates for user-friendly, high-quality complex learning environments assisted with CFD simulations. Many researchers have investigated the integration and implementation of CFD simulation data in virtual reality, especially for visualization purposes [2]. However, no study has been found in the literature implementing an immersive complex learning method with CFD simulations in a digital environment.

In this paper, we present the VR application “Virtual Garage”, as an immersive complex learning environment, composed of a holistic interactive experience to educate students through real-life engineering problems solved with CFD simulation data using a VR headset. Our fundamental objective is to develop an immersive learning environment and investigate its effect on cognitive and behavioral aspects. First, we should ensure a proper virtual reality experience to accomplish this. Therefore, as a preliminary investigation, we assessed usability, user experience, task load and cybersickness in the Virtual Garage based on available standard tests.

2 METHODOLOGY

2.1 Design of complex learning environment

A task-centered educational experience is adapted to design an immersive complex learning environment with the four-component instructional design (4C/ID) model. Among many interesting instructional design methodologies, the 4C/ID model has become a prominent tool to support complex learning environments in numerous disciplines [3]. The model presents four major components to enable complex learning; learning tasks, supportive information, just-in-time information and part-task practice. The learning environment in the Virtual Garage is fundamentally structured by applying the 4C/ID components together with various instructional design principles highlighted by the design tool. A sequential principle is set for the learning task to increase complexity in the learning environment gradually. Multimedia and signaling principles are mainly implemented in the supportive and just-in-time information, respectively. As a part-task practice, a pre-training module is developed to teach interactions in VR and let users explore the learning environment and routine aspects of usability in VR. The entire VR experience is divided into two subsequent sections, Module1 and Module2, as shown in Fig. 1. Module1 is composed of pre-training and theory sections. Module2 is the assignment with CFD simulations to solve problems introduced in the theory. Both sections take approximately 20 min to complete. Users are strongly advised to take a 5 min break between modules by taking the VR goggles off, thereby alleviating cybersickness.

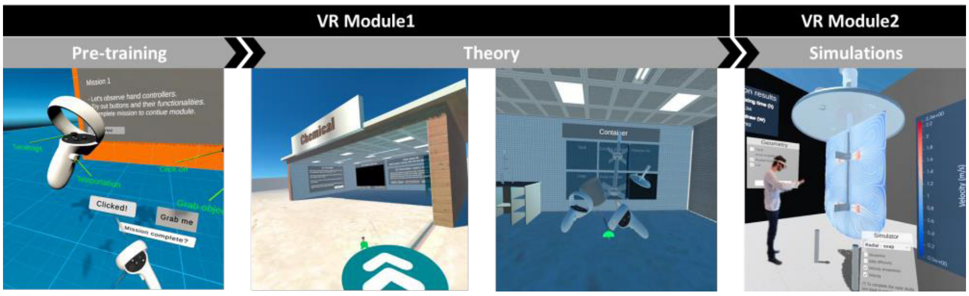

Fig. 1. Scenes in the Virtual Garage; Module1 and Module2

2.2 Software and hardware

To develop the Virtual Garage, we utilized the Unity game engine. CFD simulations were calculated in a workstation with COMSOL v5.6, and integrated into Unity using an extract-based data processing approach [4]. The VR experience was developed for Meta Quest 2 VR goggles.

2.3 Data collection

Usability, user experience, task load and cybersickness were assessed by participants. Questionnaires were repeated after each module. Participants additionally filled out other questionnaires to provide sociodemographic information, experience, and self-reported questions on content. Additionally, a semi-structured oral interview was carried out at the end of the session to point out positive and negative aspects of the Virtual Garage.

3 RESULTS

Experiments were conducted at the department of chemical engineering at KU Leuven with 24 participants from the graduate school. All participants completed the entire test without any issues. Prior to the study, ethical approval was obtained from the ethics committee at KU Leuven. National and regional safety measures with regard to COVID-19 were strictly applied during the experiments such as proper ventilation of the testing environment, disinfection of equipment and social distancing.

Preliminary results on the usability with the system usability scale (SUS) are shown in Fig. 2. Both Module1 and Module2 were well received by users resulting in mean scores of 74.37 and 73.85, respectively. A SUS score above 68 is considered good [5]. More interestingly, it appeared that participants scored differently between Module1 and Module2. Statistical analysis should be performed to clarify the reasoning behind participants' preferences to identify differences in these patterns, for example, experience with simulation content. For the time being, our data processing is still work-in-progress. Future work will focus on data processing to comprehend more participants' behavior. Fig. 3 shows overall scores measured with the NASA Task Load Index (NASA-TLX) test to assess the workload in the modules. Results showed that participants overall found Module2 more demanding than Module1. Only physical demand was lower in Module2, which can be explained by the simplistic design of the simulation environment in Module2. In Module1, users move inside the VR environment to consume supporting information that could be used while solving the problem in Module2 with simulation data.

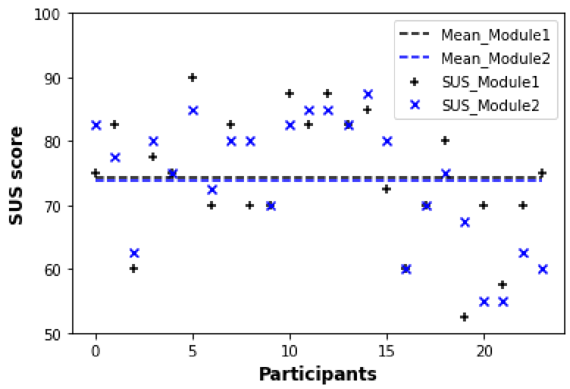

Fig. 2. SUS score

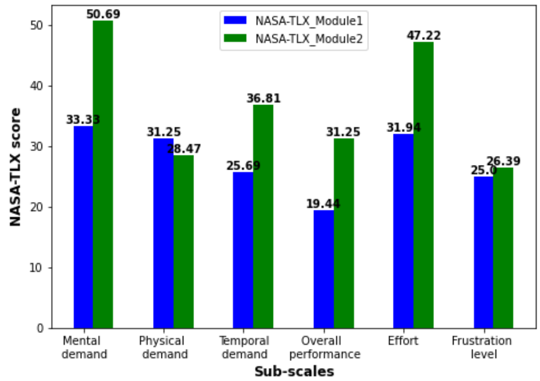

Fig. 3. NASA-TLX score

Meanwhile, Table 1 presents simulator sickness questionnaire (SSQ) scores for different subscales and total simulator sickness. Participants successfully completed the VR experience and didn't verbally report any sicknesses. Participants scored 23.53 for Module1 and 11.53 for Module2. Digital environments with an SSQ score below 40 are assumed to be safe in terms of cybersickness [6].

Table 1. SSQ scores in VR modules

SSQ	Total simulator sickness
Module1	23.53
Module2	11.53

4 SUMMARY AND ACKNOWLEDGMENTS

Our preliminary analysis has shown promising results regarding the development of an immersive complex learning environment with CFD simulations. Data processing is currently underway and more will be reported about the assessment from this set of experiments. Future work will focus on improvements in the prototype and assessments of knowledge gain, task performance and technology acceptance.

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New Tools to Motivate STEM students towards Early-career Self-management

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Conference Key Areas: *Curriculum Development, Physics and Engineering Education*
Keywords: *Soft skills and competences; Transition to labour market; Career development; Engine4STEMers.*

ABSTRACT

The Universitat Politècnica de Catalunya (UPC), the Czech Technical University in Prague (CTU) and the Universidade de Lisboa have recently undertaken the Engine4STEMers project, a joint initiative devoted to generating a new culture of young STEM graduates willing to assume early-career responsibilities, oriented to satisfy societal challenges. It also aims to provide guidance and motivation to help young graduates adopt early-career leadership and managerial skills. In this context, this short article describes the objectives and content of a short pilot seminar that is currently taking place at UPC and that is dedicated to the concept of service, a central educational tool of Engine4STEMers that aims to motivate students to proactively manage a successful transition from university to the labour market.

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1 INTRODUCTION

1.1 The Engine4STEMers context and motivation

In order to cope with fast-changing social and economic environments, STEM graduates are increasingly in need for specific personal and professional development techniques aligned to their career evolution in the technology business [1][2]. Additionally, to embrace continuous innovation, companies get progressively flatter, less hierarchical, evolving from traditional pyramidal and segregated organizations to an organizational model of shared responsibility. This new and highly demanding context requires STEM graduates to undertake a rapid change in attitude and work

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methodology to evolve from a user culture (student) to a service provider culture (employee or entrepreneur). That is, moving quickly from a task executor role (doing) to assuming greater responsibility in terms of management roles (directing) and finally to leadership roles (deciding).

While STEM graduates are usually aware of their scientific and technical knowledge, they often lack deep insight into their true potential as key drivers for innovation and to effectively impact industry and society. They are also often unaware of the skills and competences required to do so. As key players for innovation and entrepreneurship in the tech market, young STEM professionals should play a key role in developing a positive attitude in the industry and a new mindset towards sustainable development and a higher concern for the impact of technology on society. To address these goals, Engine4STEMers develops a “competences to become competent (C4C)” approach that includes a set of short teaching and learning modules arranged around three topics:

- Early career tools in the tech arena.
- Critical thinking for successful career development in STEM.
- Leadership: a STEM graduate as an effective human being.

We can find a lot of literature regarding the key transversal competences demanded by employers that, in general, give growing importance to social, emotional and higher cognitive skills [3]. In this sense, STEM education is progressively including programs devoted to developing these skills. What is scarcer, however, is space for students to reflect on their current set of skills to improve their self-awareness and self-esteem. Also, to find out what they need for their near future and, more importantly, to motivate them to acquire such skills in their transition to the labour market. This is a critical need covered by Engine4STEMers, which also aims to motivate STEM graduates to engage early in management and leadership responsibilities to provide fast added value to their employers and rapidly impact on industry transformation.

1.2 The concept of service as a self-awareness and motivation tool

Within the Engine4STEMers context, this short paper presents an innovative approach, based on the concept of service, aimed at facilitating a smooth transition to the tech job market mindset. The concept of service is envisaged to help students to improve their self-awareness and self-esteem by visualizing the key competences already developed in their academic stage, but also the early career skills that require further development and the need for career planning, with a short and long-term perspective.

The main thesis of this short paper starts by highlighting the role of universities as Higher Education service providers (Fig. 1). This service provider role has proved to be highly effective in the education of STEM students since just a few years are needed to provide them with relevant knowledge and competences related to scientific and technical work. It also develops a strong "user" mindset in students, which is useful to maximize the benefits that they obtain from the formal and informal learning activities undertaken during their university stage. However, students must be aware of this fact and take the path to become service providers in their transition to the labour market. In other words, a young graduate must smoothly switch from enjoying the benefits of university services to becoming fully responsible for their work in order to satisfy the needs of others. This change in service direction has strong implications that may require a change in attitude and work methodology to successfully accelerate career growth in the tech market.

2 METHODOLOGY

2.1 Improving self-awareness and self-esteem

Before trying to engage students to introduce and further develop soft skills and interpersonal competences, it is important to improve their self-awareness and self-esteem. In this sense, the seminar begins with a discussion of the general competences developed within formal STEM education that complement the general and specialized knowledge provided by STEM degrees (Fig. 2).

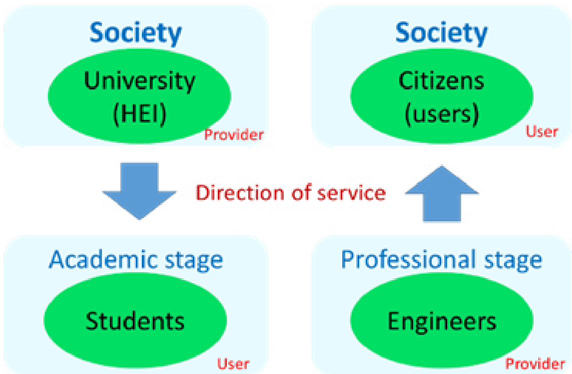

Fig. 1. From user to service provider

- Mental structure and logical thinking
- Methodical, rational and unbiased worker
- Analytical and synthesis skills
- Hard work capability
- Perseverance and resilience
- Creativity
- Skepticism
- Problem solving skills
- Orientation towards action and results

Fig. 2. Competences acquired at the university

Then, the concept of change in the direction of service (from user to service provider) is used for group discussion to help students visualize the need to undertake a change in the work methodology and attitude. These discussions are conducted through several key questions aimed to identify the main differences related to the tasks undertaken in the academy (as students) and the work in the labour market (Fig. 3). These discussions are used to help students envisage the need to further develop instrumental competences. An introduction to these skills is planned in other seminars within Engine4STEMers "Grow to your career academy": interviews, meetings, time-management, effective communication, basic interpersonal skills, positive attitude, career planning or self-management, among others.

In order to further introduce the instrumental competences and the need to further develop them, a set of case studies has been developed based on early-career "to do" and "not to do" situations [4]. These cases are constructed around situations that young graduates may have to face in their first jobs: work overload, poor supervision, unclear responsibility, poor communication, or interpersonal conflicts. Students discuss the likely causes that may have led to these undesirable situations and how a proactive attitude, soft skills, and interpersonal competences could have prevented the conflict.

2.2 Long-term career evolution

Finally, the seminar ends by introducing the need for long-term career planning. Discussions on formal and informal job performance evaluation lead to the concept of professional reputation, which is related to the evolution of professional competence (Fig. 4). The young graduates' career progresses as their comprehensive competence level evolves from a junior role to senior expertise. In this sense, the key competences are presented as Personal and Professional Development Techniques (PPDT), conceived as accelerators of experience, which aim to help a young graduate to reach senior roles faster and with higher levels of competence (Fig. 4).

- How is work performance evaluated?
- How is work organized and scheduled?
- How are work goals set?
- How is feedback grasped?
- How do individual and teamwork change?
- How does the role of expertise change?
- Work quality standards: What's important?
- How work responsibility changes?
- How does the decision-making process change?
- How do working rules and principles change?

Fig. 3. Discussing differences

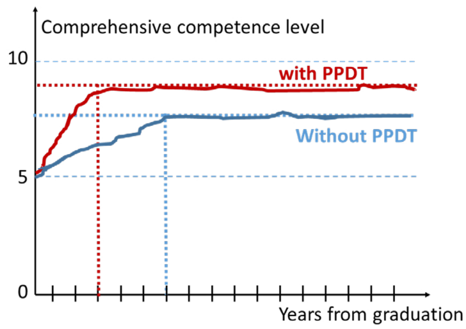

Fig. 4. STEM graduate competence evolution

3 CONCLUSION

Mastering the soft skills and competences required to develop a successful professional career in today's fast-changing tech labour market may require years. Some of them can only be properly developed along with the development of experience, working on real projects, and facing real situations. In this sense, STEM academic programs should motivate students to self-manage their professional careers and to develop the tools required to do so. This short article has presented an innovative approach for this purpose.

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Tackling perception and deception in STEM: A critical thinking skill for early-career development

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Conference Key Areas*: Curriculum Development, Physics and Engineering Education*
Keywords*: Soft skills and competences; Critical thinking, Transition to labour market; Career development; Engine4STEMers.*

ABSTRACT

The Universitat Politècnica de Catalunya (UPC), the Instituto Superior Técnico (IST-Universidade de Lisboa) and the Czech Technical University (CTU) have recently launched the Engine4STEMers project, a joint initiative whose objective, among others, is to guide young graduates in their transition to the job market and motivate them to adopt management and leadership skills early in their careers. In this context, this short paper describes the objectives and contents of a Critical Thinking seminar, currently underway at UPC, which is aimed at motivating young STEM graduates to develop the principles of a skeptical attitude towards the information and stimuli that we perceive in order to face uncertainty, biased information and hidden agendas. Engine4STEMers needs analysis has revealed the importance of a good understanding of the concepts of perception and deception to develop effective interpersonal skills and, more importantly, to ease decision-making processes in a VUCA (volatile, uncertain, complex and ambiguous) environment.

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1 INTRODUCTION

1.1 The Engine4STEMers context and motivation

The emphasis of STEM student education has been almost exclusively on acquiring technical and scientific knowledge, leaving a gap in terms of their preparation for the labour market that needs to be filled. In order to cope with fast-changing social and economic environments, STEM graduates are increasingly needing specific personal

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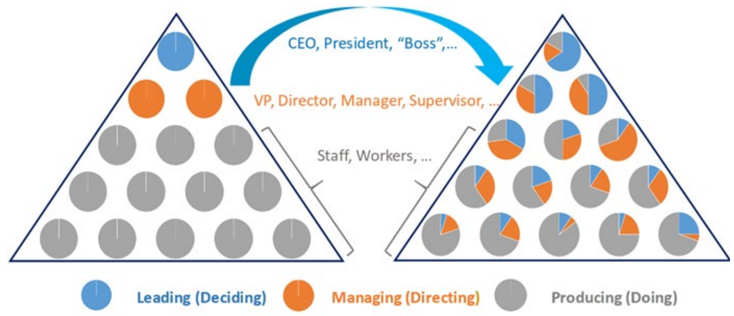
and professional development techniques aligned to their career evolution in the technology business [1][2]. To embrace continuous innovation, companies are progressively flattering, less hierarchical, evolving from traditional pyramidal and segregated organizations to an organizational model of shared responsibility (Fig. 1). This new and highly demanding context requires the STEM graduate to undertake a rapid change in attitude and work methodology to evolve from a user culture (student) to a service provider culture (employee or entrepreneur) (Fig. 2). That is, moving quickly from a task executor role (doing) to assuming greater responsibility in terms of management roles (directing) and finally to leadership roles (deciding) (Fig. 1).



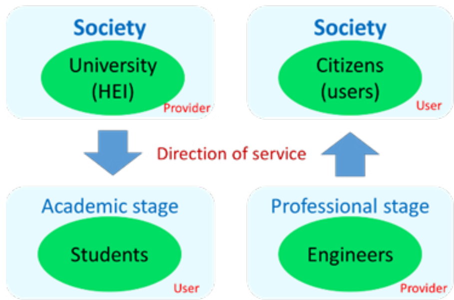


Fig. 1. Companies tend to be flatter and less hierarchical *Fig. 2. Direction of service*

Given the greater than ever impact of technology and engineering in our lives, STEM students are particularly important in leading XXI century societal transformation towards a sustainable and prosperous future, and must be ready to play that role. In this sense, Engine4STEMers aims to develop a set of short teaching and learning modules organized around three themes:

- Early career tools in the tech arena.
- Critical thinking for successful career development in STEM.
- Leadership: the STEM graduate as an effective fair human being

1.2 Critical thinking for successful career development in STEM.

The increasing acceleration of change, the need for continuous innovation, or the reduction in the useful life of products and services, requires a new brand of STEM professionals prepared to deal with VUCA (volatile, uncertain, complex and ambiguous) labour market demands. To attend to these demands, recent surveys give growing importance to social, emotional and higher cognitive skills, such as Critical Thinking, as key transversal competences demanded by employers [3]. In this context, Engine4STEMers aims to provide last year's students with a grasp on critical thinking basics: creativity and innovation, growth by generating added value, creative problem solving and (ethical) engineering design. Critical thinking has also emerged as a crucial skill in decision-making processes to manage the overwhelming amount of information we have to deal with. In addition, given that it is becoming increasingly clear that the information we perceive may be tainted with intentional or unintentional biases intended to influence our behavior, special attention should be paid to developing a skeptical attitude towards the information we perceive, as a fundamental step in the decision-making process. Likewise, STEM graduates must be aware that "what is technically impeccable does not necessarily have to be humanly correct". The motivation of final-year STEM students to start this path is one of the main objectives of the seminar presented in this short paper.

2 METHODOLOGY

2.1 Impact of perception bias on personal and professional development

The first block of this seminar is related to developing how information is generated, transmitted and perceived by people (Fig. 3). The main sources of perception bias are discussed with the students in terms of their impact on the development of personal and professional competences. Discussions focus on three key issues:

-Self-awareness: The seminar uses practical examples to discuss the fact that we do not react to the real world but to how we perceive it. Being aware of potential sources of information bias emphasizes the need to be skeptical, even of one's own beliefs and perceptions. This first section aims to motivate students toward a self-awareness attitude as the first step to self-manage their personal and professional growth.

-Interpersonal relations: The seminar presents how the fact that different people perceive the real world in different ways has a strong influence on how we interact and communicate. This stresses the need to develop open-mindedness and active listening: first, understand, be empathetic, then communicate in a fair, inclusive way.

-Proactivity. Discussions about perception bias and the limitations of self-awareness aim to emphasize the importance of inhibiting the automatic (emotional) reaction to the stimuli we receive. It helps develop the principles of the strong habit of making decisions based on reason rather than emotion. This is important in a number of situations, particularly when risk and uncertainty are involved, as illustrated by an introduction to the principles developed by Nobel Prize D. Kahneman [4].

This first block concludes with an introduction to the concept of selective perception to reinforce the need to be skeptical of the information we receive. It is illustrated with examples of fakes, frames, storytelling, and nudges to engage students in discussions and to raise their awareness of the need to be very proactive in understanding the big picture before any decision-making process.

2.2 Data literacy

The second seminar block is devoted to data literacy. While STEM graduates have a good ability to read, write, and communicate data in context, they are often not fully aware of the main sources of deception that they may have to address due to intentional or unintentional misuse of data (Fig. 3). The implications that data misuse deception can have on decision-making processes are particularly highlighted. To engage students in discussions, this concept is illustrated with examples extracted from the media and the literature [5]. The main sources of bias in (poor) data analysis are also introduced.

Finally, a section is devoted to probability. The general public's low knowledge of probability theory is a major source of non-rational decisions and is highly prone to be used in demagoguery and deception [4]. Students are challenged with probability-related examples to highlight that, in many cases, emotions can be more decisive than reason in decision-making. This section ends with some case studies related to conditional probability (e.g. the prosecutor's fallacy) and the important implications that a deficient understanding of the Bayes' theorem can have on trials or epidemiology studies, given as examples. As discussion exercises, challenged with misleading headlines, students are asked to ascertain the induced message and then to rephrase them in terms of conditional probability to provide a better insight (Fig. 4).

Seminar on perception and deception

1. Perception bias
2. Self-perception
3. Selective perception
4. Fakes, frames and storytelling
5. How to lie with statistics
6. Misleading graphics
7. Bias in (poor) data analysis
8. Deception by probability

Fig. 3. Critical thinking seminar content

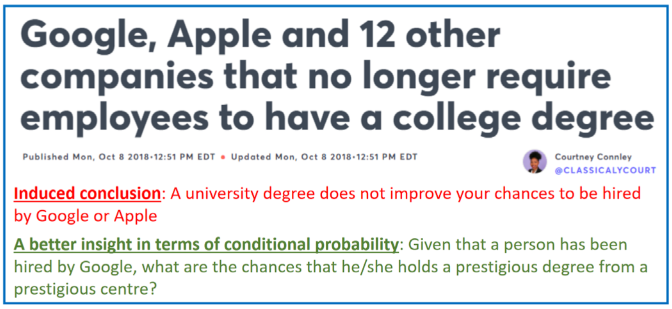


Fig. 4. Misleading headlines

3 CONCLUSION

This short paper presents a seminar on Critical Thinking that focuses on how we acquire and transfer knowledge and the main sources of information bias that a young STEM graduate may have to face. The main objective of the seminar is to introduce STEM students to the concept of perception and highlight the great influence that self-awareness and the knowledge of how others may perceive reality can have on the development of personal and professional skills. It has also been highlighted that, to thrive in the tech labour market, in a fair and responsible way, STEM graduates may have to deal with potential sources of deception in graphs and statistics, with (poor) data analysis, and with people's misunderstanding of probability.

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PROMOTING SUSTAINABILITY IN EDUCATION THROUGH THE IMPLEMENTATION OF GREEN WALLS FOR GREYWATER TREATMENT

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Conference Key Areas: *Sustainability. Sustainable Development Goals.*
Keywords: *Sustainability, green wall, grey water treatment, civil engineering, environmental engineering*

ABSTRACT

This study describes the methodology followed to design, build and operate a pilot green wall treating greywater from a vocational training center. The study was carried out in the framework of a master thesis in Environmental Engineering carried out in collaboration with the vocational training center where the pilot system was built. The system consisted of several pots arranged in rows planted with different species of macrophytes. Results showed a successful removal efficiency of the main pollutants (total solids and organic matter), while further post-treatment would be needed to reduce turbidity and pathogens in order to fulfill water reuse standards. This work shows how teaching in certain engineering studies can focus on sustainability and perform a practical work involving younger students from a vocational training center.

1 INTRODUCTION

1.1. Background and motivation

Green walls are Nature Based Solutions (NBS) able to provide several benefits such as greening, CO_2 trapping, O_2 production, climate regulator, and household insulation. In addition, they are able to minimize wastewater treatment footprint and to provide an onsite solution and a local source of reclaimed water. This technology responds to Sustainable Development Goals 6, 11, 13, 14. However, green walls have only been

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used for wastewater treatment in a few specific cases [1, 2] and treatment efficiency still needs to be further proven and optimized before the massive implementation of this technology.

The study consisted in designing and building a pilot plant for the treatment of greywater by phytoremediation in a vocational training center with about 1,000 students, located in Barcelona.

The study was carried out in the framework of a master thesis in Environmental Engineering at the Universitat Politècnica de Catalunya. This included dimensioning, design, set-up, operation and monitoring of the pilot plant. The students from the center were involved in the design, in charge of the construction and actively participated in the operation of the system.

The Center, as a Green School, promotes activities with two objectives: (1) to raise students' awareness of the importance of their carbon footprint, and (2) to use training activities that promote good practices within their profession, encouraging respect for the ecosystem and the fight against climate change.

At the curricular level, the project was developed in the 2nd year of the course on Gardening and Floristry. This is a synthesis and consolidation of the modules related to gardening and plant nursery, and the transversal modules studied throughout the degree.

1.2. Objectives

The main educational objectives of the study were: (i) to consolidate the learning outcomes achieved throughout the course; (ii) to experiment new ways of treating and reusing wastewater for irrigation; (iii) to implement a scientific research through the design, construction and evaluation of a pilot plant; and (iv) to participate in a real and relevant professional context for the Gardening and Floristry sector while promoting the transfer of knowledge between vocational training and the university.

Regarding the research objective, the main goal was to test the feasibility of greywater treatment in a vertical garden at pilot scale, in order to assess the treatment efficiency and the possibility of generating a local source of reclaimed water.

2 METHODOLOGY

The project was based on learning through active methodologies. The most important aspects of the teaching methodology were:

- The challenge of the project was fully contextualized in the reality of the school and in the professional reality of the degree.
- The students worked in self-managed groups with puzzle methodology and specific roles to design the prototype of the pilot plant.
- Each phase of the project presented activities that contained research elements that students, with the support of the teacher, must solve.
- Cooperative teamwork was evident in all phases of the project.

- Diversity was taken into account as students could work at different paces and present prototypes and projects with multiple possibilities, depending on their interests and skills.
- The staff of the university introduced the scientific method in the project and at the same time, positively encouraged students.
- The designs and projects created were shared with the group, looking for spaces and activities. This helped students to contrast ideas, include improvements, and generate new ideas.
- Both co-assessment and student self-assessment had been included, especially with regard to teamwork, oral communication, student autonomy and initiative.

The project required a dedication of 86 teaching hours, spread over 14 weeks, and was divided into the following five phases:

Phase 1. Presentation of the project (challenge) and student's theoretical training, during the first sessions of the module, students received theoretical training on the specific topics and contents of phytoremediation and vertical gardening.

Phase 2. Design of the pilot plant by groups (3-4 people) under the leadership and advice of the university staff. The puzzle learning technique was used in this phase; the roles of responsibility encompass the main areas of work of the project in order to present a prototype to the class. The university advised and evaluated the proposals. From this process, the prototype that best suited the needs of the project was selected. The prototype was designed emulating a 3-step subsurface vertical flow wetland (Figure 1). The system was organized in three rows and four columns. The influent wastewater (greywater from the sinks of the toilets of the center, dosed with primary sludge of a wastewater treatment plant) was fed by drop irrigation pipes on the top row and then percolated vertically through the rows of pots. This configuration enhances oxygenation, hence improving treatment performance. Different substrate materials were tested in the different columns (two columns with mineral and the two others with organic substrate), dividing the system in 2 modules working in parallel.

Phase 3. Construction of the pilot plant, the whole class group worked collaboratively to build the pilot plant (Figure 1).

Phase 4. Commissioning and monitoring of the pilot plant, the pilot plant was started up and then operated and monitored for one month. Samples of the influent and effluent water were took by the students twice a week and transported to the university where the master student performed the lab analysis in order to evaluate the performance of the vertical garden in terms of organic matter, suspended solids, turbidity, pathogens and nutrients removal.

Phase 5. Drafting of a vertical garden to treat the waters of the sink of the center. With the results obtained during the pilot study (loads, retention time, plant species, substrates, efficiency, etc.), the students designed a full-scale vertical garden capable of treating the greywater from the sinks of all the toilets of the center.

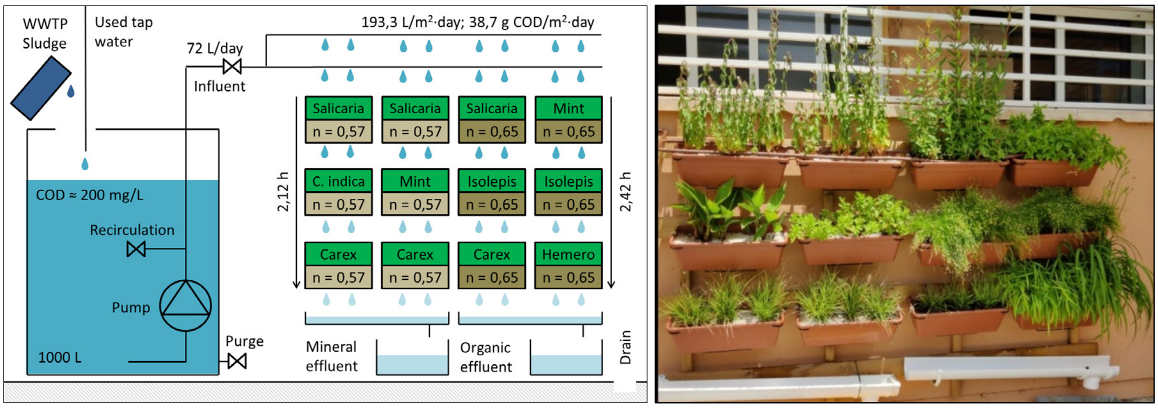

Figure 1. Scheme of the pilot plant (left) and picture of the vertical garden (right)

3 RESULTS AND CONCLUSIONS

The prototype was designed, built and operated and monitored according to the methodology described above. Overall, the expected performance was achieved in terms of wastewater treatment, achieving suitable removal of pollutants (>60% removal of total solids and organic matter), while further post-treatment would be needed to fulfill water reuse standards (turbidity and pathogens).

Moreover, this methodology and this study can be used to respond to different Sustainable Developing Goals. Indeed, nature-based solution applied in the field of wastewater treatment are directly linked with SDG6 (clean water and sanitation) and SDG14 (life below water). Green walls are also a suitable solution for cities, contributing to SDG11 (sustainable cities and communities). Finally, considering the positive effect of green walls in terms of CO_2 trapping, O_2 production and water sanitation, also SDG13 (climate action) is addressed.

Concerning students' experience and participation, a reduction of school absenteeism was observed compared to data from previous academic years. Phases 3 and 4 of the project (construction and monitoring, respectively) were the most motivating activities for students and had the best learning results. These also prepared their problem-solving capability to later develop a full-scale vertical garden project.

This work shows how teaching in certain studies as civil engineering, architecture, and environmental engineering can focus on sustainability and SDGs, performing a practical work involving younger students from a vocational training center.

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Investigation of student reasoning skills about flow processes in logistics (Short Paper)

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ABSTRACT

We present preliminary results of a pilot study investigating the reasoning skills of students in logistics and mobility in the context of hydrodynamics. Particularly, we were interested in the students' thinking of parcel flow in logistics and steady-state pipe flow.
Our goal was to investigate if students of logistics would show more, less, the same, or different misconceptions commonly found in students confronted with hydrodynamics problems. We hypothesize that, due to their exposure to flow-like systems (transport chains, band conveyors, hub systems etc.), students develop a certain intuition about flow processes.
Interviews were held with several students that attended "Transportation and Handling Technology" at Hamburg University of Technology (TUHH) in the two winter semesters of 2020/2021 and 2021/2022.
We found that half of the students were unable to solve questions regarding the parcel flow on a band conveyor or the steady-state flow in a narrowed pipe, while the other half of the participants showed the correct understanding of flow processes to solve all the problems. We present evidence that misconceptions about hydrodynamics strongly affected participants' ability to solve logistics problems.
We also discuss the application of our findings for instruction in logistics.

1 INTRODUCTION

In their studies and later careers, students of logistics are confronted with a variety of flow processes, such as transportation on band conveyors, supply chains, hub systems and material transport in mines, factories and harbours. Based on this, we raise the question if these students obtain a certain intuition about the continuity concept. This encompasses the laws of flow processes, mainly the idea that material cannot be lost which leads to various conditions for possible flows.

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Continuity and flow are usually discussed in physics in the context of hydrodynamics, but students of logistics have rarely contact with a formal education in this field. Therefore, we designed several related questions in logistics and hydrodynamic to shed light on the following research questions:

A) Do students of logistics have any intuition about flow processes and can they transfer these insights in order to solve problems of hydrodynamics?
B) What are their thought processes and possible misconceptions when confronted with these problems?

We know that hydrodynamics problems are often difficult to solve for students of various fields. Whereas this problem is known and relatively well documented for students of physics and engineering ([1],[2],[3]) few studies have been conducted on the intuition and reasoning skills in students of logistics.
Therefore, we are not only interested in the existence of an intuition about the continuity concept, but also in misconceptions the students might have if they lack this intuition. Such insight into students' ideas may help design better instruction for the field of logistics where flow processes play an important role.
There have been several studies concerned with knowledge and skill transfer between known concepts and novel situations [4]. This cognitive ability is troublesome and difficult [5]. Though there are many psychological and didactical models to understand transfer, these lie outside the scope of this paper. For now, we are focusing on observing transfer (or the lack thereof) and will postpone the discussion of appropriate cognitive models to a later point in time.

2 METHODOLOGY

We conducted interviews in January and February of 2022 with four bachelor students who had attended the lecture "Transport and Handling Technology" in the winter semester of either 2020/21 or 2021/22. All students had attended introductory mechanics and math courses but none had had any instruction in fluid mechanics. This makes for an interesting background because we can assume that their intuition about fluid dynamics either stems from logistics or day to day intuition and not formalized education in these fields.
Here we present and discuss two of the four items that had been given to the students. These two items yielded the most interesting responses and give a first look into the understanding of flow processes in the participants.

<u>Question I</u>

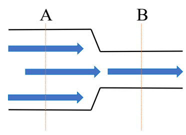
"Two band conveyors (A and B) are serially-connected and are packed with small parcels that are separated by a long distance compared to their own size. At the end of A the parcels fall an band conveyor B and both band conveyors operate with the same speed.
Due to a malfunction, the speed of band conveyor B must be reduced by half of its original speed. After a long time, does the delivery rate increase, decrease or stay the same?

Our expected answer is that the delivery rate stays the same. While the velocity of band conveyor B is halved, the parcel density is doubled. Therefore, the delivery rate stays the same, except for the time the less densely packed parcels need to reach the point where the delivery rate is measured. However, since we want to look at a steady state, students are asked to consider the delivery rate "after a long time".

In this question, the parcel flow behaves like a compressible steady state flow. We wanted to see, if students could make this (or another helpful) connection to solve the problem.

Question II

In the following drawing, we can observe a liquid flowing through a pipe. At one point the pipe narrows. Which statements can be made about the volume flow and the velocity of the liquid? Explain your reasoning.



This is one of the many variants of a common hydrodynamics problem.
As in question (I), the volume flow stays constant; for an incompressible fluid, however, this means, that the velocity must increase.

3. RESULTS

Two of the participants had little to no problems solving the tasks. The other two struggled and revealed some misconceptions about the topic.
We will focus on Participant 2 and 3, who did show misconceptions in their rationale.

3.1 Question I: Failure to see or ignoring the density change

In question (I) the misconception we anticipated is that students might think that it is imperative for the delivery rate to go down after the second band conveyor goes to half its original speed. This misconception is presented well in the following statement from participant 2:

> *"The delivery rate is of course reduced because the velocity is reduced by half. This means the delivery rate is also reduced by half."*

Interestingly, participant 2 did realize that the space between parcels must be smaller:

> *"The same amount [of parcels] reaches the end but later…or slower with a smaller space in between."*

While participant 2 realized conservation of parcels as well as the decreased space between parcels, they did not see a connection to the delivery rate.
Participant 3 had similar problems, even though imagining two identical set ups (1 and 2) next to each other but with one band conveyor system (1) running without malfunction (A1 and B1 have the same speed.).
While they may have realized that the parcels move slower on B2 but with a higher density compared to the unthrottled system they still arrived at the wrong conclusion:

> *"The delivery rate of band conveyor 1 would be of course greater."*

3.2 Question II: Inferring lower flow rate because of decreased diameter

In question (II) we saw similar reasoning. Both participants argued that the volume flow must be smaller due to smaller volume in region B. Participant 2 stated about the volume flow:

> *"Of course, the volume in A is much larger than in B.*
> *(…) Naturally this leads to a jam and the velocity is lower in B."*

Here, the use of the term "jam" even hints at some form of compressibility. According to participant 2, liquid must backlog at the narrowing.
While both first stated that the velocity must therefore decrease, Participant 3 later changed their mind and argued:

> *"Either the velocity stays the same and the flow decreases*
> *or the volume flow stays the same and the velocity increases."*

But they finally decided on the wrong conclusion:

> *"The volume flow is decreased because if the pipe is smaller, less liquid can fit inside."*

We found that the relation between velocity, density and delivery rate/volume flow is not clear for these students.

4. INTERPRETATION

Though small, the study showed interesting results.
Half of the students could solve all questions with ease, the other half showed common misconceptions about flow processes. This suggests that we can indeed expect a certain level of intuition about hydrodynamics from students of logistics.
On the other hand, the results also indicate that some students have similar struggles as other populations and their misconceptions are related to the idea of continuity.
At this point we can only speculate about the exact mechanism that leads to these misconceptions. Both questions are very similar in design. The difference lies in the variables that are fixed by the scenario and the variables that depend on these.
For question (I) it is the velocity that is changed through the malfunction. This leads to an increase in density so that the delivery rate ultimately stays the same. The compressibility adjusts for the reduction in velocity.
In question II the change in velocity is the result of a disturbance (narrowing), not the disturbance itself. But since the density cannot change, the velocity must increase. In either case the flow rate stays the same.
One could argue that the students have the same intuition about both problems: that a change in velocity must lead to a change in flow rate.
In both scenarios, compressibility and its implications are not well understood.
In question (II) students failed to see the incompressibility therefore concluding that the flow rate must decrease. In question (I) they recognize the compressibility but do not see its implication for the (unchanged) flowrate.
Interestingly, the conservation of mass seems to be clear. The liquid in question (II) cannot disappear, therefore there must be a jam at the narrowing, participant 2 argued. This is, in this mind set, a logical conclusion. The concept of continuity

seems to be understood to some extent but it cannot be brought to its practical and logical conclusion.
Question (I) might reveal a certain confusion about the steady state character of the problem. Future questions might adjust for that by rephrasing the problem in terms of comparison of two time independent situations.
Further study is needed to pinpoint the exact mechanism of these misconceptions.
The results encourage us to look further into the reasons why some students of logistics seem to be able to handle hydrodynamics problems well and how this transfer of intuition, and its failure, works.
During the upcoming semester, we plan to interview more students of logistics to get a broader picture of their reasoning skills.
Our findings suggest an early and focused treatment of flow processes in logistics education, with a special emphasis on the underlying principles of continuity and (in)compressibility.
Since the first submission of this paper, six more interviews were conducted. These showed similar results and opened up a deeper view of the subject. The combined results could not be submitted in this paper, but will be discussed in the presentation of our work at the SEFI Annual Conference in 2022.

Acknowledgment

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Skills for learning across disciplines in project-based learning

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ABSTRACT

Education focusing on developing interdisciplinary skills is gaining traction in Higher Education. Often this type of education takes shape through project-based learning. Prior research shows that the focus of such interdisciplinary learning should lie on attaining synthesis and that the end result of an interdisciplinary project should be more than the sum of its disciplinary parts and be truly synergetic. Two important prerequisites of successful interdisciplinary (project)work are reaching a common goal in which each discipline is of added value towards synthesis and attaining a common ground of methods, concepts and views.

In this research project, the focus was on mapping if students were able to reach a common ground and synthesis during working on an interdisciplinary project. The context is the Smart Solutions Semester of Saxion University of Applied Sciences, where third- and fourth-year students from three or more (engineering) disciplines work together in project teams on large (25 ECTS) projects, provided by research groups and the business community. A learning activity was developed for and conducted with four student teams after which semi-structured interviews were held with the students and corresponding tutor. Results confirm the importance of a common goal and common ground. Additionally, results show the importance of fostering interdisciplinary exchange and the crucial role of the tutor in guiding students toward synthesis.

1 INTRODUCTION

1.1 General introduction

Complex challenges in society ask for innovative, out of the box, solutions. These solutions often take shape by utilizing various perspectives and ideas, both within and between disciplines. Interdisciplinary group work is increasingly present at universities, focused on fostering skills for students to work on these complex challenges. At Saxion this takes shape in the Smart Solutions Semester (3S). In this semester students from various disciplines work together in project groups on large, complex challenges which are provided by the business community and research groups. One of the goals of the 3S is to challenge students to cross their disciplinary boundaries towards creating ‘smart solutions’.

1.2 Theoretical Framework

Various definitions and interpretations of multi- inter- and transdisciplinarity exist. During this research the following definition of interdisciplinarity has been used: *"The capacity to integrate knowledge and modes of thinking in two or more disciplines or established areas of expertise to produce a cognitive advancement, such as explaining a phenomenon, solving a problem, or creating a product, in ways that would have been impossible or unlikely through single disciplinary means"* [1. pp. 219]. In concrete terms this means that **synthesis** between disciplines is crucial on both the project level and the subtask level [2].

Four processes are key to interdisciplinary collaboration [2].The first being **setting common goals**. This first step concerns matching the correct disciplines to the complex challenge at hand and identifying the added value of each discipline. Subsequently a **common ground** has to take shape. This entails further exploring the added value of each discipline concerning knowledge, methodologies, terminologies etc. to obtain a common framework from which the challenge can be addressed. During the entire project it is important to foster an attitude of **critical awareness**, e.g. being able to constantly reflect on the possibilities and limitations of each discipline concerning the complex challenge. Finally, students should constantly aim for **synergy**, e.g. interdisciplinary collaboration on the complex challenge at hand should be more effective and rewarding for participating disciplines compared to going at it by themselves. To obtain a common goal and a common ground students should understand and appreciate the perspectives of students from other disciplines [3]. Fostering **interdisciplinary exchange** revolves around being able to relate their own disciplinary perspectives and matching motives and intentions to the motives and intentions of students that are grounded in/based on other disciplines.

Interdisciplinary exchange concerning the complex challenge thus is the core of the initial phase of an interdisciplinary project. Prior research [4] showed that students in the 3S struggle to exchange, utilize and integrate disciplinary knowledge. Therefore, the focus of this current research is to map if students were able to reach a common ground and attain synthesis during their 3S project.

2 METHODOLOGY

2.1 Context

This research project was executed during the 20/21 academic year. Two researchers (e.g. the first and third author) were involved in the data gathering. The research took place in the 3S, in which third- and fourth-year students of 22 bachelor programs collaborate in interdisciplinary project groups of 6-8 students (25 ECTS). Over a 1000 students and 100 tutors work and learn in this semester. During the semester students develop competencies in three domains: professional behaviour, application and development of research capabilities and application and development of knowledge and skills from their own and other disciplines. Each project group is supported by a tutor.

2.2 Research questions and design

The main focus of this research was identifying to what extent students are able to obtain a common ground through interdisciplinary exchange whilst working and learning in an interdisciplinary project group and to what extent they are able to reach synthesis. A learning activity (see 2.3) to foster interdisciplinary exchange was designed and conducted with four project-teams (see table 1 for their composition), five weeks after the start of the semester. This session took place online and was recorded. The four teams participated in a focus group which took place within two weeks after the learning activity. The focus group was partly semi-structured around the four processes crucial to interdisciplinary collaboration and partly based on questions concerning recorded chapters from the learning activity. The focus of the interview laid on both project-work leading up to the learning activity, as well as the learning activity itself. Furthermore an interview took place with the tutor of each group, leading to three interviews (one tutor was absent). This interview mimicked the semi-structured part of the focus group interview with students. Because of Corona-measures, all these interviews took place online via Teams.

Table 1. Composition of project-teams

Case	N	Disciplines
1	6	Nursing (4), Information and Communication Technology (1) and Creative Business (1).
2	8	Forensic Research (1), Civil Engineering (3), Archaeology (2) and Mechatronics (2)
3	7	Nursing (3), Industrial product design (1), Technical Informatics (1) and Creative Business (1)
4	6	Archaeology (2), Forensic Research (1), Technical Business Administration (1), Information and Communication Technology (1) and Creative Business (1).

2.3 Learning activity

The goal of the one-hour learning activity was fostering interdisciplinary exchange to reflect on if a common ground was attained. One researcher led the learning activity and the tutor was not present during the activity. The learning activity was based on the concept of triangular reflection [5] and revolved around three subsequent activities. Students were asked to complete a mindmap in which they both explained the added value of their own discipline for the challenge at hand and reflected on the added value of the other disciplines within the project group. The first phase was aimed at *exchanging* relevant disciplinary knowledge and skills from their own discipline. The second was aimed at *creating* the coherence between disciplines and the complex issue at hand. The final phase was aimed at *reflecting* on how to integrate interdisciplinary knowledge and skills throughout the further course of the project.The researchers challenged students to put under words their own perspective concerning the complex issue, but also explain how and why the other disciplines were of added value for solving the complex issue.

3 RESULTS

3.1 Common ground and synthesis

An analysis within and between cases was conducted focused on whether a common ground and synthesis was attained within the cases. A rubric for ranking interdisciplinary work [6] was used to determine the amount of interdisciplinarity in each group. Results showed that only one group was partly able to attain synthesis.

Several factors negatively affected the ability of students to reach synthesis. Firstly, the complex challenge was not truly an interdisciplinary challenge in three out of four cases and did not offer the possibility for interdisciplinary collaboration aimed at synthesis. Students noted they did not see the “match” between their own discipline and the challenge. In addition, students did not have the opportunity to decide the common goal for the project because in two out of four cases this goal was already set by the client. Furthermore, even if the challenge offered the opportunity for student goal-setting and synthesis, students often organized themselves multi-disciplinary by working with for instance only the nursing students on sub-tasks, since synergy was not necessary for solving the challenge. Finally, only one out of four project groups focused on interdisciplinary exchange prior to engaging in the learning activity and was able to reach some sort of common ground. Critical awareness thus was not fostered during working on the project. The 3S is the first time for most students to engage in interdisciplinary collaboration. Whereas students have no or limited interdisciplinary skills when enrolling in the semester, these need to be fostered in order for them to reach synthesis whilst working on complex challenges.

Support offered by the tutor on guiding students to attaining a common ground through interdisciplinary exchange differed between tutors. Mostly tutors mentioned the importance of getting to know each disciplinary background, but left it to students to take action on engaging in this dialogue. Results showed tutors focus mostly on supporting research activities of students and on personal introductions. Professional (disciplinary) introductions and disciplinary orientation concerning the complex challenge received little attention by both students and tutors. Possibly tutors lack the insight in the importance of fostering interdisciplinary exchange, which led to them being passive on this matter.

3.2 The learning activity

Students from all four cases responded positively to engaging in the learning activity. The level of perceived impact of the learning activity differed based on the phase of interdisciplinary collaboration. When students had not yet engaged in any interdisciplinary exchange and working towards attaining a common goal and common ground, the learning activity made them aware of the importance of interdisciplinary exchange. When students already had engaged in interdisciplinary exchange prior to the learning activity, participating in the learning activity invited them to elaborate on their insights concerning the common goal and common ground. It led to confirmation of their own insights related to the insights of other group members.

3.3 Recommendations

This exploratory case study further strengthens insights concerning interdisciplinary collaboration. Although the number of cases was limited, combined with the prior research mentioned earlier [3], it is plausible that a larger number of students within the 3S and within higher education in a broader sense are unable to reach synthesis during interdisciplinary collaboration. Four recommendations are at the core of improving and fostering interdisciplinary collaboration in higher education when working on complex interdisciplinary challenges. First, to be able to collaborate interdisciplinary, it is important for students to be able to work on complex and **ill-defined challenges** where they truly have enough room and **autonomy to set or adjust the common goal**. This allows them to consider whether and by which means their discipline can be of added value for reaching synthesis. Second, to encourage interdisciplinary exchange, **learning activities** can play a crucial role, for example focused on **reflecting on disciplinary knowledge and skills** related to the complex challenge. Third, when guiding students during interdisciplinary collaboration, **tutors** play an important role in guiding students when working on complex challenges. By showing tutors the means through which they can foster interdisciplinary collaboration and offer them opportunities for practice, the impact on student learning should increase. Finally, when developing interdisciplinary education, it should be taken into account that this requires **complex skills which should be developed throughout the curriculum**. It is important that students are offered opportunities to get acquainted with interdisciplinarity early on in their studies. This allows them to realize and determine when interdisciplinarity is of added value and which processes are important to take into account when working on complex challenges across disciplinary boundaries.

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Identity and agency of engineering educators in Zimbabwe

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ABSTRACT

Educational transformations require educators with competences to deliver quality education. This raises the issue about capacity building in staff and in particular in the engineering disciplines where pedagogical practices are heavily reliant on didactic approaches such as traditional lectures and tutorials. The global Covid19 pandemic has forced educators to move away from traditional approaches and although the response was quick it is unclear if many of these changes will remain in future, given that they were not done by design but as a reaction to the unexpected situation. This study considers the training of engineering educators in different engineering disciplines and in a number of higher education institutions in Zimbabwe who were part of a HEPSSA-Royal Academy of Engineering UK project. At this conceptual stage the study explores how effective capacity building activities are in enabling educators to transform their practice to an active student-centred approach both in face-to-face and online modes. It further explores how the training experience might empower educator's sense of agency and change their identity within the boundaries of their institutions and country. The research design is grounded on the theories of agency and, self-efficacy and motivation. It uses an interpretative approach, Qualitative Content Analysis, for the analysis of data collected via interviews with the engineering educators participating in the project. This research design aims to find how engineering educators can be supported through their educational transformation journey and also to inform policy makers at institution and national level in order to enhance sustain development.

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1 INTRODUCTION

1.1 Background

The socio-economic development of Zimbabwe requires capable engineers able to face current and future challenges in the country. This makes it essential for institutions delivering on engineering education to consider the best approaches to provide students with opportunities not only to develop their knowledge but also the skills for meeting societal needs. Didactic pedagogies where the students are passive recipients of knowledge [1, 2] are the most common current approaches in compulsory education in sub-Saharan countries [3]. These same practices persist through higher education, and, until recently, were prevalent in engineering education in Zimbabwe, hindering opportunities for students to develop professional skills. Pedagogical approaches that are student-centred and promote active learning support the development of professional skills [4, 5] so needed by graduates to be able to face new and uncertain career situations.

Although Kurasha and Chabaya [6] conclude that curriculum development in higher education should adapt to global trends Tabulawa [7] argues that past failure of educational reforms from didactic approaches to student-centred approaches has not been based on deficiencies in the implementation of innovation but rather in the oversight of the socio-cultural context when trying to embed new pedagogical practices. The epistemological stance of educators and their perception on the purpose of education as well as social structures plays a key role in determining the success of sustained pedagogical change in schools [7].

Clearly, educational transformations required not only changes in systems and structures but also educators with competences to deliver quality education. This raises the issue about capacity building in staff in relation to adequate pedagogies for professional skill development and how we can establish what support is needed and why educators might or not be inclined to change their practice.

In 2019 the Zimbabwean government launched their Education 5.0 initiative as a policy driven approach to support the transformation of the higher education sector in areas of education, science and technology [8].

The Higher Education Partnerships in Sub-Saharan Africa (HEP SSA) scheme, supported by The Royal Academy of Engineering through the GCRF-Anglo-Platinum Foundation, focuses on training engineering educators in the broad range of academic activities and to enable them to build their capacity in research and teaching and in turn transform the educational landscape of their country. It is within the context of a project sponsored through the HEPSSA programme in Zimbabwe that the current research is situated. Pedagogical transformation in practice requires more than simply participating in a set of training activities. The socio-cultural and professional context of educators needs to be carefully considered if changes are to be sustained. The questions that this study explores are how do capacity building and training activities impact on the development of the engineering educators' agency and identity and how these activities can produce sustained change.

1.2 Theoretical framework

A critical element of this study is the importance of context and the understanding of the individual's experience and their social constructions and, therefore, this study is framed within the Interpretativist paradigm [9,10]. In addition, the theory of human agency [11] serves as a framework to guide the research design and later as a lens to interpret the data. The research design is primarily guided by the ideas that individuals as agents can self-regulate their actions and influence themselves and the environment around them. Similarly, individuals do not operate in isolation but rather in socially situated contexts given raise to interpersonal transactions where each one can act as someone else's environment. A key element, within Bandura's theory of human agency, that is relevant to this study is the idea of self-efficacy which is a key aspect associated to personal development and change [11].

Based on different approaches to agency Eteläpelto et al. [12] have conceptualised the idea of professional agency at work, that is, an approach to agency that pays "attention to [the] subjects' construction of their identity position at work, and focusing on how they negotiate agency in education and working life in order to construct meaningful careers and life courses". Given that the current study considers the socio-cultural context as critical in understanding the potential success of pedagogical training, this approach will serve as a lens for the data analysis.

2 RESEARCH DESIGN

This study is specifically defined within the context of two workshops, with participants from a range of institutions and industries, were carried out at different points in time during the life of the HEPSSA project and, led by Midlands State University in Zimbabwe. The first workshop (early 2019) focused on participants' discussions about state-of-the art of curriculum in Zimbabwe whereas the second workshop (late 2020) was delivered online and focused on active-learning and student-centred pedagogies including online delivery.

The analytical approach considered to explore the data is Qualitative Content Analysis which in line with the questions to be explored [13]. Data will be collected via means of interviewing engineering educators working in different engineering disciplines within different higher education institutions in Zimbabwe. The interviews are carried out online and recorded for subsequente transcription. Only people who participated in the capacity building activities of the project were invited to take part in this study. Ethical approval has been obtained from the University of Strathclyde Departmental Ethics Committee.

3 SUMMARY AND ACKNOWLEDGEMENTS

Data collection has unfortunately been delayed due to slow participant recruitment and interview availability. Results and analysis are not available yet as interviews are being conducted. However, the research design and theoretical framework used for the study of 'professional identity' [12] provides benefits for the larger engineering community. The review of the literature reveals that any educator training needs to attend to the local needs and cultural expectations of those participating in the learning process (i.e. students and staff alike). Sustained change requires to alter the epistemic stance of educators in relation to their belief about knowledge, the goal of education and their roles as educators. This study will provide answers to these questions and will help to inform policy making.

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INCLUDING DIGITAL AWARENESS AS A COMPETENCE IN A NETWORK ENGINEERING DEGREE

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ABSTRACT

Information and communications technology (ICT) engineers play a key part in our society's digitization process. To foster that role, the Castelldefels School of Telecommunications and Aerospace Engineering (EETAC) of UPC's Degree in Network Engineering currently includes a new competence termed digital awareness. This report demonstrates the initiative's first outcomes, including the teaching resources created, and feedback from students and teachers. In addition, the findings of a high school poll are presented, indicating a high level of interest in this new competence.

1 INTRODUCTION

1.1 Context

The digitization of our society is most likely the first technology transformation that can be termed universal and essential. In this era, controlling individuals' data, the digital gap, fake news, algorithm bias, and cybercrime are all key issues that society, governments, and corporations are dealing with at the moment. Engineers in ICT play a vital role in this challenge. To overcome this, we feel it is critical to introduce a new competence known as digital awareness into their education. Its goal is to analyse both the positive and negative elements of a certain technology or technical solution, and to provide guidelines not only for its design, which should adhere to digital awareness guidelines, but also for its righteous use.

Digital awareness relates various topics linked to the safe and responsible use of technology, which we categorise as follows [1]: digital wellness, cybersecurity, reliable information, digital identity, online education, digital parenting, digital inclusion, digital development, data protection, and digital citizenship. Some of them can also be found in the new release of the European Digital Competence Framework for citizens [2]. Currently, we are incorporating digital awareness competence into the Castelldefels School of Telecommunications and Aerospace Engineering (EETAC) at UPC's Degree in Network Engineering following the plan presented in [1]. Note that the number of girls enrolled in this degree is below 20% [3].

1.2 Motivation

This paper aims to show the initial results of this initiative. The educational materials designed and their level of success, are determined by conducting a poll research and comparing the results to instructor evaluations.

One additional reason for building this ability is to investigate the impact of technology on society, thereby providing a social viewpoint to engineering courses, which is often lacking. This new perspective has the potential to increase the number of girls pursuing technical education [4][5]. Then, we provide the preliminary results of a poll conducted in high schools to determine whether acquiring this new ability could increase the attraction of this degree, with a special focus on the interests of female students.

2 METHODOLOGY

2.1 Introduction of the competence in the degree

Five topics related to digital awareness have been introduced this academic year. Taking Bloom's taxonomy [6] as reference, the competence is presented in "Business Management" (1st course) and understood in "Internet Architecture and Protocols" (2nd course); the upper levels of the taxonomy are worked in "Mobility Networks and Services", "Applications Engineering", "Network Security" (3rd course) and, in the future, in the bachelor thesis (see the syllabus here [7]).

To work the competency, audiovisual content is used, typically one video for each subject. Teachers offer a description of the video material and supervise the script, which is generated by a specialised firm, as well as the production, which is handled by the campus's audiovisual services. A single video [8] was created and tested during the first semester test this approach. Teachers used it in the project-based course "Applications Engineering" to convey the notion of digital awareness in the context of their subject matter, so that students may incorporate it into the design, execution, and presentation of their project. The competence is addressed similarly to any other evaluable part of the project. In other words, its progress is reported on in follow-up meetings, and its execution is evaluated in the project presentation. In other disciplines, the videos created will be used to develop H5P-based interactive elements that will aid in the competence evaluation.

2.2 Poll-based study

A survey was carried out at the end of the first semester to assess the introduction of the competence in the "Applications Engineering" subject from the student's perspective. Its findings are compared to the data provided by the teachers. During the second semester, a more comprehensive investigation was conducted among students from three high schools: two in the province of Barcelona, and one in the province of Tarragona. We asked 26 questions in four blocks concerning the film itself, its content, as well as their interest in studying engineering and, in particular, ICT, and the viability and relevance of adding social impact concepts such as digital awareness in their studies.

3 RESULTS

3.1 Undergraduate students

All 17 enrolled students responded to the survey by offering examples of their digital awareness projects. However, some of the responses show a superficial or possibly incomplete attainment of the competence. The feedback supplied by teachers reinforced this perception. Better results are expected when students have worked on this competence in multiple disciplines. A whopping 94.1% believe they will use this skill in their careers. Concerning the film itself, teachers have used it as a classroom material, and 94.1% of students agree it is beneficial for presenting digital awareness content.

3.2 Secondary school students

We received 221 responses, with 46.6% male (blue), 48.9% female (red), and 4.5% undefined. The distribution of courses is as follows: 27.5% from the first compulsory secondary education course (12 years old), 5% from the second, 30.6% from the third, 21.2% from junior high-school, and 15.8% senior high-school. Regarding the response values, 5 signifies "strongly agree" and 1 means " strongly disagree."

Figure 1 illustrates that the concept of digital awareness is relevant to most people (98.2% ≥ 3). The average values, shown by dashed lines reveal only minor variances across genders. When asked if app developers should follow digital awareness guidelines, students responded in a similar way". Fig. 2 shows a poor interest in following engineering studies, particularly among females: 18.45% more girls are not interested (answers ≤ 2) in these degrees, while 15.03% more boys are (answers ≥ 4). Respondents' interest in a subset of engineering degrees, namely the ICT area, deteriorates slightly, as expected: 48.4% rate it as 1, and 19.6% rate it as 2, showing similar gender disparity.

When it comes to the appeal of including the social impact of engineering and digital awareness in engineering or ICT degrees, respectively (see Fig. 3), the global responses are quite balanced. Looking into the level of studies and gender, senior high-school students show the highest interest, with girls having higher average values than boys: 3.71 vs 2.83 for adding the social impact of engineering, and 3.73 vs 3.16 for digital awareness inclusion in ICT degrees. This is also noteworthy given the poor interest in engineering and ICT degrees, with average values of 2.33 and 1.85.

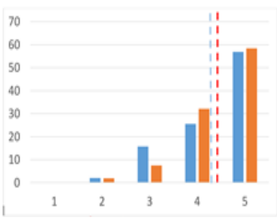

Fig. 1. Importance of digital awareness

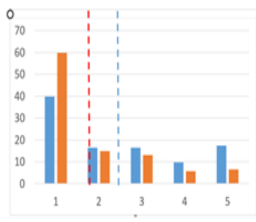

Fig. 2. Interest in follow a engineering degree

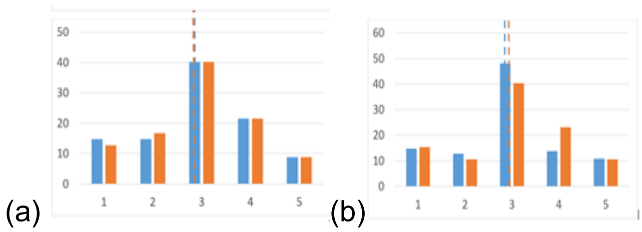

Fig. 3. Attractiveness of social impact of engineering (a) generic (b) digital awareness in ICT degrees

Both studies show the interest in the digital awareness concept. For undergraduate students, its incorporation as a competence will demonstrate if, as in the situations discussed in [5], more EETAC girl students pick the Degree in Network Engineering at the end of the common courses. Concerning secondary school, our aim is to conduct studies related to talks and experimental activities similar to [4] but focused on digital awareness, to better know its capacity to attract girsl to ICT degrees.

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Making spatial pedagogy: using insights from spatial ability research to develop maker education pedagogy

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ABSTRACT

Maker education has been shown to effectively raise children's interest for STEM subjects. Creative maker activities, which mostly take place in informal learning environments such as museums and libraries, hold potential to teach children scientific concepts and train cognitive abilities that are critical to success in engineering in an engaging way. One of these often-overlooked skills fundamental to STEM is spatial ability, which is known to commonly function as a gateway skill to STEM disciplines. Spatial ability is malleable, and training can effect gains not only in psychometrically assessed spatial ability but also in mathematical skills, further demonstrating its importance to STEM learning. In practice maker education often lacks explicit pedagogical attention to the development of scientific skills and cognitive abilities such as spatial ability, instead overemphasising technological skills, and thus limiting its potential to increase learning related to science and engineering. Therefore, maker education practice would greatly benefit from a pedagogy that recognises spatial elements and scaffolds spatial ability development. In this paper the opposing pedagogies that lie at the roots of the maker education

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and spatial ability education are examined, as a prerequisite step to redesigning maker education practice. The final aim is to transform maker education practice into a STEM learning practice through which spatial ability development is scaffolded and can be assessed. This would help realise maker education's potential for scientific learning and may help a wider audience to meaningfully partake in STEM-related activities from a young age.

1 INTRODUCTION

1.1 Maker education

'Making' is often described as using both high and low-tech prototyping tools to design and build physical and virtual objects [1]. Over the last decade, this type of activity has garnered significant interest from educational circles [2]. The type of activities that have come to be known as 'maker education' have their roots in the progressive and constructivist tradition of education and take place in both formal and informal education settings [2]. Maker education interventions in schools have been shown to successfully improved self-reported measures such as motivation for STEM [3]. Throughout Europe, South-East Asia and the United States, informal learning centres have also emerged in places such as museums and libraries [2]. Aimed mainly at children of primary-school age, and sometimes secondary-school age, activities in these makerspaces generally revolve around a playful process of iterative problem solving of an open-ended or challenge-based task with a strong emphasis on the children's creativity [4].

1.2 Potential for STEM and spatial ability learning

Educational maker activities have been ascribed significant potential to link science and technology learning in a creative way [2]. An important feature of these activities is the ability to break the commonly-held belief of a dichotomy between hands-on and intellectual work. Scientific concepts such as e.g., force, friction, momentum, motion, or electrical circuitry become tangible as they are explored as integral parts of the educational maker activities the children take part in [2]. Furthermore, children realise that they can engage with scientific matter, instilling a positive attitude toward science and engineering from an early age [4].

Fig. 1. Typical project integrating crafts and electrical circuitry from a library maker education workshop

Through the creative and constructional characteristics often found in maker education activities, there is significant potential for the development of spatial ability. Spatial ability is often overlooked in traditional education, but the critical role it plays to success in STEM disciplines, particularly engineering, has become increasingly clear [5]. For a variety of reasons, from lack of access to spatial toys to gender-related stereotypes, girls and children of low socioeconomic status tend to underperform on measures on spatial ability [6]. Through educational maker activities, children could be reached with activities that would help them develop this crucial cognitive ability.

2 DEVELOPING SPATIAL MAKER PEDAGOGY

2.1 Maker education practice – potential and limitations

The term 'making' originates from a movement of people gathering in shared spaces, referred to as makerspaces, where members of a community, club, or university can make use of shared traditional workshop tools as well as more technologically advanced prototyping tools such as 3D printers and laser cutters [7]. Maker education efforts taking place in out-of-school contexts such as museums and libraries form the bulk of implemented interventions and hold significant promise for reaching a wide variety of children [2]. Most maker education efforts are rooted in the belief that letting children explore the available prototyping tools will give children unique learning opportunities and allow them to express themselves creatively [8]. This mirrors the way in which professional designers use these tools to ideate and prototype to explore solutions, which is described by Kirschner as confounding epistemology for pedagogy [9]. Within this constructionist pedagogy, children are supposed to construct an understanding of e.g., scientific elements as a natural by-product of the self-defined projects in a makerspace [10]. In contrast to other forms of constructivist/constructionist forms of education such as project-based learning and design-based learning, maker education activities often lack explicit attention to pedagogy [2]. However, contrary to this constructionist approach to learning, in practice maker education activities are often extensively planned and pre-structured by facilitators due to the technical skills required to make use of typical ‘maker tools’ found in makerspaces and the time constraints of (after-) school activities [4]. The current value of these activities to participants’ STEM learning is questioned by educators, as scientific learning is most often not explicit and not actively assessed, and if present, is subordinate to the successful use of the technological tools to create an attractive product during the activity or workshop [1][2]. Furthermore, studies on teacher preparation and effectiveness of maker education activities, both in formal and informal education settings, are not well-represented within the maker education literature [8]. Despite these current limitations, maker education holds significant potential, particularly as a valuable form of additional education in parallel to formal curricula, with room for multiple epistemologies; room for exploration and creative freedom, while also integrating explicit learning about scientific concepts in hands-on way, to bring engaging STEM-learning to a wider audience.

2.2 Approach to training spatial ability

Recent interventions aimed at developing spatial ability have generally centred around direct instruction aimed at improving the performance on tests measuring the psychometrically determined factors of spatial ability. One of the most illustrative examples of this is an extensive course that has proven to be effective at developing spatial ability among first-year university engineering students, showing that through well-structured direct instruction and scaffolding of activities spatial ability can be developed [5]. Similar examples of successful spatial training exist for younger age groups in primary school [11] as well as middle school [12]. The educational approach taken in these interventions is seemingly opposed to that in most maker education efforts. However, there is a good indication that construction activities with an emphasis on spatial elements within them will particularly help children to develop spatial ability [13]. The hands-on creative design activities often associated with maker education thus hold potential to not only teach scientific concepts, but also to significantly aid the development of spatial ability of participants. This could be realised by creating applied and hands-on instructional elements within maker education activities that specifically elicit the same mental transformations also elicited by paper-and-pencil tests that measure spatial ability. To effectively develop spatial ability through maker education activities it is crucial to develop an effective pedagogy for spatial maker education.

3 DEVELOPING AN EFFECTIVE SPATIAL MAKER PEDAGOGY

3.1 Scaffolding of spatial concepts and transformations

By emphasising and scaffolding specific spatial transformations described in the psychometric literature, similar to the direct training of spatial skills [5], maker activities can be developed to aid in the development of spatial ability. This could be done through making spatial transformations required steps of the activity and slowly increasing the complexity of those steps as integral part of the challenges posed to the participants. Maker education can employ pedagogical approaches from crafts and design and technology education, utilising clear instructions and a strong emphasis on first sketching and copying, after which the reins are gradually loosened to allow for more creative freedom and increasing the cognitive load on factors of spatial ability. Therefore, activities need to be designed that take this type of spatial scaffolding as a core element of the activity. This will also allow facilitators to assess the spatial ability development of participants during the workshop.

3.2 Assessment of spatial ability

To develop spatial ability effectively through maker education activities, it would be beneficial to allow facilitators to assess the spatial ability of participating children during the activity. The assessment of spatial ability usually relies on the use of psychometric tests, as it relies on internal thought processes [14]. Especially within maker education, where constructionist pedagogy is leading and success is hinged on children's voluntary engagement with the activity, it is less suitable for facilitators to extensively test children with these paper-and-pencil based tests. First attempts have been made to develop assessment resources and strategies to identify children's use of spatial reasoning during play-based activities [14]. For example, through identifying the use of non-verbal cues such as gestures, movements, and creative output within the context of play-based spatial activities, educators' ability to assess spatial reasoning was improved, allowing for the children's learning to be supported [14]. Within a maker education activity this could for example be realised by assessing the performance on the scaffolded spatial transformations that are required throughout a pre-designed spatial maker education activity. For a facilitator to assess a participant's spatial performance on the targeted spatial transformations, a tool that allows a facilitator to assess the participants' spatial ability more informally during activities will be particularly effective. As this type of more informal assessment can happen during the activities, it will allow facilitators to intervene to scaffold the activity more actively with struggling participants with low spatial ability.

3.3 Professional development for spatial maker pedagogy

For this pedagogy to be implemented successfully, it is imperative to train facilitators to integrate these elements in their teaching practice. Therefore, future work will consist of an approach taken around professional development of educators, akin to training for spatial ability education [11][12], applied to a maker education context. Assessment of the effectiveness of the proposed pedagogy for maker education is centred developing a mixed-method design to qualitatively assess and co-design the pedagogy in practice, and quantitatively assess its effects on participants' performance on traditional psychometric measures of spatial ability.

4 SUMMARY AND ACKNOWLEDGMENTS

The creative construction element of maker education holds significant potential for increasing spatial ability by exposing children to spatial elements in a crucial stage of their development. This could be of particular benefit to those who are generally underexposed to activities and toys of a spatial nature in childhood, a group that is over-represented by girls and children of low socio-economic status. This short paper argues for the development of a spatial maker pedagogy that considers how to scaffold and assess the development of spatial ability. By adding a spatial pedagogy, maker education practice could be advanced from an engaging way to increase motivation and interest in STEM into a worthwhile STEM learning practice that fills a gap of creative craft-related teaching and spatial ability development.

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MASSIVE DEVELOPMENT OF ONLINE LEARNING MATERIALS

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ABSTRACT

We participated in collaborative development of more than six hundred comprehensive online teaching materials for higher professional schools in the Czech Republic. The paper focuses on explaining the procedures and methods that we used to make the development process as efficient as possible, which was necessary with respect to the quantity of the materials and the limited time. Managing the logistics was the key, as several hundred people took part in the project. We are also describing, from the edagogical point of view, the OER structure, its division into educational blocks, and types of educational objects.

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1 INTRODUCTION

1.1 The Project in a Nutshell

Our department had the opportunity to collaborate on three major nationwide projects that focused on innovation in higher professional education. Within this project, we were in charge of the complete provision of the technical and logistical background for the development of so-called Open Educational Resources (hereinafter referred to as OER). The assignment was – in addition to ensuring high professional quality, which was based on the selection of authors and other creative staff – to guarantee smooth progress of this demanding operation (orchestrating the work of more than 600 people to develop more than 600 OERs) as well as high quality of the ouputs (in terms of graphics, form and structure). It is also very important that all ideas, guidelines and recommendations for the authors (as well as for other creative) staff had to be available before the start of their work; that is, at a very early stage of the project, when it was not yet possible to imagine all the situations that might arise. The completed OER set is available in the library [1].

1.2 Context and Motivation

The project activities builds on our long-term (since the 1990s) efforts in the field of modern teaching methods, modern education and innovative work in the field of pedagogy and didactics.

As for the high-volume development of teaching materials, their largest numbers can be observed in relation to various MOOC platforms, such as edX, Coursera, FutureLearn and many others. However, such teaching materials are comprehensive courses, while the discussed project aims to create supplementary teaching materials, usually for blended learning. What they have in common with the courses provided on the MOOC platform is their openness, i.e. unlimited free access, as the licenses from the Creative Commons family apply to the newly developed OERs.

Large-scale production of online materials is more common in the commercial environment, often without the possibility of general access to the outputs. In this sense, our open-source project is unique in a way.

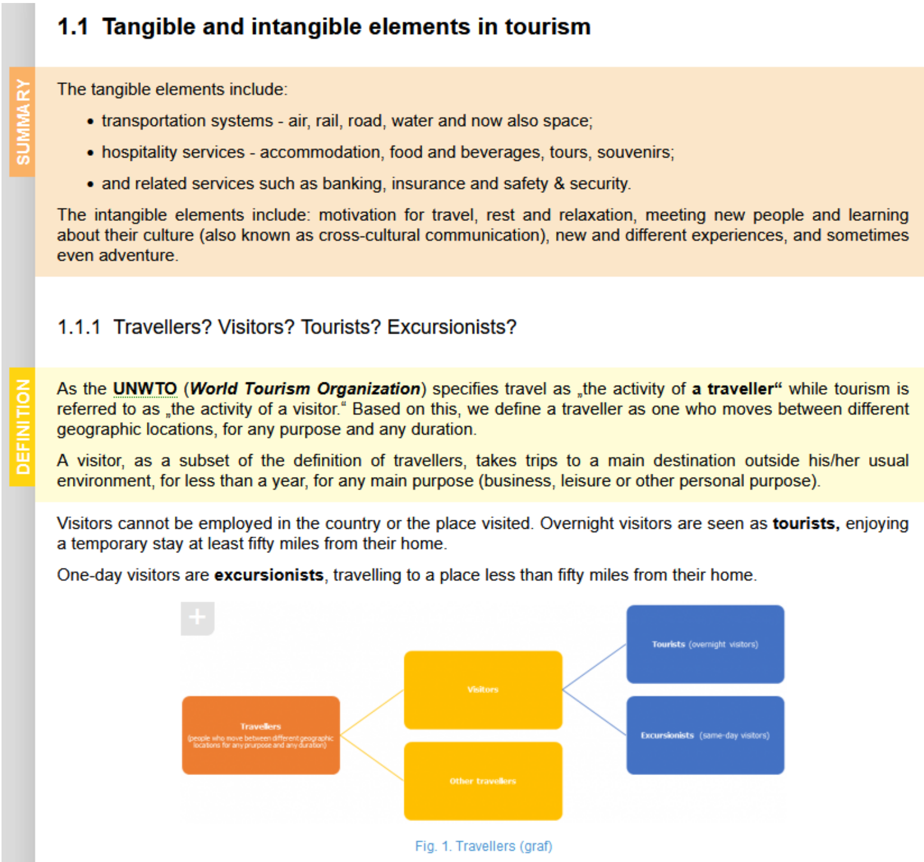
The motivation for the preparation of a large number of teaching materials was the idea of creating a universal environment (bookstore) that would accommodate a large amount of them, will therefore be frequently visited, which will put further pressure to expand the number available of teaching materials. At the same time, our major advantage was the massive financial injection for the creation of the basic set of learning packages.

2 PEDAGOGICAL POINT OF VIEW

Having the intention to create a huge library of teaching materials, we needed to prepare a solid pedagogical and didactic concept of the individual OERs and the library as a whole. This concept is based on defined sets of mandatory and optional elements, which are available to authors and other creative workers, and which can/must be (according to the given rules) integrated into larger units.

2.1 Structure

The highest-level hierarchical element is the storage organized in a clear way as an electronic bookstore. There we can find the individual topics (inaccurately: “books”) which, after clicking on their “envelope”, offer basic metadata about the topic, namely: title, list of authors, annotation, license, year of origin, price, language, methodology for use, and feedback (rating, errata reporting). It is then possible to open a page with further details about the OER, such as objectives, keywords, required level of study effort, references and recommended resources.



1.1 Tangible and intangible elements in tourism

SUMMARY

The tangible elements include:

- transportation systems - air, rail, road, water and now also space;
- hospitality services - accommodation, food and beverages, tours, souvenirs;
- and related services such as banking, insurance and safety & security.

The intangible elements include: motivation for travel, rest and relaxation, meeting new people and learning about their culture (also known as cross-cultural communication), new and different experiences, and sometimes even adventure.

1.1.1 Travellers? Visitors? Tourists? Excursionists?

DEFINITION

As the **UNWTO** (***World Tourism Organization***) specifies travel as „the activity of **a traveller**“ while tourism is referred to as „the activity of a visitor.“ Based on this, we define a traveller as one who moves between different geographic locations, for any purpose and any duration.

A visitor, as a subset of the definition of travellers, takes trips to a main destination outside his/her usual environment, for less than a year, for any main purpose (business, leisure or other personal purpose).

Visitors cannot be employed in the country or the place visited. Overnight visitors are seen as **tourists,** enjoying a temporary stay at least fifty miles from their home.

One-day visitors are **excursionists**, travelling to a place less than fifty miles from their home.

Fig. 1. Travellers (graf)

Fig. 1. Educational blocks

Subsequently, it is possible to explore the actual educational content. We have defined the following standard educational parts (functional blocks):

1) *Basic text* – not marked in any special way; used for common learning content.
2) *Definition* – serves to clearly separate definitions of basic terms.
3) *Note* – educational block suitable for providing additional explanations.
4) *Example* – in this block it is appropriate to enter the assignment of solved and unsolved examples or tasks (e.g. calculations) or questions.
5) *Solution of an example* – a special block where the solution of a task or example according to the previous point can be stated; the special nature of this block consists in the fact that it is hidden by default, and revealed only after clicking on it (which displays the correct solution of the task or example).
6) *Advantages* – simply to highlight advantages of what is described in the text.

7) The block of *disadvantages* is defined in a similar way.
8) *Summary* – suitable for placement at the end of a section (chapter), where it can summarize the most important findings.
9) *Interesting* – additional facts, trivia or even jokes can be contained there.

The educational blocks are highlighted in color in the final version of the teaching material, thus helping to make the content clearer, as can be seen from Fig 1.

2.2 Educational Objects

The educational objects belong – similarly as educational blocks – to the basic parts of the OER structure. They can be used, in principle, in any part of an OER, either within the *Basic text* educational block (most often) or within other types of blocks. We defined the following basic learning objects:

1) *Text, equations, formulas* – common content of a “book” publication. From a formal point of view, it is necessary to follow the set format, specifically the consistent use of styles. This will help to seamlessly convert the learning material into HTML (a format that is optimal for displaying on the Internet); it also makes the learning material significantly clearer and unifies the form of different learning materials by different authors, which means significant added value for students.
2) *Figures, tables, graphs* – again it is a common “book” format, which is suitably transformed into HTML. Even in this case, it is mandatory to use a unified format so that the results are formally and graphically identical in all OERs.
3) *Videos, animations, sounds* – effective inclusion of multimedia elements is only possible with electronic materials, so this is an added value of online courses. Multimedia elements are one of the essential attributes that distinguish “book” publications from e-learning teaching materials. For technical reasons (storage reliability, bitrate), the multimedia elements are stored on the YouTube platform. In the teaching materials, the authors can use either their own multimedia elements, or elements by other authors (typically videos) placed online. In such a case, however, OER would often not be able to have a free Creative Commons license; therefore, such elements have a warning notice and the element used (video, image, etc.) is not a part of the material – only a link is available.
4) *Tests* – it is appropriate to include a comprehensive part of the explanation at the end. Both *1 of n* and *m of n* types of tests are available. It is possible to assign an explanatory or additional comment (feedback) to each answer (whether it is correct or not). The evaluation of the correctness of the answers typically takes place at the moment chosen by the user (student).
5) *Interactive elements* – we consider them to be one of the most important parts of OER. These are various interactive tasks that can only be included in electronic learning materials. There are 13 template-based types of interactive elements (online tasks such as text with drag and drop / delete / delete words, matching, sorting, grouping, flashcards, crossword puzzles, interactive videos); examples in the Czech language are available in [2]. It is also possible to create tailored ones, which is, of course, demanding and expensive. See an example in Fig. 2.

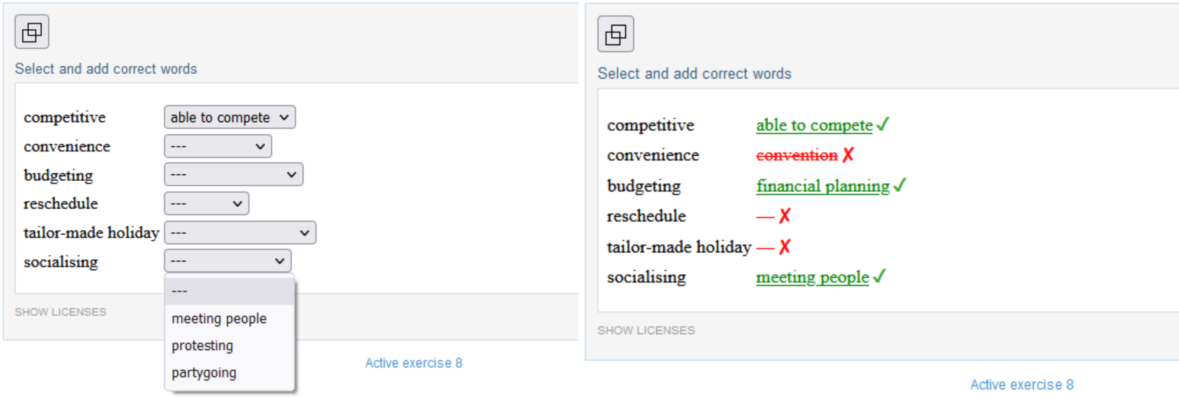


Fig. 2. Example of an interactive element in the text (the first image shows an assignment; the second one shows a solved and evaluated task)

The use of a variety of learning objects in an OER will ensure that the material is varied, interesting and readable – from a pedagogical point of view, there is nothing worse than boring textbooks that contain only long paragraphs of text; and from the point of view of modern teaching resources located in the virtual world, there is nothing worse than teaching materials without interactivity.

2.3 Variety of Topics

Thematically, the individual OERs touch a number of fields, divided by the following professional areas: Technical, Agricultural, Economic, Medical, Pedagogical, and Social.

3 LOGISTIC SCHEME

The OER library currently contains 662 teaching materials. More than 600 people from various parts of the Czech Republic took part in their development. The production process of each OER involved over 15 major steps (including corrections and reviews). It was necessary to guarantee the high quality of individual OERs and the purity of the content from the point of view of copyright (preservation of the Creative Commons licensing model [4]). The related procedures are outlined in [3]; Therefore, we present only the basic ideas here:

1) *Competent worker* – each creative worker underwent basic training (face-to-face or online), had a complete set of supporting online materials and the option of telephone/e-mail support.
2) *Robust workflow* – defined flowchart for creating OERs with 15 essential steps, relative timeline and many feedbacks for outputs quality control.
3) *Sophisticated task manager* – the managementof the development process was supported by a semi-automatic web tool, which monitored the production of the individual OERs step by step (entering and submitting partial tasks), pointed out problems (especially work delays), saved all outputs (including partial ones), monitored and archived time stamps of work and individual actions. To give an idea of the scope: during the three-and-a-half-year project, a total of 666 people registered in the task list and 7231 sub-tasks were assigned.

4 EXPERIENCE FROM PRACTICAL TESTING

The OER library is currently a widely used tool to support teaching at many schools. Although the individual OERs were originally intended for a specific segment of higher professional education, we know that the individual teaching materials are used for both secondary and higher (bachelor and Master) education. Every month, several thousand users visit the library.

4.1 Quantity data

The data obtained from the production server show a relatively strong use of the individual OERs. The server has been in operation since February 2020 when we stored the first OER on it; we had been gradually supplementing other ones until approximately October 2021 when the above-mentioned number of more than 600 OERs was reached. Thus, as of September 2022, the serverhas been in full operation for 12 months.

For technical reasons, out of those more than 600 OERs, 427 are included in the evaluation. A total of 143,913 users (from unique IP addresses) have viewed individual OERs during the monitored period (by July 7, 2022). The highest view count of a single OER was 3792 users, while the average one was 337 users per OER. By sector, the most users (70,205) have viewed medical educational materials; technical and agricultural materials have been viewed by 43,669 users, and economics materials by 30,039 users.

It should be noted that the actual numbers are likely to be even higher, as the production server, including all OERs, has its clone operated by one of the project partners (which is allowed by the licensing policy); however, we do not have their data available.

4.2 Quality data

Each OER allows feedback from students to be passed to its authors via the system administrator. The system also includes the “stars” rating of the OERs. We assumed that approximately one tenth of users would provide their comments, point out possible errors or recommend various improvements or additions. This assumption did not prove realistic: we only have a minimum of data from the electronic feedback channel, namely the “stars” rating. Thus, only 70 OERs were rated by users with an average rating of 3.73 stars (out of 5).

That’s why we decided to expand the feedback tool and explicitly ask the visitors to use it. We believe this will make it possible to obtain relevant data and subsequently increase the quality of the OERs.

Therefore we almost do not have electronic feedback from users; on the contrary, we have enough feedback based on direct contacts of the creative team and teachers who work with the OERs in their classes. This feedback is valuable, but since it is based on personal contacts, its extent is obviously limited.

5 SUMMARY

In the years 2017–2021, a remarkable online educational support was created, which is available on the web as an online bookstore with 662 titles. All of them are available free of charge, exclusively under open CC CC or CC BY-SA licenses.

We gradually started publishing the first teaching materials from this series in February 2020. This date coincided with the beginning of the COVID pandemic in Europe. We were therefore able to offer online teaching materials to secondary and higher education teachers, which they greatly appreciated; there was pressure to complete the materials faster and use them as soon as possible during lock-downs.

Although the project formally ended in 2021, teaching materials are still widely used and the system is still supported, which will be continued in the future. Currently, models of economic sustainability are being sought so that the e-bookstore and its titles can be developed, in addition to simple maintenance.

We also appreciate the success we achieved in the eLearning 2021 competition: the portal for electronic resources vovcr.cz was awarded the 2nd prize.

6 ACKNOWLEDGMENT

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WHORKSHOP FINAL

MONDRAGON ZTIM HUB: tematic challenges to promote STEM vocations among students

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MONDRAGON ZTIM HUB: tematic challenges to promote STEM vocations among students

1. Motivation and learning outcomes

The term STEM (Science, Technology, Engineering and Mathematics) is one of the most commonly heard concepts in both education and business when talking about the needs of the future (Li et al., 2020). However, one of the challenges facing our society is the lack of motivation and interest in STEM disciplines of secondary-school students, especially girls (McKinsey Global Institute analysis, 2020). At the same time, the implementation of STEM initiatives in education is not easy due to the need for change that is required in the classroom.

For this reason, it is necessary to generate initiatives to help schools implement STEM activities. In this sense, the MONDRAGON ZTIM HUB project has been set up. The main aim is to promote STEM vocations among young people as a tool for providing scientific-technological solutions to the different challenges facing our society. It is a network of interconnected socio-economic agents that work at a local level to develop STEM activities in both curricular and extracurricular areas.

In summary, those attending will be able to:

- Get to know the MONDRAGON ZTIM HUB initiative.
- Learn about the methodology followed for the development of thematic challenges (Challenged based learning (CBL) methodology (Nichols et al., 2016) and specifically the ETHAZI model (TEKNIKA, 2020)) that help to raise awareness and promote STEM activities in the classroom.
- Sharing of similar problems and collection of proposals for improvement of STEM proposals.

2. Background and rationale.

Nowadays, the labor market needs STEM workers: On the one hand, because the demand for jobs related to this disciplines and careers is not currently covered; on the other hand, because, although many of the future jobs have not yet been created, they will be directly related to the scientifical, technological and digital development. In this context, in all levels of education, female students continue to be underrepresented. Furthermore, the number of women pursuing STEM studies and careers is far lower than that of men (EUSTAT, 2019). Therefore, it is essential to awaken professional vocations in STEM areas among students, ensuring gender equality and starting at the lowest levels (Eusko Jaurlaritza, 2018).

Moreover, it is known that secondary-school students' interest in and motivation for STEM disciplines, studies and careers is low. It seems that their choice of pathways changes as they grow older (Valero-Matas & Coca-Jiménez, 2021); their interest progressively decreases as they progress to higher levels (Hernández-Serrano & Muñoz-Rodríguez, 2020).

Several studies claim that there are many factors creating loss of interest in STEM, such as the traditional approach and the use of expository strategies (Hernández-Serrano & Muñoz-Rodríguez, 2020). In order to achieve greater interest in these disciplines, it is necessary to employ a practical approach to learn through interdisciplinarity, the development of practice contexts, and new and adapted teaching materials (Valero-Matas & Coca-Jiménez, 2021). This is why it is necessary for schools to implement thematic challenges in the classroom in a curricular way to make science vocations visible.

3. Workshop design.

The workshop is divided into 4 main parts as follows:

- **Contextualization: Context and introduction of the MONDRAGON ZTIM HUB initiative. (25 min)**

  The MONDRAGON ZTIM HUB initiative and its context will be introduced to the attendees. Special emphasis will be placed on the importance of collaboration between actors. Our collaborative model developed for the promotion of STEM vocations will be presented.

  Afterwards, we will proceed to create a small debate with the attendees to see which is the STEM situation in their origin region, if the objectives are aligned and gather for similar needs. Then, we will give our vision on the concepts mentioned above. With this small interaction, we intend to align the knowledge on the general objectives covered by our initiative and try to search for partners.

- **Development: Development of the thematic STEM challenges. (20 min)**

The core of the presentation lies in the design of the thematic challenges, designed for the 4 grades of High School. The details of the methodology followed will be shown through a practical example.

The proposal to incorporate MONDRAGON ZTIM HUB network agents in the thematic challenges developed in the classroom is shown as an innovative initiative. The challenges take place both inside and outside the classroom, this is due to the collaboration in the design of the challenges between schools and external agents that aim to provide a more real context for the challenge as well as to bring the local socio-economic environment closer to high school students.

At this point, a participatory intervention will be carried out in order to visualize the strengths and weaknesses of the proposal presented as well as get to know the interest that such a proposal can arouse.

- **Results: A sample of the results obtained to date. (5 min)**
  As a result the challenge's current implementation status will be presented. Challenges have been designed with constant feedback from both school and companies. This collaboration framework will be emphasized.

  Again, an interaction with attendees will be done in order to look after other methodologies applied for this aim. It will be interesting to identify similarities or how they differ.

- **Conclusions, lessons learnt and future lines: Sample of the conclusions and future lines of the initiative. (10 min)**
  To conclude the presentation, the lessons learnt and conclusions obtained will be presented, as well as future lines of action. A decalogue of outputs will be presented to serve as aspects to be taken into account for future developments. The session will end by collecting information on similar projects from the participants, so that similar experiences can be shared and learnt from.

4. Significance for Engineering Education and attractiveness of the topic.

The importance and need of a STEM educational model is becoming increasingly evident both locally and globally. In Europe, for instance, a 70% job growth in sectors such as ICT and health is expected. Accordingly, the data published in 2020 by the Basque Business Confederation indicate that the most in-demand professional profiles correspond to STEM-related higher degree studies. Nevertheless, the interest of students in STEM careers is low and industry has difficulties in finding such profiles.

If one of the principal reasons for this lack of talent is the unawareness and prejudices associated with STEM professions among young people in relation with engineering education, it is vital to break stereotypes to change the *status quo*, which are the objectives of MONDRAGON ZTIM HUB. The thematic challenges specially seeks to use STEM skills to face real-world problems and consequently to show the importance and usefulness of STEM topics. The participation of external agents provides the students a better understanding of the reality surrounding them and makes more visible and understandable engineering careers as well as reduce the fears of studying them. At the same time it encourages innovation and creativity too.

Therefore, the main value contribution of the challenges is the participation of external agents through pills or parallel actions to the challenge that allow students to acquire the knowledge or inspiration necessary to face the challenge. These will provide context and tools for their development.In short, the purpose is to bring the reality of the professions to generate solutions to a challenge in a collaborative way. This will facilitate the transition and approach to the world of the STEM professions, improving their professional development through the acquisition of technical and specifically engineering skills and improving their future employability.

The thematic challenges provide an insight into different fields of engineering, bringing students closer to the profession and showing examples of real applications. And most importantly, it reaches more girls through examples of applications with a social vocation, because that is what engineering does from our point of view.

Key words: STEM education, Challenge based learning, STEM projects, Secondary Education.

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Workshop SEFI 2022

Key principles of integrated STEM: cross-fertilization between Engineering and secondary STEM education

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Secondary STEM education and engineering higher education: a match made in heaven?

Highly educated STEM professionals, and engineers in particular, increasingly top the lists of most wanted profiles on the European labour market (European Commission, 2020). For higher STEM education to be able to deliver the required number of STEM graduates, a sufficiently high number of students should be enrolled at the start. However, by the end of secondary education (SE), a large share of pupils who were initially enrolled in a STEM programme, opt out of STEM when enrolling in higher education (HE) (De Meester et al., 2020; Kersanszki & Simonics, 2022). From the pupils who do enroll in a HE STEM programme, an alarmingly high proportion lacks the attitude and skills necessary to successfully complete their first year (Broos et al., 2021). Moreover, pre- and in-service teachers lack sofisticated Nature of Engineering (NoE) views (Kaya, 2020), inhibiting transfer of the NoE to their pupils. This insufficient preparedness and lack of understanding of the NoE urges a new, integrated approach to STEM SE (European Committee of the Regions, 2019), that can be inspired by practices in the first years of HE engineering programmes (Engberg & Wolniak, 2013). In turn, SE practices in integrated STEM (iSTEM) can also inform HE engineering programmes. In summary: HE engineering programmes and iSTEM SE share two common goals: (1) motivating students for STEM studies/careers, and (2) preparing students for these studies and careers. This workshop aims to enhance cross-fertilization between iSTEM SE and engineering HE, in the pursuit of these goals.

A guideline for designing qualitative integrated STEM projects in six key principles

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Six key principles form the basis of iSTEM education that helps pupils develop competences required in engineering and science programmes as well as in future STEM careers (Thibaut et al., 2018; Flemish Government, 2015). These principles are: (1) problem-centered learning and problem solving, (2) integration of learning contents from different STEM subjects, (3) modeling, (4) inquiry-based learning, (5) design-based learning, and (6) cooperative learning. In an ERASMUS+ partnership project launched in 2021, five European HE institutions joined forces with the primary goal to embed these principles in (i)STEM teacher education programmes in a sustainable and effective manner (CiSTEM², 2021). Through an online training that immerses student teachers in each of the six key principles, the partner institutions aim to prepare these future (i)STEM teachers to incorporate the principles in their own classroom practices.

Finding common ground through interactive group discussions

In this workshop we want to exchange good practices and stumbling blocks with respect to each of the six key principles of high-quality iSTEM education. Two central questions will be addressed: (1) How are the six iSTEM key principles embedded in HE engineering programmes (e.g., projects in the bachelor programme, theoretical courses, interdisciplinary courses…)? (2) What can (i)STEM teacher education and engineering HE learn from each other regarding these key principles to achieve their two common goals?

Small group discussions and interactive media (PollEverywhere, padlet, lucidchart, …) will be used to gather input from the public and summarize participant take-away. Via the interactive workshop activities outlined below, we want to enable participants in identifying actions and good practices for their education practice (specifically in assessing project quality, implementation and student competence training and evaluation) based on the iSTEM key principles.

(1) We open the workshop by presenting the six key principles and their implementation in STEM SE and (i)STEM teacher education.
(2) Together with the participants, we derive indicators of successful classroom implementation of each of these principles. The participants are invited to share specific examples from their practice in engineering HE to enrich the meaning of these indicators.
(3) We reflect upon the implementation in current SE and HE STEM programmes: which principles are strongly integrated, and which deserve more attention? Do SE and HE STEM implementations encounter the same struggles and opportunities? Can we get to a common understanding of practices underpinning qualitative STEM education?
(4) Additionally, we will focus on how to evaluate students' competences related to the iSTEM key principles.
(5) Finally, we want to introduce a tool to train STEM teachers and secondary school pupils in some of the iSTEM key principles. With the participants, we reflect on the usefulness of this tool for iSTEM SE and for their own HE STEM practices.
(6) We ask the participants to identify two action points for their HE engineering programme as well as for STEM teacher education with respect to the iSTEM key principles and with the aim of creating truly inspiring, competence-oriented integrated STEM education.

Outcomes of the group discussion

During the workshop the relative importance of the six iSTEM key principles in secondary and higher education and out-of-school-initiatives was discussed, along with concrete examples of practices associated with each principle. The participants agreed on the importance of problem-centered and cooperative work, along with integration between the STEM-disciplines. This further triggered the discussion about the semantics of STEM versus STEAM education, where the importance of creative thinking (be it imbedded in the A-discipline or inherently underlying the S, T, E and M-disciplines) was elaborated on. The CiSTEM^2-results, measuring the activation of the six iSTEM key principles during the iSTEM design process of multidisciplinary teams, were shared. Participants acknowledged the importance, but also the challenging nature of meaningful, deep, integrating links between the STEM-disciplines.

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Reviewing Manuscripts in Engineering Education Research Journals: fairly, constructively, effectively

This session focuses on the peer review of journal manuscripts in the field of engineering education research. To the workshop we invite both experienced and new reviewers, and especially doctoral students in engineering education research.

The function of the peer review process is first to support *fair* decisions by helping journal editors identify which manuscripts most deserve to be published. The task is further to *constructively* support the authors in improving their manuscript before publication. It is through this process of selection and enhancement that the quality of the journal papers is safeguarded. By extension, this is how the whole research field cab establish and maintain respect. Therefore, reviewers play a vital role – without peer review there can be no respected field.

It is a rewarding task to review manuscripts, as a lot can be learned from it. Not least when taking one's own manuscript from submission to successful publication, it is helpful to have experience of the editorial process also from the inside. However, reviewing can also be time consuming, making it a wise investment to improve one's skills to do it *effectively*.

After the workshop, participants will be able to:

- Explain different quality criteria for scholarship in engineering education, and how to apply them
- Highlight particular aspects of a manuscript that a reviewer should consider
- Discuss how to support editors in making fair decisions and authors in improving their manuscripts
- Consider how reviewers can spend their own time wisely

The workshop is facilitated by a team of editors of the leading journals:

- European Journal of Engineering Education (SEFI)
- IEEE Transactions on Education (IEEE)
- Australasian Journal of Engineering Education (AAEE)

Workshop outline

Introductions

- Brief introductions: participants and session leaders. [5 minutes]

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- The journals: aims and scope, review criteria and review process. [15 minutes]

Group activity
- Make a poster in groups of four: “Advice for reviewers”. [30 minutes]
- Vernissage (hanging the posters).

Synthesis
- Plenary discussion of results. Editors’ picks. Collected wisdom and conclusions. [30 minutes]

Participants can sign up to receive documentation from the session, and to volunteer as reviewers for the journals.

Game-based Learning in Computer Engineering: A Workshop

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Abstract

Gamification has gained popularity in the last years, it is used in primary and secondary schools, as well as in companies and universities (Call, 2021). Along with this growth in popularity the number of available computer tools that facilitate the implementation of quizzes, competitions, simulations, WebQuests etc. has also grown.

Play engages students and enhances learning, however not all sorts of games are equally fruitful. As in (Dave Eng, 2019), we make a distinction between gamification and game-based learning (GBL). An example of gamification is a contest where students get points for solving the usual exercises of the subject matter. An example of game-based learning is an escape room where students get involved in studying and solving subject matter problems to get the required hints to continue the game. In this sense, game-based learning is an instance of problem-based learning (PBL) [Lima, 2017]. An interesting reflection on GBL can be found in [Valero, 2018].

The main objective of GBL is to provide an active learning environment, where students need to learn and apply the subject matter in order to participate and eventually solve the game. Compared with frontal lectures, active learning has been shown to provide higher motivation and deeper learning [Call, 2021] [Lopez-Fernandez, 2021].

From a general point of view, we can say that learning takes place in five stages [Bofill, 2007]. Namely: motivation, information retrieval, understanding, application (or practice) and reflection or feed-back. GBL, then, reinforces the autonomous realization of each of these stages.

An escape room is a game where players must solve different puzzles and riddles in order to finish the game (in order to *escape* from the room). Escape rooms have been used extensively in education, since they allow for the organization of subject matter exercises in a pleasant way [Veldamp, 2020].

Learning outcomes
We present a workshop session where we expect the participants to:
(i) Notice the difference between gamification and GBL and reflect on it (see activities below).
(ii) Learn how a well designed escape room reinforces the autonomous realization of the five stages of learning defined by (Bofill, 2007)
(ii) Finish the workshop session with some ideas on how to introduce GBL into their subjects.
We hope that this workshop will inspire participants and, maybe, engage them in proposing GBL activities for their own students.

We propose the workshop to include the following **activities**:

1. A short introduction: GBL and gamification are introduced and the timelines of the workshop are presented.
2. Participants engage in a gamification activity: they will be required to solve a simple questionnaire, and we will monitor their progress using Socrative tool (socrative.com)
3. Participants will be invited to participate in a GBL activity: an escape room where they will be required to solve simple computer programming exercices to obtain the keywords to progress on the game and exit the escape room. Notice that we do not expect the participants to know computer programming so they will be allowed to use other means (like google) to provide the answers to the riddles. In a real situation, the students are required to write the programs to solve the questions.
4. A reflection in small groups to compare the strength and weaknesses of both approaches.
5. We will continue with an open debate, where we may discuss topics such as: assessment, comparing game-based learning versus gamification strategies, strategies and tools for applying such gaming techniques in the classroom and online. The debate will be aimed to formulate conclusions and get feedback and ideas to improve our game-based activities.
6. Finally to end the session participants will be invited to take home the design of a simple escape room situation involving problems for their own courses.

Inspirational questions to open debate:
-Which sort of gaming experience provided higher motivation?
-What differences can you see between gamification and GBL?

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-Think of ways to introduce GBL into your subject
-Regarding the quality or level of understanding, which experience do you think provides a deeper understanding?
-Does GBL encourage creativity? critical thinking?

Requirements
Participants are expected to bring their own laptop (or tablet, or phone) to the workshop and a headset.

Results
In this section we present the reflections of the participants to the workshop.

Strengths of the gamification strategy:

- Increased student motivation
- Quick gain
- Creates competitive learning environment between groups
- Direct and quick feedback
- "Kids" nowadays are more used to games

Weaknesses of the gamification strategy:

- The activity can be stressful.
- Focusing on the quiz without actually learning
- Only one try. It should have the option of more than one answer.
- It could be a distracting activity
- The motivation is external
- Risk of losing part of the student population
- Rewards are trivial, students may not be interested.

On the other hand, the strong points expressed about the game-based learning activities were:

- Diverting
- Focused on the topic
- Immediate application of the knowledge
- Group work (twice)
- Immersive
- More motivating than gamification
- The moments of success are rewarding
- Less risk of gender issues
- Engaging by story
- Can be very engaging
- Can foster further self-directed learning
- Learned lessons:
    - for life or
    - for community
    - for the next stage

And as weak points:

- The escape room could be run presentially, rather than digitally.
- Complex usability of the escape tools.
- Not balanced knowledge among the team members
- Too much distraction
- Different computer literacies of students
- The game should include some reflection (what have you learned, how dit you do it,...)

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Keywords: Escape room; Gamification; Game-based Learning; Design of Student Activities; Active Learning.

A GAME-BASED APPROACH TO DEVELOP ENGINEERING STUDENTS' AWARENESS ABOUT ARTIFICIAL INTELLIGENCE ETHICAL CHALLENGES

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Conference Key Areas: *Artificial Intelligence in Education, Ethics in Engineering Education*
Keywords: *Ethics education, Game-based learning, Artificial Intelligence*

ABSTRACT

The past few decades have seen important efforts to introduce more ethics into engineering education programs around the world, while adapting to the evolution of ethical concerns, notably in relation to digital technology and artificial intelligence. Even if pedagogical approaches based on the use of case studies or code of ethics remain among the most popular, other less well known techniques such as game-based approaches have also been identified as effective. The goal of this workshop is to offer participants an opportunity to explore how games can be used as learning experiences to develop students' ethical knowledge and skills. Participants will first get to play an online game which focuses on ethical issues in the domain of artificial intelligence, before reflecting on their experience and discussing the potential of game-based approaches for engineering ethics education.

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1 BACKGROUND AND RATIONALE

There is an overall agreement that, besides technical knowledge, engineering graduates should have skills that would enable them to better serve humanity in their future jobs [1] and to deal with the uncertainties of future challenges [2]. Meta-analyses indicate that significant efforts have been made to introduce science and engineering students to ethics in the last decades [3, 4]. However, staggering developments in digital technology, particularly in the field of artificial intelligence (AI), create new ethical challenges for engineers [5]. The specific nature of the ethical issues arising from digital technology (e.g. privacy, algorithmic bias or transparency issues) require engineering students to develop new knowledge and skills to be able to walk through the dilemmatic process of decision making that significantly impacts the users of digital designs.

While the most popular teaching methods in engineering ethics education rely on the use of codes of ethics, case studies or discussions / debates [6], other less well known techniques using films and videos, science fiction or games have been explored recently [7]. The use of games – notably digital games – for learning and education has generated increasing interest in the last two decades [8]. Educational games have been used in a range of disciplines, and meta-analyses have shown positive effects of educational games on cognitive, affective or motivational skills [9, 10]. In particular, some studies suggest that games could be used to foster problem-solving and critical thinking skills [11] or to develop moral sensitivity [12]. However, prior research also shows that, to achieve ethics education goals, games should implement specific strategies such as providing "ethical choices and decision-making, which have an effect on the game play," or integrating personal reflection through the use of diaries or other devices [13].

In this workshop, participants will explore how a game can be used as a learning experience to develop engineering students' ethical knowledge and skills, and investigate more generally the potential of games for engineering ethics education. In the following, we first present the game that participants will play, before describing the learning outcomes and the format of the workshop.

2 THE GAME

Based on an original idea by two Master students at our institution, Ester Simkova and Alexandre Pinazza [14], the game that participants will play in the workshop is an online interactive story. Players play the role of a data scientist who faces design dilemmas while developing machine learning models. The decisions that players make (see example on Figure 1) change the course of the story and lead to different ethical consequences. The narrative includes two applications of machine learning technology, based on real case studies of algorithmic bias: criminal recidivism prediction (inspired by the COMPAS case [15]) and automated translation (inspired by the Google Translate case [16]).

Aiming to develop students' ethical awareness in the domain of machine learning, the game is accessible *without any background in machine learning or in ethics*. It is specifically designed as an educational tool by implementing a series of well-documented ethics education strategies [13]: players are guided to analyse their decisions before committing to a choice, they get a chance to reflect after observing the consequences of their decisions, and they are led to identify their emotional reactions at specific points in the unfolding story. Particular attention has been paid to the gamification of these features in order to preserve the immersive properties of the game.

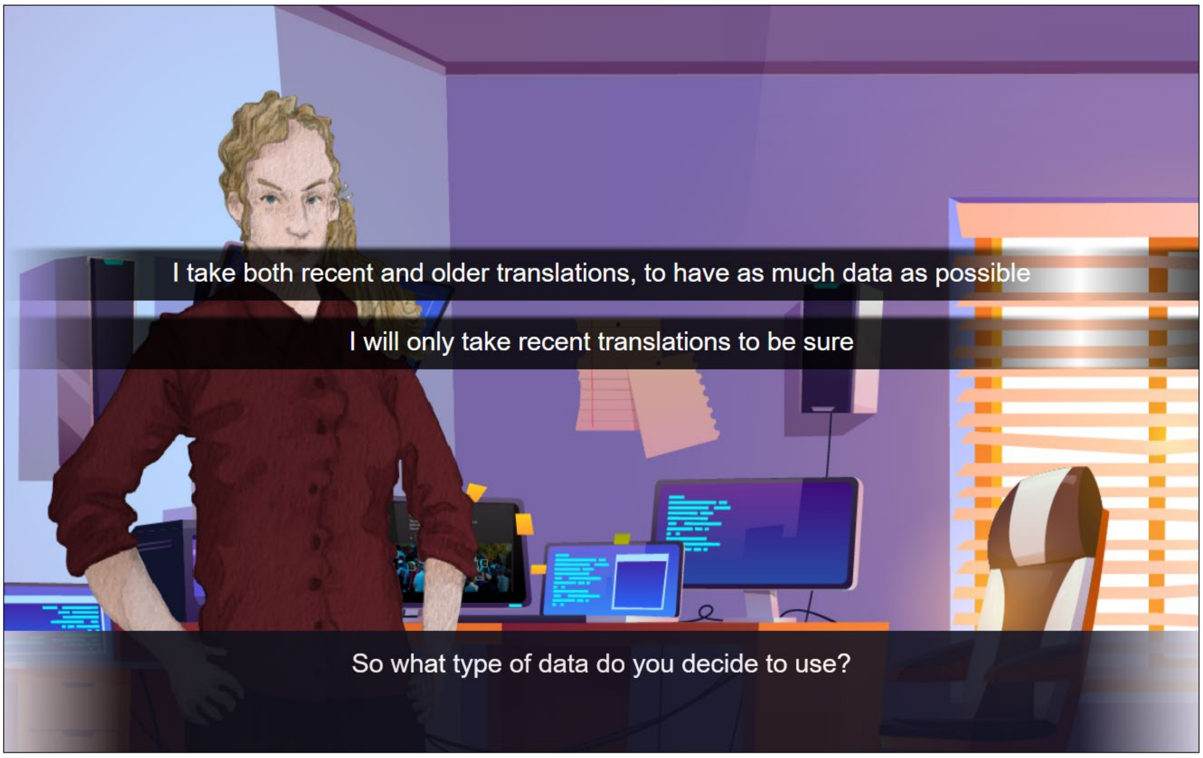

Figure 1: example of a decision that players can make in the game.

3 LEARNING OUTCOMES

Through letting participants first experience the game as users and then reflect on this experience, the workshop aims to develop participants' knowledge and skills both in the domain of ethical artificial intelligence and in the domain of game-based approaches to engineering ethics education.

At the end of this workshop, the participants should be able to:

- Explain some of the ethical issues which arise in the domain of artificial intelligence design.
- Identify features of a game that can foster students' ethical knowledge and skills.
- Evaluate how a game can be used as a formal learning activity in the context of a course to foster students' ethical sensitivity and decision-making skills.

4 WORKSHOP DESIGN

The workshop will implement an interactive and hands-on format with the following program:

- Introduction: structure of the workshop (presentation, < 5 minutes)
- Discovering the game (participants individually play the game online, 15 minutes)
- Identifying ethical questions in the game (think-pair-share, 10 minutes)
- Using a game as a teaching activity: reflection in groups and evidence from research on game-based approaches to engineering ethics education (think-pair-share and presentation, 20 minutes)
- Conclusion: take-home messages (collective summarization activity, 5 minutes)

Note: Participants will need a laptop with a web browser and internet connection to play the game. No specific prior knowledge is expected.

5 SUMMARIZATION OF THE RESULTS

More than 40 participants attended the workshop in total and played the game on the online demonstration platform hosted at EPFL (https://go.epfl.ch/MLethicsgame).

The discussions during the workshop highlighted that the game includes content related to different types of ethical issues, not only in relation to AI ethics. Participants identified questions at several levels of granularity, from individual perspectives on decision making (e.g. personal values) to more global systemic issues (e.g. inequalities), including questions of organizational culture.

Using the EPIC framework [13] as a lens for analysis, the participants identified that the features of the game support a number of the ethics education goals identified by Karen Schrier, albeit in different proportions. Overall, the game was seen as an effective way to raise awareness about ethical issues related to AI, thanks to its narrative based on realistic case studies. A number of participants indicated that the game also enables students to practice ethical reasoning and ethical reflection to some extent. Although some participants noted that the use of emojis to report emotions could lead to variations in interpretations, the “mood meter” feature of the game was thought to be useful for practicing emotion identification.

In terms of the limits of the game, some participants argued that the options offered in the decisions points of the game are too limited to be realistic. Others felt that being able to actually make these decisions and see their consequences has pedagogical value since it creates a feedback cycle in a low-stakes environment that allows for mistakes. To compensate for the individual nature of the game, some participants suggested that students play the game in groups to be able to discuss the different decisions. Overall, participants concluded that the game should be used with a follow-up debriefing activity to highlight both its underlying principles and its limits in order for students to consolidate their learning.

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A CANVAS FOR THE ETHICAL DESIGN OF LEARNING EXPERIENCES WITH DIGITAL TOOLS

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Keywords: *Digital tools, Ethics, Responsible design, Teacher training*

ABSTRACT

The use of digital tools has drastically increased in engineering education, accelerated by the COVID-19 pandemic. These tools generate important ethical issues, in particular in terms of privacy and fairness. However, very few teacher training programmes address those topics, which means that teachers are often left to figure out by themselves how to address these issues when they want (or have) to use digital tools in their teaching. In this workshop, participants will be introduced to a pragmatic approach to the ethical design of learning experiences that involve digital tools using a visual thinking guide called a ‘canvas’. Applied and hands-on, this workshop will help participants to develop a practical understanding of the

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specific ethical issues related to the use of digital tools in teaching and to integrate ethical reflection into design processes when digital technology is involved.

1 BACKGROUND AND RATIONALE

Digital tools are increasingly used in engineering education, and the COVID-19 pandemic has drastically accelerated their adoption. These include general purpose tools such as search engines, translation tools or content management systems, or more specialized applications like MOOC platforms, audience response systems or learning analytics. Distance/online teaching has also developed the use of video conferencing systems, online whiteboards or collaborative document edition tools. Because they generate digital traces of users [1, 2] and can potentially be algorithmically biased [3–5] – among other issues, these tools must be used with special attention to ethical questions and this is often left to the responsibility of teachers.

While the need to develop teachers' digital competence (including the use of ICT) is clearly identified [6] and an increasing proportion of teacher training curricula address it [7, 8], ethical considerations are generally remarkably absent from their descriptions [9]. This is all the more an issue that staggering developments in digital technology, in particular artificial intelligence, create new ethical challenges which require both engineers and engineering educators to acquire new specific knowledge [10]. In the conclusions of their review of published research on teaching and learning technological practices during the pandemic, Boghian, Popescu and Ardeleanu highlight the urgent need to "instruct both teachers and students on the ethical use of information technology regularly" [11].

This workshop seeks to fill this gap by proposing a pragmatic approach to the ethical design of learning experiences that involve digital tools in the form of a 'canvas' – a thinking tool that guides analysis and design based on three main ethical principles. In the following, we first present our 'canvas', before introducing the learning outcomes and the design of the workshop.

2 THE 'CANVAS'

Frequently used in business and technology education, a canvas is a tool that implements a conceptual framework in a visual way to guide a thinking process [12]. A canvas generally takes the form of a one-page grid or diagram, which serves as a support for individual or collaborative tasks.

First developed for the humanitarian context [13], the canvas we propose implements a "principled approach" to analysis and design: central to the canvas is a set of *ethical principles* that are used as a lens to look at a specific *digital tool* when used in or designed for a specific *teaching or learning context*. The visual organisation of the canvas reflects this approach, with the principles at the centre, forming a bridge between a zone dedicated to the tool and a zone dedicated to the context, as illustrated on Figure 1.

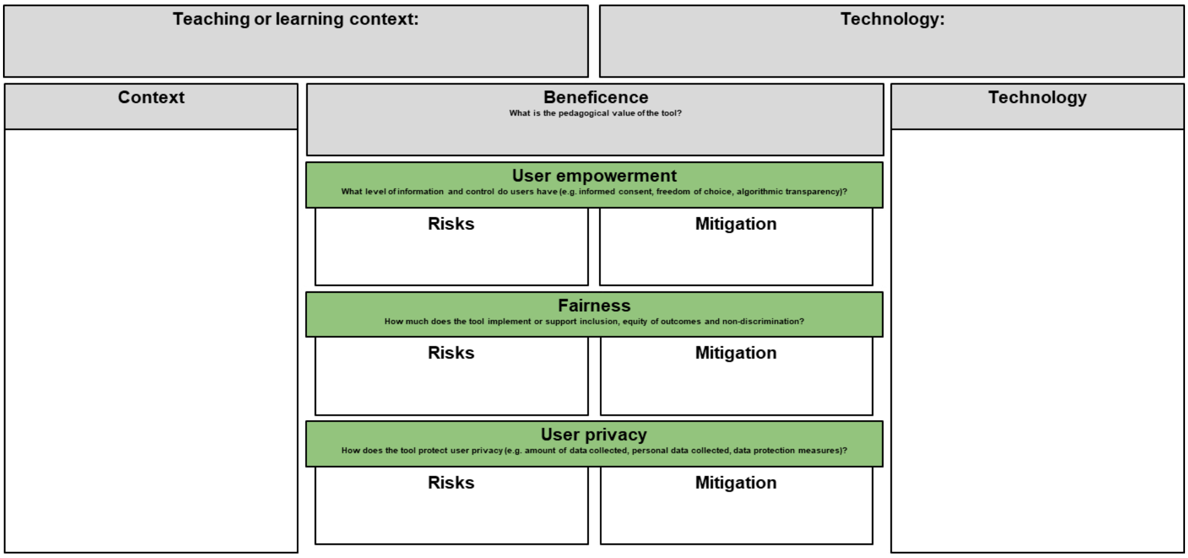

Fig. 1. The canvas with its three ethical principles at the centre.

Following a review of existing codes of digital ethics, we identified three overarching ethical principles that should we considered when using or designing digital tools:

- User empowerment: what level of information and control do users have over the tool (e.g. informed consent, freedom of choice, algorithmic transparency)?
- Fairness: how much does the tool implement or support inclusion, equity of outcomes and non-discrimination?
- User privacy: how does the tool protect user privacy (e.g. amount of data collected, type of personal or sensitive data collected and data protection measures)?

For each principle, the canvas guides participants to think about the risks associated with the use of the tool in the given context, but also to envisage mitigation options. The use of the canvas should help participants not only to develop a practical understanding of these ethical principles, but also to acquire a general methodology to integrate ethical reflection into analysis and design processes.

3 LEARNING OUTCOMES

After an introduction of the specific ethical issues related to the use of digital tools in education (as well as in general) and a presentation of the three ethical principles implemented in the canvas, participants will be given the opportunity to practice using the canvas by analysing collaboratively a real learning scenario with well-established existing technologies (e.g. Miro, Mentimeter, Google docs). Then we will step back and reflect on this experience to discuss with participants how this canvas could be used as a teaching tool, for instance as a framework for the socially responsible design of digital tools.

At the end of this workshop, participants should be able to:

- Describe examples of ethical issues related to the use of digital tools in education

- List and define ethical principles that apply to the design and use of digital tools
- Use the canvas to design and assess pedagogical activities that involve the use of digital tools
- Evaluate how the canvas can be used as a teaching tool, for instance as a framework for the socially responsible design of digital tools

4 WORKSHOP DESIGN

The workshop will implement an interactive and hands-on format with the following programme:

- Introduction: ethical issues with digital tools in teaching and learning activities and digital-specific ethical principles (interactive presentation with mini-activities, 20 minutes)
- Designing learning experiences with digital tools using the canvas (collaborative activity in groups of 4/5 people, 25 minutes)
- Reflecting on the use of the canvas and the ethical principles it implements, evaluating how it could be used as a teaching tool (collaborative activity in groups, 10 minutes)
- Conclusion: take home messages (collective summarization activity, 5 minutes)

5 SUMMARIZATION OF THE RESULTS

A total of 15 participants attended the workshop. They identified around 10 different types of software technologies that are frequently used in their educational contexts, including Learning Management Systems, forum tools, interactive whiteboards, polling systems or programming-related technologies (e.g. online programming environments or auto-grading tools).

When working in groups to design a learning experience with a specific digital tool, participants engaged with all three principles embedded into the canvas, not only the privacy aspects, as is often the focus because of laws and regulations. Mitigation options described by participants included both technical aspects, such as the types of accounts best suited to access the service, and non-technical approaches such as fairness charters for online collaboration. Some participants reported that despite some prior awareness about the potential ethical issues with the considered tool, they were sometimes surprised by either the range of data collected, the location of the data storage or the extent to which this data was shared with third parties (participants were provided with a summary of the privacy policies and terms and conditions for the considered tool).

The participants identified three different use cases for the canvas as a teaching tool:

a. As a tool to co-develop learning experiences with students, defining which tool to use and how to use it;

b. As a support for discussion with students about digital ethics and to raise student’s awareness about the ethical issues with digital technologies;
c. As a device to use in design activities, for instance in empathy exercises or as a more focused alternative to general analysis frameworks such as SWOT (Strength, Weaknesses, Opportunities, Threats) and PESTLE (Political, Economic, Social, Technological, Legal, Environmental) [14].

Finally, the participants also raised questions about how to engage educators more broadly with these issues, and how students, faculty and IT services could better collaborate and work together on this topic.

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Shaping the embedding of reflection in engineering education

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Conference Key Areas: *Engineering Skills, Lifelong Learning*
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Update (Sept 26th 2022) visible at the end of document

Motivation

A world without reflection is incomprehensible. Yet why is it that educating reflective engineers is so complicated? In this workshop, participants will experience an approach that aims to embed reflection as an integrated practice of engineering education.

Relevance for Engineering and Engineering education
Today's, and tomorrow's networked society requires engineers that are able to deal with many uncertainties and complex problems, work with any other discipline, understand stakeholders of all walks of life and be open and critical towards new and different insights. At our university we want to educate those engineers of the future, for whom we believe reflection is an essential professional attribute.

The challenge
In our institution we observe that it is difficult to adopt this seemingly universal and critical attribute in engineering education. Why is that? First of all, literature on reflection has a multitude of definitions of the word 'reflection'.[1] Next to that, based on a qualitative exploration in our university, we learned that reflection is deeply context dependent. Not only is the domain of application of reflection great in its variety (e.g. reflection on yourself, on collaboration, on the design or work process or on its outcomes), there is also a cultural factor in reflection. The role and habit of reflection can be different between departments within the same institute, between institutes, let alone between countries. So, it might be completely normal to share your mistakes in one department and be frowned upon in the next. In short, next to having a plural definition, we spot a *couleur locale* in the relevance and habit of reflection.

Learning outcomes
After the workshop participants are able to:
1. Recognize the wide scope and definition of reflection. (20%)
2. Recognize, identify, describe, explain, and discuss the limited *integration* of reflection in engineering education and the limiting and supporting factors for *implementing* reflection in (engineering) education. (30%)
3. Recognize, identify, and classify how the eco-normalization model[2] helps successful embedding of reflection in (engineering) education. (20%)
4. Interpret, distinguish, and examine what are the limiting and supporting factors for implementing reflection in (each of) the participant's own context specific education. (20%)
5. Formulate first steps to improve implementation of reflection in (each of) the participant's own context specific education. (10%)

Rationale of the session
Brilliant ideas from literature and best practices of others don't survive the battlefield of teaching practice, and the application of seemingly clear-cut concepts mismatch with the messy reality of a new context. Longevity and fidelity of educational innovation [2] is quickly undermined. [3, 4] Yet embedding reflection as a core competence is a big educational innovation. So, if we want to *secure* reflection in our current and future education, how should we deal with the identified generic and context-specific varieties?
We believe this requires a particular attention to implementation. With our university-wide program called the Reflective Engineer, we grow, foster, and embed reflection as a core practice in our disciplinary education and organization. Our guide in this innovation process is the model by Hamza

& Regehr on eco-normalization, that describes the interaction between the innovation, the system where it is embedded, and the people doing the work. Moreover, to align this interaction and to embed *couleur locale,* we use co-creation as one of our main tools.
Our workshop is a representation of all beforementioned aspects: the (context dependent) plurality of reflection, eco-normalization as implementation strategy and co-creation to effectively include couleur locale.

Workshop setup
In the workshop together we (I) deconstruct the *couleur locale* of participants' contexts and we (II) analyze the stimulating and limiting interactions between system, innovation and people doing the work. (III) We ground this in theory and share an example to illustrate how we manage that in our own messy reality. This allows participants to apply these insights to their own contexts. This workshop will ask an active role of participants and will stimulate interaction.

Step	**min.**	**Activity & Facilitator role**	**Relevance & (l.o)**
Preparation		• Facilitators: prepare framework (see fig 1) on the floor of the room, using tape & paper.	Set blueprint for interaction.
Entrance	3	• Participants each receive two big paper 'dots' of approx. 15cm in two different colors. • Participants write their name on their 'dots'.	Activate participants.
General introduction	7	• All: very short round of introductions. • Facilitators introduce program.	Get familiar, set expectations.
Gather collective data	20	Participants (see fig 2): • Place first 'dot' (color 1) in the framework: role of reflection in their education. • Place second 'dot' (color 2) in the framework: role of reflection in their own practice and development. Facilitators stimulate: • Participants reflect and discuss out loud on where they place 'dots' and repositioning dots accordingly.	Benchmark of what we mean with reflection, application domains of reflection and the amount of reflection (1).
Collective data analysis	10	Facilitators enquire: • Factors in (un)successful implementation of reflection in the participants' education.	Understand (why) not all parts of reflection are in education (2).
Reinterpret implementation according to eco-normalization	15	Facilitators: • Introduce eco-normalization (fig3, Hamza and Regehr). • Plot of step 4 factors to eco-normalization. Facilitators and participants:	Familiarize with eco-normalization and based on that interpret and improve local

		• Enquire context-specificity of factors. • Explore first steps towards better local implementation.	implementation of reflection (3, 4, 5).
Case-study	5	Teaser about our inter-faculty approach to bring more reflection into disciplinary education using previously explained and experienced knowledge.	(3, 4, 5)

Fig 1: Reflection chart

Fig 2: reflection charts with positioned circles

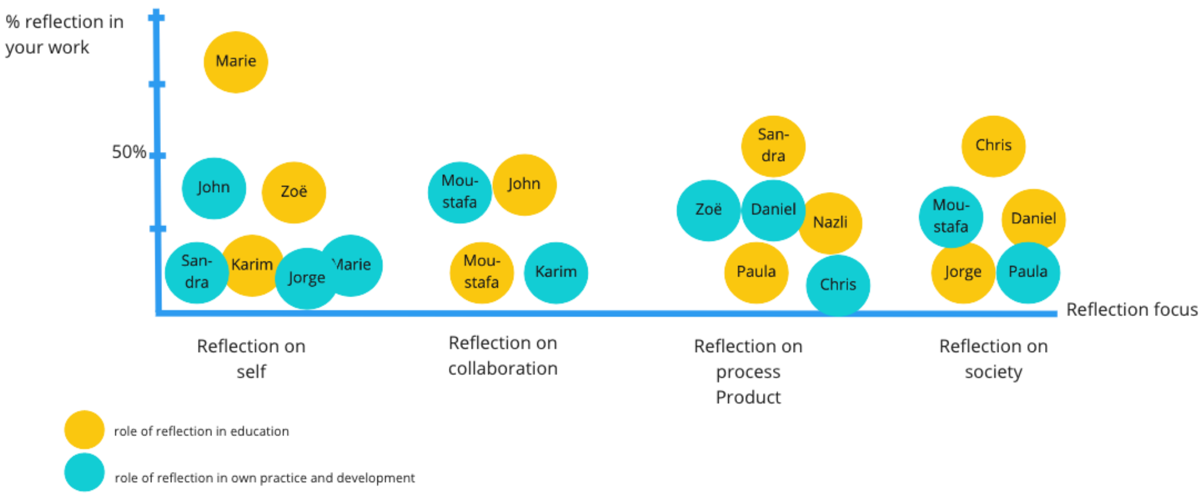
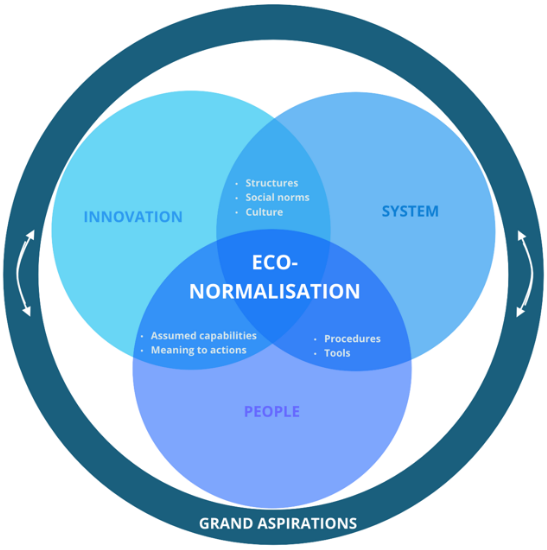


Fig 3: Eco-normalization Model – adapted from Hamza -Regehr 2021



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Follow up (sept 26th 2022)

For many participants our workshop was a hands-on experience with the ambiguity of reflection as a concept as well as its implementation in our engineering education.

Visit our website (https://www.tudelft.nl/teachingacademy/themes/reflective-engineer) to continue exploring how we develop usable, viable, long lasting interventions, or to get in touch with us on that topic (also directly through reflectiveengineer@tudelft.nl). In two weeks we will publish the results of the workshop and our reflections through our website.

Thank you all for an exhilarating session!

TEACHING ANALYTICS SKILLS IN ENGINEERING: A HANDS-ON INTRODUCTION USING JMP

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Conference Key Areas: *engineering skills; student engagement*
Keywords: *problem solving, data skills, employability*

ABSTRACT

Engineering curricula often require students to learn a range of analytics skills, which are critical for all practitioners who want to learn from data. With the right software, learning these skills can be hands-on and engaging, allowing students to explore and analyze realistic data without struggling with a clunky or tedious statistics tool. JMP is interactive and powerful point-and-click software for solving real-world engineering problems. It is ideal for engaging, hands-on teaching of relevant data skills in engineering and is also used by scientists and engineers at leading companies across the globe.

While the fundamental skills addressed in this session include understanding variation and uncertainty, we will also look at applications like data modeling, designing experiments and quality management – all from a student's perspective.

This interactive session will demonstrate how JMP can help to engage students' curiosity and teach engineering data skills which are most in-demand in industry today. We'll guide you through a series of brief demonstrations, so that you can directly experience the difference JMP can make for your course. Participants will receive a free trial license before the workshop, and the presenters will provide sample data and lead you through several hands-on examples in JMP. We will also discuss best practices and share resources to support integration into engineering courses.

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1 TEACHING WITH REAL CASES

This short paper summarizes the key ideas from the practical workshop by JMP and provides the links to all free resources shared with the audience.

1.1 Why teaching with real cases?

Why should you consider using real problems – typically shared as case studies – in teaching data analytics? There are many good arguments, which include

1. Real cases help to teach the analytical skills which will be relevant for students in a future workforce (refer to customer stories [1] for examples who shared or inspired the cases discussed here)
2. Storytelling by real cases can boost the engagement of students (see [2] for a demo of visual storytelling)
3. Instead of applying a single method, students take a journey of statistical discoveries (the JMP analytical workflow [3] shows a “landscape to travel from data to insights”).

We will also discuss that real cases perfectly support the GAISE standard in statistics education [4], especially the first recommendation on teaching statistical thinking. Each case is an example for a "problem-solving and decision-making process" and requires multivariable thinking:

a. **Teach statistics as an investigative process of problem-solving and decision-making.** Students should not leave their introductory statistics course with the mistaken impression that statistics consists of an unrelated collection of formulas and methods. Rather, students should understand that statistics is a problem-solving and decision-making *process* that is fundamental to scientific inquiry and essential for making sound decisions.

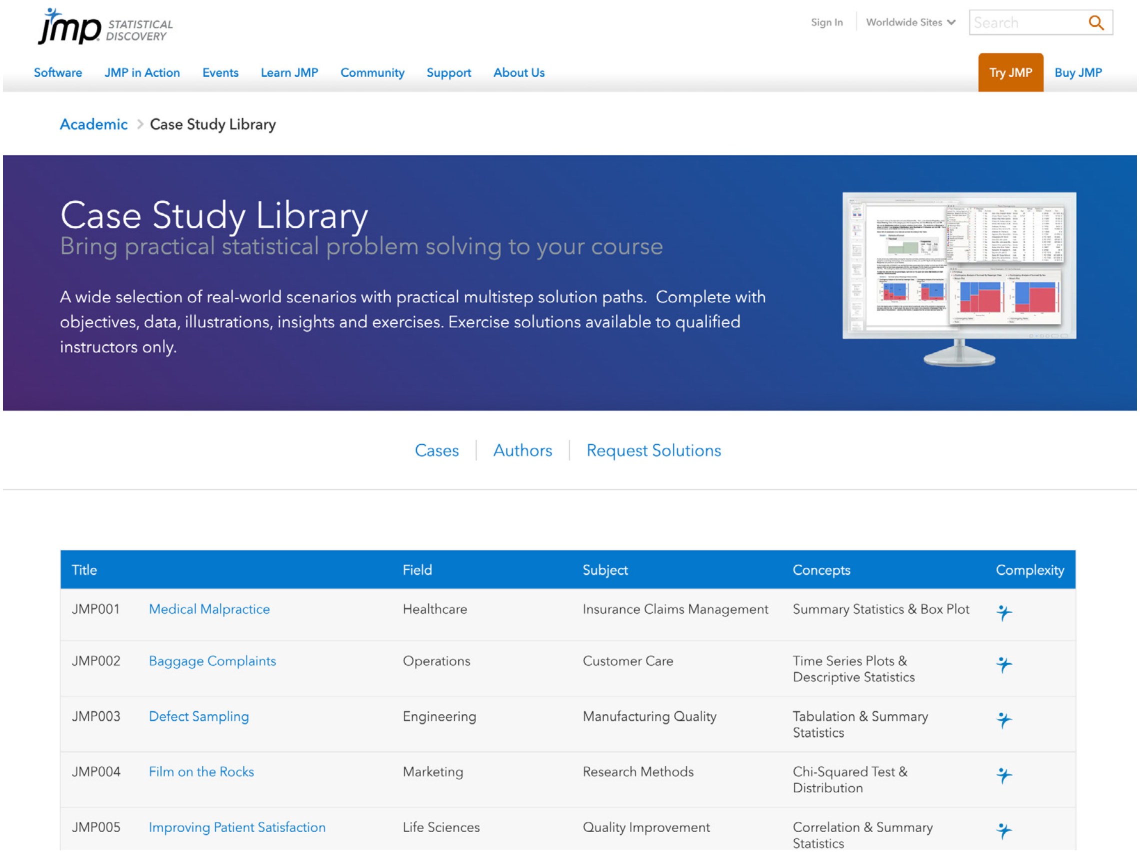
b. **Give students experience with multivariable thinking.** We live in a complex world in which the answer to a question often depends on many factors. Students will encounter such situations within their own fields of study and everyday lives. We must prepare our students to answer challenging questions that require them to investigate and explore relationships among many variables. Doing so will help them to appreciate the value of statistical thinking and methods.

Fig. 1. GAISE I recommendation about teaching statistical thinking [4]

In addition to this guideline, other revised recommendations like “3. Integrate real data with a context and purpose” and “4. Foster active learning” support the key message of this workshop.

1.2 Access to real cases

The workshop will suggest the JMP Case Study Library [5] as an open source providing free access to more than 50 case studies. Each case comes with a background story, a problem- and task description and one or more datasets, a step-by-step solution with illustrations using JMP tools and summaries about lessons learned from a business, statistician’s and JMP user’s perspective. Solutions to optional exercises are shared with authorized instructors.



Title		Field	Subject	Concepts	Complexity
JMP001	Medical Malpractice	Healthcare	Insurance Claims Management	Summary Statistics & Box Plot	
JMP002	Baggage Complaints	Operations	Customer Care	Time Series Plots & Descriptive Statistics	
JMP003	Defect Sampling	Engineering	Manufacturing Quality	Tabulation & Summary Statistics	
JMP004	Film on the Rocks	Marketing	Research Methods	Chi-Squared Test & Distribution	
JMP005	Improving Patient Satisfaction	Life Sciences	Quality Improvement	Correlation & Summary Statistics	

Fig. 2. Examples from the JMP Case Study Library published at jmp.com/cases

Most cases have been developed by practitioners in industry. They can be chosen from a list based on field and subject, covered key concepts and level of complexity.

2 LIVE DEMO

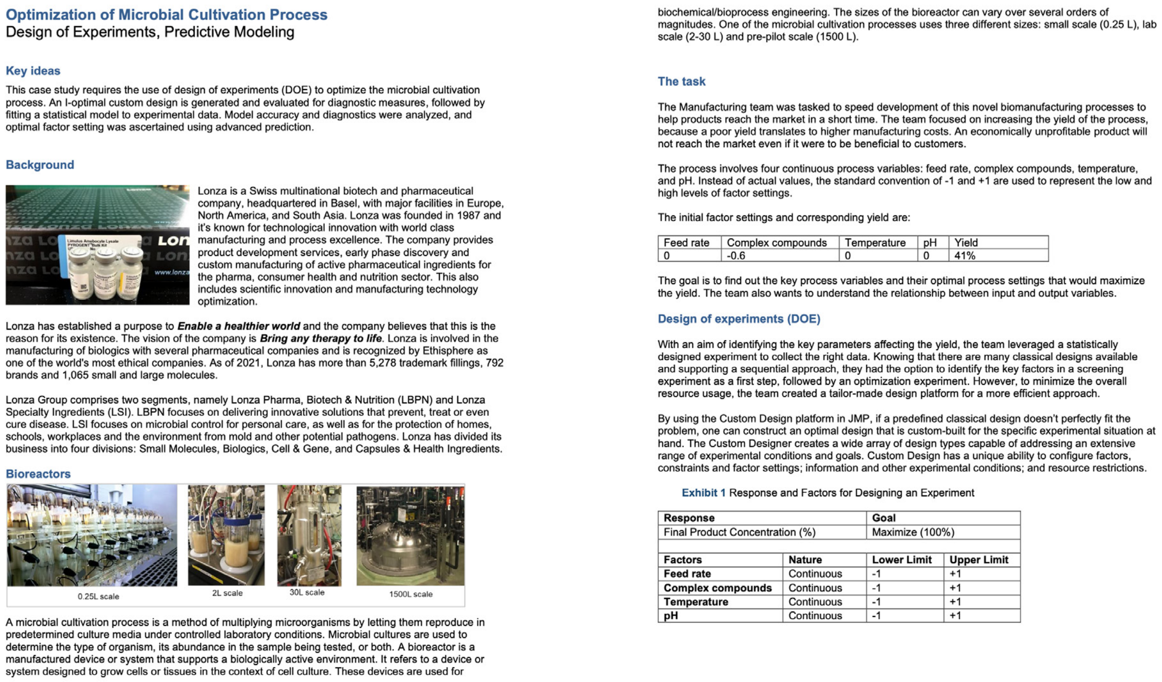
A live demo will present the solution of case #52 on process optimization in biotech from LONZA [5] (Fig. 3), showing sample content and style of a JMP case study. The demo will also provide a practical example about applying statistical thinking, combining JMP capabilities for statistical discoveries to solve a real-world problem. Alternatively, readers of this paper can watch a recorded demo [6] presented by Andreas Trautmann from LONZA, who is also a co-author of the case study.

3 CASES IN THE CLASSROOM

There are several options to use our cases studies in teaching: While educators can use case studies for in-class demonstrations, the most effective use are assignments to students as homework or group projects. The cases can stimulate discussions about which steps to take or comparisons of alternative solutions. Students can also be asked to present the learning outcome to “other decision makers”, or to explain why and how certain methods have been applied.

4 MORE TEACHING RESOURCES AND GETTING STARTED

Case studies are just one kind of teaching resources provided by JMP’s Global Academic Program. During the workshop, additional resources will be shared and



Optimization of Microbial Cultivation Process
Design of Experiments, Predictive Modeling

Key ideas

This case study requires the use of design of experiments (DOE) to optimize the microbial cultivation process. An I-optimal custom design is generated and evaluated for diagnostic measures, followed by fitting a statistical model to experimental data. Model accuracy and diagnostics were analyzed, and optimal factor setting was ascertained using advanced prediction.

Background

Lonza is a Swiss multinational biotech and pharmaceutical company, headquartered in Basel, with major facilities in Europe, North America, and South Asia. Lonza was founded in 1987 and it's known for technological innovation with world class manufacturing and process excellence. The company provides product development services, early phase discovery and custom manufacturing of active pharmaceutical ingredients for the pharma, consumer health and nutrition sector. This also includes scientific innovation and manufacturing technology optimization.

Lonza has established a purpose to ***Enable a healthier world*** and the company believes that this is the reason for its existence. The vision of the company is ***Bring any therapy to life***. Lonza is involved in the manufacturing of biologics with several pharmaceutical companies and is recognized by Ethisphere as one of the world's most ethical companies. As of 2021, Lonza has more than 5,278 trademark fillings, 792 brands and 1,065 small and large molecules.

Lonza Group comprises two segments, namely Lonza Pharma, Biotech & Nutrition (LBPN) and Lonza Specialty Ingredients (LSI). LBPN focuses on delivering innovative solutions that prevent, treat or even cure disease. LSI focuses on microbial control for personal care, as well as for the protection of homes, schools, workplaces and the environment from mold and other potential pathogens. Lonza has divided its business into four divisions: Small Molecules, Biologics, Cell & Gene, and Capsules & Health Ingredients.

Bioreactors

0.25L scale 2L scale 30L scale 1500L scale

A microbial cultivation process is a method of multiplying microorganisms by letting them reproduce in predetermined culture media under controlled laboratory conditions. Microbial cultures are used to determine the type of organism, its abundance in the sample being tested, or both. A bioreactor is a manufactured device or system that supports a biologically active environment. It refers to a device or system designed to grow cells or tissues in the context of cell culture. These devices are used for biochemical/bioprocess engineering. The sizes of the bioreactor can vary over several orders of magnitudes. One of the microbial cultivation processes uses three different sizes: small scale (0.25 L), lab scale (2-30 L) and pre-pilot scale (1500 L).

The task

The Manufacturing team was tasked to speed development of this novel biomanufacturing processes to help products reach the market in a short time. The team focused on increasing the yield of the process, because a poor yield translates to higher manufacturing costs. An economically unprofitable product will not reach the market even if it were to be beneficial to customers.

The process involves four continuous process variables: feed rate, complex compounds, temperature, and pH. Instead of actual values, the standard convention of -1 and +1 are used to represent the low and high levels of factor settings.

The initial factor settings and corresponding yield are:

Feed rate	Complex compounds	Temperature	pH	Yield
0	-0.6	0	0	41%

The goal is to find out the key process variables and their optimal process settings that would maximize the yield. The team also wants to understand the relationship between input and output variables.

Design of experiments (DOE)

With an aim of identifying the key parameters affecting the yield, the team leveraged a statistically designed experiment to collect the right data. Knowing that there are many classical designs available and supporting a sequential approach, they had the option to identify the key factors in a screening experiment as a first step, followed by an optimization experiment. However, to minimize the overall resource usage, the team created a tailor-made design platform for a more efficient approach.

By using the Custom Design platform in JMP, if a predefined classical design doesn't perfectly fit the problem, one can construct an optimal design that is custom-built for the specific experimental situation at hand. The Custom Designer creates a wide array of design types capable of addressing an extensive range of experimental conditions and goals. Custom Design has a unique ability to configure factors, constraints and factor settings; information and other experimental conditions; and resource restrictions.

Exhibit 1 Response and Factors for Designing an Experiment

Response	**Goal**
Final Product Concentration (%)	Maximize (100%)

Factors	**Nature**	**Lower Limit**	**Upper Limit**
Feed rate	Continuous	-1	+1
Complex compounds	Continuous	-1	+1
Temperature	Continuous	-1	+1
pH	Continuous	-1	+1

Fig. 3. Extract from case study #52 shared by LONZA

discussed, including the JMP Leaning Library and the Statistical Thinking online course (see [7] for “Introductory Engineering Statistics” course material).

Workshop participants and readers are welcome to contact the author for a personal discussion of JMP academic resources and capabilities.

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The role of lecturers in engineering students' personal development process and the promotion of lifelong learning competencies

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Keywords: *personal development process, lifelong learning, role of faculty*

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Professional engineers need to continuously update and up-skill their competencies, to keep pace with the changing technology and shifting requirements of the labour market (European Commission 2019). Educating resilient students requires a university setting that makes them aware of their professional identity and trains them in continuously re-inventing themselves (Knapper and Cropley 2000). Hence, the educational challenge is not only to prepare students for a specific career but also to build foundations for a lifetime of learning (Kamp 2016). Although teaching staff often acknowledge the importance of Life Long Learning (LLL) competencies they do not necessarily feel adequately prepared to support students' personal development and lifelong learning skills. However, to support students and prepare them for a life of LLL, lecturers need to be more systematically and explicitly engaged in the students' personal development process.

Lecturers' ability to support students' career development is related to academics' attitudes and beliefs, teaching and learning approaches, as well as the challenges met by the staff (Amiet et al. 2021). In the contemporary rapidly changing world, engineering graduates emphasize the need for generalist competence, interpersonal skills, and constant learning over formal credentials and specific technical competencies in securing employment (Nilsson 2010). Academics also perceive that enhancing students' general skills supports their career development more than focusing on specific careers (Amiet et al. 2011).

Research has shown that different pedagogical approaches influence engineering students' development of self-regulated learning and, by extension, lifelong learning skills differently. Problem- and project-based learning tend to promote metacognitive self-regulation, critical thinking, and help-seeking, whereas lectures with active learning activities promote more effective use of time and study environment. (Lord et al. 2012.) Some assessment and grading approaches even seem to undermine the types of goals associated with self-directed learning (Stolk et al. 2014) and may thus even inhibit the development of LLL competencies.

Although many academics recognize that they have a role in students' career development, they also call for the responsibility to be shared among students, lecturers, and professional staff. Lecturers with limited work experience outside university especially felt that they lacked confidence in supporting students' career development. Many academics also felt guilty for not being able to meet the students' expectations for support. They suggested that the responsibility for supporting students' career development should be better acknowledged in academic job descriptions and promotional guidelines, as well as being supported with faculty and university-level resources. (Amiet et al. 2011.)

This workshop launched the Erasmus+ TRAINeng -PDP project which focuses on how we can help students develop LLL competencies and support lecturers by designing and creating appropriate training materials. To begin, we needed a collection of perceptions regarding the role, responsibilities, resources, opportunities, and challenges of engineering lecturers to support the students' personal development process and a lifelong learning attitude. Hence, we called the SEFI community for assistance. The results of the workshop will inform the pilot projects, attitudinal survey, and training materials which will form the outcome of this project.

The workshop consisted of a short introduction to the topic followed by collaborative work and discussion in groups in the form of a learning café. The discussions addressed questions: "*What **could we do** to support the development of students' LLL competencies?" and "What **should we do** to support the development of students' LLL competencies?"* Both questions were addressed separately from three different realms of lecturers' tasks, namely instruction, guidance, and assessment.

The workshop resulted in over two hundred ideas for and insights on supporting the development of students' LLL competencies in teaching. Discussions were conducted in six groups rotating the three aspects (instruction, guidance, and assessment). In the first round of analysis, ideas were grouped into 33 categories and then further into six themes. As the work still continues, the categories and themes may undergo some changes in the future. Current six themes 1) Planning for active learning 2) Training and supporting reflection, communication, and teamwork skills 3) monitoring and explicating learning 4) providing different forms of feedback 5) creating an inclusive, safe, and curious environment 6) Training lecturers, combine ideas related to all three aspects.

Planning for active learning entails suggestions for using active instruction methods, encouraging problem-solving, being innovative with assessment methods, choosing and searching for supportive materials, promoting cooperation among students, demonstrating professional skills to students, and involving students in planning the assessment. However, it also contains reminders of remembering the different dimensions of assessment as well as the need for balancing the course requirements and not just adding LLL objectives on top of everything else.

Training and supporting reflection, communication, and teamwork skills includes many different means for encouraging and helping students to reflect on their knowledge (or lack of it), learning process, perspectives, etc. Training for reflection, teamwork, and communication skills for learning but also for assessment is emphasized. Scaffolding for the development of different metacognitive skills is perceived to be part of the guidance.

Monitoring and explicating learning refers to the ways the lecturers can help students to understand learning as a process on a general and personal level. Communicating assessment effectively is considered important and providing role models and stories is thought to enhance especially students' attitudes towards LLL. Getting the right kind of information through assessment activities is also crucial for monitoring the students' learning processes.

Providing different forms of feedback in instruction, guidance, and formative and summative assessment is often brought up in the ideas. Valuable feedback can be received from the teacher, peer students, and through self-assessment or even from experts from outside academia. Enabling students to act on the feedback is often emphasized and especially peer feedback is seen as an important way to enhance students' evaluation skills.

Creating an inclusive, safe and curious environment is seen as a prerequisite for learning from mistakes, which is considered to be a powerful way to learn through reflection. An inclusive environment calls for the lecturers to see and value students as individuals, to value diversity, and demonstrate variety in their knowledge and opinions. Especially guidance by asking questions is seen as a powerful way to support students in developing their LLL competencies and especially questions and situations which stimulate students' curiosity are valued.

Finally, it is brought up that in addition to the students, also lecturers may need training and help in understanding and mastering the same skills, whose development they are supposed to scaffold for students. Especially help for conducting a meaningful assessment, discussing assessment with students, and training for reflecting on teamwork processes is suggested as resources for supporting students' LLL.

Asking about 'coulds' and 'shoulds' did not reveal any stark lines of division and it seems that many lecturers are willing to conduct the actions they deem necessary for supporting students. Lecturers seem to be ready to act as role models and also share their imperfections and learning needs with the students to show that also they need to engage in lifelong learning. This appears to be an excellent starting point for our project aiming to help both students and lecturers in enhancing students' LLL competencies.

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CAREER DEVELOPMENT WORKSHOP FOR EDUCATION-FOCUSED ACADEMICS

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Topics: *Building Communities and Coordination, Mentorship and Tutorship*

Keywords: *education-focussed academics, academic career framework, teaching-focussed academics, education-focussed career pathway*

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Overview

The workshop will give an overview of recent developments in education-focused academic career pathways, with specific reference to engineering disciplines. Workshop participants will discuss strategies for developing their academic careers through teaching excellence, Engineering Education Research (EER) and SOTL (Scholarship of Teaching and Learning), and leadership in Engineering Education. The workshop will also discuss how engineering schools can improve the support they offer to their education-focused academics.

Background and rationale

The number of academics in the UK (United Kingdom) employed on education/teaching-only contracts (as opposed to joint research and teaching contracts) has increased steadily since the turn of the century. In 2020/21, 32 percent of all UK academics were on teaching-only contracts [1]. The growth in the number of academics on teaching-only contracts appears to be part of an international trend within Europe, Northern America, and Australia driven by changes in the higher education environment such as the massification of higher education, cuts to higher education funding, research funding selectivity, and marketisation of higher education. These changes have led to institutions restructuring and adopting new strategies to ensure survival, including the increased casualisation of academic staff, and the introduction of separate academic contracts for research, education, and research and education [2].

The introduction of teaching-only academic contracts has led to the development of education-focused career pathways with opportunities for promotion to senior academic roles based on teaching excellence, scholarship, professional practice, and education leadership. However, the newness of such pathways means that there is a shortage of education-focused senior academics to provide role models and mentoring for junior academics seeking promotion to senior grades. This is further compounded by uncertainty and lack of consensus on what counts as evidence of good education practice, particularly when considering promotion to senior grades [3, 4].

The SEFI conference brings together academics of all levels and contracts with an interest in Engineering Education, including academics on education-focused career pathways. The workshop seeks to take advantage of this by bringing together these individuals, with those among us who hold senior leadership roles, to discuss and share ideas, experiences, and insights into developing successful education-focused academic careers. It is hoped that this workshop will help participants to establish supportive networks that will continue to exist beyond the conference.

Audience

Engineering academics on education-focused career pathways, and senior academics with line management for such academics and/or educational leadership and career promotion responsibilities within higher education institutions.

Timeline

Education-focused Academic Career Pathways – 10 minutes

Content outline:

- Discuss the unbundling of the academic role into specialised functions focussing on research, education (teaching and learning) and service (to include a brief overview of the underlying factors driving this change).

- Identify the emergence of education-focused distinct academic career pathways in individual universities
- Highlight the challenges and opportunities for establishing an equitable career progression for education-focused academics in different universities and countries.
- Discuss similarities and difference of the academic profession in various countries.

Career Progression through Excellence in Education Practice - 10 minutes

Content outline:

- Discuss the contested concept of teaching/education excellence in higher education
- Discuss national frameworks for recognising teaching/education excellence, e.g., the UK Professional Standards Framework (UKPSF).
- Discuss the use of teaching/education excellence frameworks in developing institutional teaching-based promotion criteria for academic staff

Establishing an EER and Scholarship Career – Strategies, Challenges & Opportunities - 10 minutes

Content outline:

- Discuss how EER (and SOTL) is defined and supported within individual higher education institutions and national higher education systems
- Identify and discuss challenges in developing and supporting EER (and SOTL) for promotion and recognition
- Discuss and propose strategies for evidencing EER attainments in institutional promotional criteria

Establishing an Education Leadership Career- Strategies, Challenges & Opportunities - 10 minutes

- Discuss the extent to which education (teaching and learning) leadership is recognised as a valid form of academic leadership within higher education institutions, and within engineering disciplines
- Discuss current institutional promotion policies and criteria with respect to promoting and rewarding those who teach and lead on education
- Discuss emerging “good practices” in relation to promoting and rewarding education leaders within higher education institutions, and, specifically, within engineering disciplines

How Engineering Schools can support education-focused academics – 10 minutes

Discuss institutional and departmental policies and practices that support career development, promotion, and recognition for education-focused academics, including:

- Fostering an inclusive academic culture that supports and encourages academics to play to their own strengths
- Continuing professional development opportunities for education-focused academics
- Promoting parity of esteem at all levels of the career ladder between education-focused academics and mainstream (research and teaching track) academics.

Wrap-up and closing comments – 10 minutes

Acknowledge emerging good practice in promoting and rewarding education–focused academics and identifying areas for collaborative research in this area.

Workshop organisation

The workshop will be organised as an interactive session in which participants are invited to actively contribute their experiences and insights in all the workshop segments. The workshop is intended to stimulate discussion amongst the workshop participants, with the hope of initiating collaborative research on academic careers and practices within engineering education.

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USING PEER ASSESSMENT IN INCLUSIVE DIGITAL EDUCATION

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Conference Key Areas: *Digitalisation & Hybrid models, Assessment*
Keywords: *Peer assessment, Peer Evaluation, Hybrid Learning, Blended Learning*

ABSTRACT

This workshop is part of the ERASMUS+ project: RAPIDE: on Relevant Assessment and pedagogies for Inclusive Digital Education (https://rapide-project.eu) and is open to anyone who is interested in implementing or improving peer assessment in their

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courses. At the end of the workshop, participants will be able to make an informed decision on a suitable form of Peer Assessment for their courses.

Over the past few years, many of us have faced operating in a frequently changing teaching environment which has made evaluating and assessing students' learning outcomes and more importantly giving students feedback on their learning much more complicated.

One pedagogical tool that has been increasingly used is that of peer assessments where students give each other feedback and assess each other's work.

In this workshop, participants will be introduced to many different types of peer assessment that can be used in engineering education, such as peer reviewing (each other's work), peer grading(continuous feedback on mastery), and peer evaluation (group work) whether face-to-face, hybrid or in a fully online environment and how to do so in an inclusive way thus maintaining the important safe place that education should be.

Participants will then in small groups discuss what types of peer evaluations they use or want to use in their courses and brainstorm on ideas for implementation in their own specific case or for one of the general cases that the facilitators will have available.

At the end of the workshop participants will present their main findings back to the whole group so that they may also learn from each other. We aim for participants to leave feeling inspired at the end of the workshop to implement or improve peer assessment in their own courses.

The aggregated main findings and ideas contrived in the workshop on how to implement peer assessment will also be shared with a wider audience through the conference proceedings and the RAPIDE project website.

1 INTRODUCTION

This workshop is part of the ERASMUS+ project: RAPIDE: on Relevant Assessment and pedagogies for Inclusive Digital Education (https://rapide-project.eu) and is open to anyone who is interested in implementing or improving (digital) Peer Assessment (PA) in their courses.

2 WHY THIS WORKSHOP?

With increasing student numbers entering Higher Education across the globe and with an increasing need for flexibility in how education is delivered, lecturers are in need of more digital tools to help them in their teaching. As the recent COVID-19 pandemic has shown us, lecturers must be able to almost seemingly switch between online, blended, flipped classroom (FC), or face-to-face education in the case of on-campus education. At the same time, similar tools are needed to support Work-Based Learning (WBL) and fully online or remote learning.

One area where lecturers can struggle to deal with both the required flexibility and the increasing student numbers is in the area of assessment. At our own institution, for instance, student numbers have increased by over 15% in the last four years. Next to the debatable, all-important grade, it is also important that students are provided with timely feedback on their performance and their deliverables if we want our students to truly learn and mature. However, this can have serious implications for the workload of the lecturers involved.

3 PEER ASSESSMENT AS A SOLUTION

One pedagogical tool that has been increasingly used is peer assessment, where students give each other feedback and assess each other's work. Being able to reflect and give and receive feedback are important transversal skills for engineering students to learn to enhance their employability [1]. Already in 1998, Keith Topping published a literature review on the use of Peer Assessment in Higher Education [2]. He defined PA as:

> *"an arrangement in which individuals consider the amount, level, value, worth, quality, or success of the products or outcomes of learning of peers of similar status."*
> (Topping, 1998, p.250 [2]).

Whereas PA in the 20th Century was very much a paper-based or verbal exercise, these days optimal use can be made of Virtual Learning Environments such as BlackBoard, Brightspace, Canvas or Moodle and the digital software tools available to educators when it comes to using PA.

4 WHAT WILL PARTICIPANTS LEARN & DO IN THE WORKSHOP?

In this workshop, participants will be introduced to different types of peer assessment that can be used in engineering education, whether face-to-face, hybrid or in a fully online environment and how to do so in an inclusive way thus maintaining the important safe space that education should be.

The main learning outcome at the end of the workshop will be that participants are able to make an informed decision on how to design or select an appropriate form of Peer Assessment for their course.

Participants will be introduced to the pros and cons of the different methods and which type of PA type is suitable for what educational activity, using some of the case studies developed in the RAPIDE project as an example.

Case studies to be covered are Peer Assessment in terms of reviewing students' products, peer grading where students grade each other's work and peer evaluation where students review each other's performance in group work

Participants will also learn about the requirements digital peer evaluation systems must meet to provide a safe and inclusive learning space as well as meet the various data protection requirements.

Participants will then in small groups discuss what types of peer evaluations they use or want to use in their courses and brainstorm on ideas for implementation in their own specific case or for one of the general cases that the facilitators will have available.

At the end of the workshop, participants will present their main findings back to the whole group so that each group may also learn from the other.

5 MAIN TAKEAWAYS

We aim for participants to leave feeling inspired at the end of the workshop to implement or improve peer evaluations and peer assessment in their own courses. Participants will also be provided with some of the resources developed within the RAPIDE project for them to take home with them and use when looking at implementing PA using digital systems in their own courses.

The aggregated main findings and ideas contrived in the workshop on how to implement peer assessment in courses will also be shared with a wider audience through the conference proceedings and the RAPIDE project website.

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Mapping Engineering Education Research in Europe

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Conference Key Areas: *Niche & Novel, Fostering Engineering Education Research*
Keywords: *Mapping, Engineering Education Research, Europe*

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Context

The growth of Engineering Education Research (EER) has led to claims about it becoming a globally connected field of inquiry. Following from this, recent studies have employed scientometric data drawn from SCOPUS to provide insights into the research careers of EER practitioners in parts of Europe: Portugal, Spain and the Nordic countries. Within the SEFI EER SIG, ongoing work by the workshop organisers is studying how national contexts influence the EER output in the various European countries.

Workshop Aims

1. To share with participants scientometric data on EER publication output and research careers across the countries of Europe;
2. To guide participants to situate this scientometric data in the light of their knowledge of their own institutional and national context and to compare international contexts;
3. To learn new insights from participants that broaden the base of relevant EER data from across Europe. This could lead to future work in which the findings are explored in relation to the contextual factors associated with each of the geographical regions, thus providing insight into ways to support development of EER in the future.
   It is also hoped that its findings could also involve other stakeholders who could lobby for a parity of esteem between EER and engineering research (for career progression or promotion) both at national and European levels, and for more funding for EER by European research bodies.

Workshop structure

- Participant introduction activity
- Plenary session: presentation of scientometric data on EER publications and careers in European countries
- Group activity: participants work in international breakout groups to compare and contrast the EER landscapes in their respective countries
- Plenary session: reports back from group activity
- Wrap-up, including discussion on any follow-up to workshop

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WHORKSHOP SIG

How can *you* contribute to the social responsibility of your university's education?

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Keywords: responsibility, ethics, teacher, university, eco-system

In this SEFI ethics SIG-workshop, we actively engage with the question: "How can *you* contribute to the social responsibility of your university's education?"

This is an important question for university staff.
First, universities become (and see themselves) as increasingly important players to contribute to the sustainable development goals. Their missions [1]–[3] and strategies [4] broaden to more research, entrepreneurship and social responsibility. From the perspective of being recognized as important actors in the quintuple helix of innovation [5], (technical) university eco-system collaborations become increasingly co-creative, including complex interactions between political, economic, and education systems, natural environment and knowledge creation [6]. The technical universities' education also becomes increasingly intertwined with the eco-system partners, resulting in adapting curricula [7] and new and flexible [8] formats for ethics courses [9] such as research-based, community-based or challenge-based learning.
Second, in this transition, teachers change inevitably from purely internal staff to societal actors [10]. Willingly or unwillingly, you as an individual teacher get a more pronounced societal role, as an agent of social change (e.g. [11]). This means a growing realization that, in the language of Paulo Freire, "Education is politics…when a teacher realizes that he or she is a politician too, the teacher has to ask, What kind of politics am I doing in the classroom? That is, in favor of whom am I being a teacher?" [3:46].

If we approach this from the responsibility angle, Whitbeck's definition "exercise of judgment and care to achieve or maintain a desirable state of affairs" [4:159] can be a starting point here. As Fore and Hess note while introducing their five-sided framework of ethical becoming, "rules and codes found in discipline-specific standards are undoubtedly important, [but] insufficient by themselves for moral inquiry and ethical judgement" [5:1355]. The reflection of the impact of education to the university's responsibility then requires a focus on the actual context and social practices [15] and a broader perspective on all involved (students, teachers, university, eco-system) [16].

For the session, we propose the following **agenda:**

1. Short introduction of the context of the workshop
2. Break-out groups
   - What is your role in the university? (Ethics) teacher? (Educational) manager? What do you care about"? What do you want to change or influence? Do you focus on the classroom activities? Or do you reflect on how your activities (teaching, research, …) have a broader impact?

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How do you judge things as a desirable state of affairs? How does ethics come into play?
What can you "exercise"? What can you do? What is your agency or influence? How is it limited (university, other contexts)? Do you want more influence?

- Who can or should you involve in co-constructing the educational agenda and reaching educational goals?
- How do you evaluate your influence? Student satisfaction or student learning? Do you also use input from other partners?

3. Plenum discussion, in which we bring together the different inputs and have an overall discussion.

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Emerging professional skills: Insights and methods

SEFI 2022 Engineering Skills SIG Workshop Report

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Conference Key Areas: *Engineering Skills,*
Keywords: *project management, innovation and entrepreneurial mindset, communications, transdisciplinarity, complex systems, leadership, teamwork, skills*

ABSTRACT

In this workshop run by the Engineering skills SIG, attendees were given the opportunity to learn about emerging professional competencies, and strategies to overcome teaching barriers.The workshop format was “world cafe” with several tables for small groups to informally discuss these strategies within a time limit. Each table focussed on an emerging skill and/or scenario and participants each visited several tables. The session was informed by the engineering skills survey taken by SEFI 2021 conference attendees. It gave us views on new competencies, barriers to teaching them, and illustrations of good practice. Obstacles to teaching them include motivation, legitimacy, overloaded curriculums, student resistance, resource constraints, and pedagogical understandings.Ideally skills should be learned by students in contexts where they’re used. While many technical competencies are primarily developed in engineering practice, professional/soft abilities are often not. As a result, there ought to be some opportunity for the student to transfer, adapt and (re)learn them in an engineering degree. This report summarises the conference workshop outputs with sections for each table. Each section acknowledges the hosts/authors, a summary of the discussion, and any materials presented. Readers may find this paper useful when facilitating related discussions.

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1 INNOVATION AND ENTREPRENEURIAL MINDSET (RAFAELLA MANZINI, UNIVERSITA' CARLO CATTANEO - LIUC)

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1.1 What is innovation?

- Good definition: Oslo Manual (ch. 3.2, 3.3, 3.4, https://www.oecd.org/science/oslo-manual-2018-9789264304604-en.htm) and the Frascati Manual (ch 2.2-2.5, https://www.oecd.org/sti/inno/frascati-manual.htm).
- Innovation is creating value from ideas. What value? Both economic and social value.

1.2 What do we mean with “innovation skills” and “entreprenerial mindset”?

- Innovation skills: ability to contribute to transform ideas into value, with an
- entrepreneurial mindset: taking care of the idea, until it deploys its economic and/or social value.

1.3 Do we really need to teach these skills to engineering students? Aren’t they already skilled, in their specific technical area? Some provocative statements

- Engineers are highly creative, in their technical field of expertise
- Engineers are problem solvers, so they are naturally ready for innovation
- Engineers do not need to have innovation and entrepreneurship skills:

1.4 What do we really need to teach to engineering students?

- Innovation is a process, it is not only a matter of creativity and technical competences.
- The focus should be on value generation, something which is not always “natural” among engineers:

1.5 How to help students developing innovation skills and an entrepreneurial mindset

- Project – based and challenge based approaches are the most suitable;
- Case-based learning can be helpful, but it isn’t enough;
- Internships can greatly help;
- Leverage on the specialized technical knowledge and expertise of students
- Make engineering students aware of their limitations
- Create groups with mixed competences and background

1.6 References

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2 COMMUNICATIONS (NATALIE WINT, SWANSEA, AND JENNIFER GRIFFITHS, UCL)

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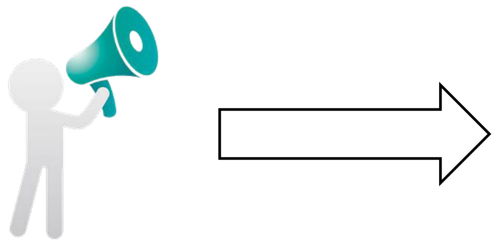
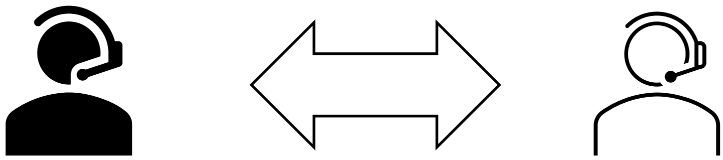
2.1 Models of Communication

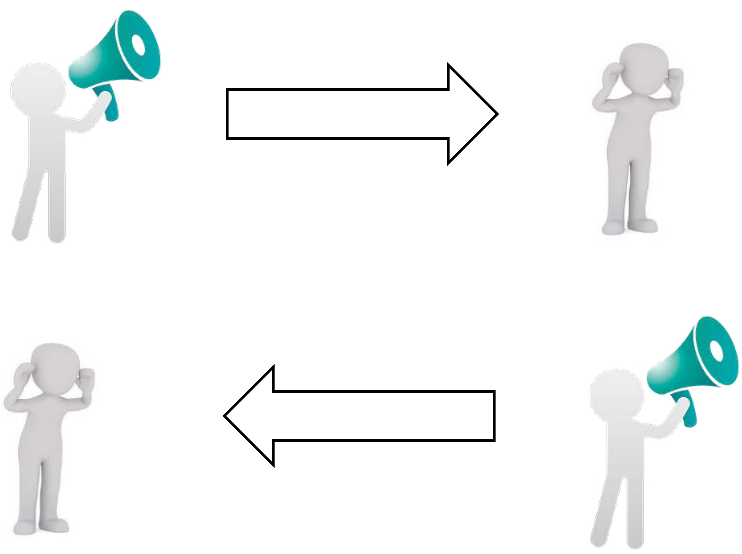
- **Linear models (e.g., Aristotle's, Lasswell's, Shannon-Weaver, Berlo's SMCR)–** only looks at one-way communication.



- **Interactive models (e.g., Osgood Schramm, Westley and Maclean) –** looks at two-way communication.



- **Transactional models (e.g., Eugene White's, Barnlund's, Dance's Helical) –** looks at two-way communication where the message gets more complex as the communication event (e.g., conversation) progresses.



2.2 Communication across disciplines

Students must communicate with people from different disciplines or cultures. They will face challenges in doing so and should therefore be aware of how to address them.

- People from different backgrounds often attach different meanings to the same word.
- People bring different perspectives to bear on what they hear and infer a different meaning than was intended. Students are therefore more likely to transcend their disciplinary perspective if they are self-aware of the set of largely subconscious assumptions.

Michael O'Rourke et al., *Enhancing Communication and Collaboration in Interdisciplinary Research,* Sage, July 2013.

2.3 Inclusive communication

Dusek J, Ferrier E, Goodner R, Sarang-Sieminski A, Waranyuwat A, Wood A. Proactive Inclusion of Neurodiverse Learning Styles in Project-Based Learning: A Call for Action. ASEE Annual Conference and Exhibition. 2018.

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3 INTER- AND TRANSDISCIPLINARITY (HOSTS: THIES JOHANNSEN, TU-BERLIN, ANN-KRISTIN WINKENS, RWTH AACHEN)

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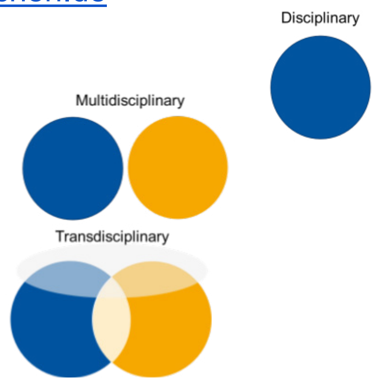
3.1 What is inter- and transdisciplinarity?

Multidisciplinarity is a sum of disciplinary perspectives.

Interdisciplinarity is a transformative process of mutual cooperation among disciplines.

Transdisciplinarity is a transformative process of mutual cooperation among stakeholders from different fields – including non-academics.



(cf. "What is transdisciplinarity" SEFI@work SIG Skills, 10 December 2021)

3.2 How can inter- and transdisciplinarity be implemented in HE teaching?

Problem- and project-based Learning

Problem-based learning begins with identifying and structuring a problem and exploring its limits (Brassler/Dettmers 2017: 5). This includes dealing with relevant terms and concepts as well as critical source work. It is a student centered learning concept that addresses complex learning (Hadgraft/Kolmos 2020: 5).

- Brassler, Mirjam/Dettmers, Jan (2017): How to Enhance Interdisciplinary Competence—Interdisciplinary Problem-Based Learning versus Interdisciplinary Project-Based Learning. In: *Interdisciplinary Journal of Problem-Based Learning* 11 (2). DOI: 10.7771/1541-5015.1686.
- Hadgraft, R. G., and Kolmos, A. (2020). Emerging learning environments in engineering education. Australasian Journal of Engineering Education, 25(1), 3–16. doi:10.1080/22054952.2020.1713522

3.3 Case-based Learning

Case learning aims to develop professional intellectual and behavioral skills through a topic-specific and problem-oriented interpretation of real-life experiences (Lynn 1999: 3). Case teaching is an inductive method that builds a bridge between theoretical-declarative and practical-functional knowledge (Biggs/Tang 2011: 163). Students gain application-oriented knowledge and develop practice-relevant competencies in the theory-based and guided examination of a case.

- Biggs, John Burville/Tang, Catherine So-kum (2011): Teaching for quality learning at university. What the student does. 4th ed. Maidenhead: McGraw-Hill/Society for Research into Higher Education/Open University Press.
- Lynn, Laurence E. (1999): Teaching and Learning with Cases. A Guidebook. New York: Chatham House Publishers.

3.4 Best practices

Blue Engineering

Blue Engineering is an international and innovative workshop-style course provided by Technische Universität Berlin. It focuses on ecological and social responsibility. The course facilitates creative, interdisciplinary and sometimes heated debates on the issues posed by technology in society and in nature.

- Baier, André (2019): Education for sustainable development within the engineering sciences - design of learning outcomes and a subsequent course evaluation. TU Berlin, Berlin. http://dx.doi.org/10.14279/depositonce-8844.

Engineering for Impact

Engineering for Impact – Responsible Innovations is an interdisciplinary project- and problem-based course that introduces students to methods and tools of how science can make an impact. Students work in groups to develop a technology-based application concept for a self-selected societal challenge.

- Johannsen, Thies (2021): Integrated Classroom Learning. How to Create an Activating and Safe Environment for Online Learning in Knowledge Exchange and Innovation Education for Engineering Students. In: Jan von der Veen, Natascha van Hattum-Janssen, Hannu-Matti Järvinen, Tinne de Laet und Ineke ten Dam (Hg.): Blended Learning in Engineering Education: challenging, enlightening – and lasting? SEFI 49th Annual Conference. Berlin, 13.-16.09.2021, S. 936–950.

Project "Leonardo"

Project "Leonardo" aims to enhance and promote interdisciplinary discourses within RWTH Aachen University. In doing so, various courses are offered from usually two lecturers from different scientific disciplines that focus on social challenges. The aim is to discuss a central topic in an interdisciplinary manner under academic supervision and to bring together both students and lecturers from different disciplines.

- Winkens, A., Böschen, S., and Leicht-Scholten, C. (2021). Interdisciplinary Teaching at RWTH Aachen University: Project "Leonardo". Paper presented at the The European Conference on Education 2021, London, United Kingdom (online).

3.5 Workshop discussion

- It is important to define terms.
- There are overlaps with other relevant skills.
- Different knowledge and different understandings may be a challenge (cf. silos); results in barriers to collaborate with teachers/educators from different disciplines.
- There is generally a lack of recognition for the process, and a focus on results.
- To enhance collaboration skills interdisciplinary thesis in groups may be an effective approach; also, it raises awareness among students.
- There is usually a conflict between depth and breadth: either deep dives or broad, inter- or transdisciplinary understanding of a problem.
- How to approach inter- and transdisciplinarity? It is useful to make experiences first and then reflect them methodologically: have students make experiences rather than explaining methods theoretically.

- Usually there are deficits in institutions in regard to inter- and transdisciplinarity whereas individuals are very competent. Raises the question of institutional support.
- It may help to have testimonials from professionals that inter- and transdisciplinarity are meaningful in professional careers.
- Collaborating with industry may result in conflict of interest regarding research and commercialisation.
- A very relevant barrier is motivation of stakeholders, be it academics, students or external partners.

4 SYSTEM COMPLEXITY (YOLANDE BERBERS, KU LEUVEN)

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4.1 What do you think System Complexity is, how would you define it, what does it include? Why is this skill important for engineers?

- Most attendees agreed that system complexity is to see non-obvious connections between things, while understanding why they behave a certain way, which gives insight into “a system is more than the parts”.

4.2 How is it taught at your institution?

- Many attendees didn’t identify a standalone teaching of this. However, in aerospace curriculum (TU-Delft) system engineering is part of the curriculum, there is a specific course on this
- Most agreed that system complexity is learned when students work on different parts of a system, and have them then integrate all these parts. Typically these are done in challenge based learning projects e.g. a Solar Car. These problems are typically “wicked”. Students should learn to model first before building, and make their reasoning explicit: ““build down the complexity to build it up” (Twente).

4.3 How is it assessed?

- A lot of visualization is necessary to understand the complexity of the system.

Report on the SEFI Working Group Workshop (19-1):

Teaching Soft Skills for Engineers of the Future by Using Projects

Organised and presented by: Nargiza Mikhridinova [1,3], Bertha Joseph Ngereja [2], Carsten Wolff [3], Wim Van Petegem [1], Mariano Alvarez Blanco [4]

[1] KU Leuven, Belgium; [2] The Norwegian University of Science and Technology, Trondheim, Norway; [3] Dortmund University of Applied Sciences and Arts, Germany; [4] Siemens Digital Industries Software, Leuven, Belgium

1. The Concept:

Workshop rational: Engineers work in projects and need certain soft skills to succeed in this work environment. Teaching soft skills to engineering students can be supported by creating project situations which generate a relevant learning experience. The workshop is intended for participants who want to look deeper into how to create such project situations in student projects.

Learning outcomes: During the one-hour workshop "Teaching soft skills for engineers of the future by using projects" participants will learn:

- How to plan, prepare and conduct agile cross-border projects with industry involvement for educational purposes
- How to select a relevant project case
- How to build the teams for project assignment
- Participants will be provided with:
    - Template and example of the course concept with learning activities' plan
    - Template and example of the case study description
    - Working template for the self-evaluation for roles identification

Concept and engagement scenarios: The workshop will have 3 parts:

- Part 1: project-based learning and agile cross-border projects,
- Part 2: roles and soft skills model, team formation and relevant exercises,
- Part 3: discussion and feedback from industry partners.

Part 1 description:

An introduction to the concept of agile cross-border projects [1] will be provided, including results of the ongoing research from students' and trainers'/lecturers' perspectives. During the session, participants get familiar with the course concept including the intended learning outcomes and the learning activity plan.

Part 2 description:

Introduction to the project case development [2] and know-how to refine and tailor a project case with companies for training soft skills [3, 4], as well as roles definition and team formation models and processes. Participants of the workshop will perform a role identification exercise based on Belbin's team roles [5]. After exercise the discussion will follow about matching their results with the Scrum roles.

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Part 3 description:

a) Discussion between industry partners and the workshop participants on impact of soft skills in ongoing projects, training strategies to develop soft skills of employees, as well as perspective of the industry on skills of “fresh” engineering graduates.
b) Feedback and discussion about soft skills and personality traits [6] in order to train a desired set of soft skills.

Participants will be asked to assess and evaluate the concept; the workshop materials will be made available to all participants after the workshop (via cloud storage).

2. Results and Discussion

The workshop was attended by appr. 50 people (Fig. 1). After Part 1 on project-based learning and agile cross-border projects was concluded, the participants applied the Belbin’s test by their own with assistance of organisers (Part 2), and then in Part 3 we had a discussion and feedback from Siemens Digital Industries Software (Leuven, Belgium).

Fig. 1. Organisers and attendees of the workshop

From our point of view, the workshop was very relevant and interesting to participants. Particularly Part 1 arose a high interest of participants, and they were actively engaged in the discussion on conducting agile cross-border projects, and how they can replicate the same methodology in their courses.

Important to mention, Part 2 arose an interesting discussion about ending the use of the term "soft" as it sends the wrong message to students and lecturers, and other people in organizations. That because they are soft, it doesn’t mean they are less important. (You may be interested in reading a paper on a similar matter: *A hard stop to the term “soft skills”,* https://doi.org/10.1002/jee.20442).

The discussion from Part 3 also emphasized the need for higher education institutions to really focus on soft skills for engineering students. Companies are investing a lot to ensure that their employees possess both technical and soft skills. But there is still a need for higher education institutions to bridge the soft skills gap early enough in learning trajectories.

The participants were given the link to download the workshop materials, which can be accessed via https://fh-dortmund.sciebo.de/s/jxS7pIx5Do0WIra.

At the end, the participants evaluated the workshop. Although, the response rate was very low (16%), below you may find some interesting results, and insights (Table 1).

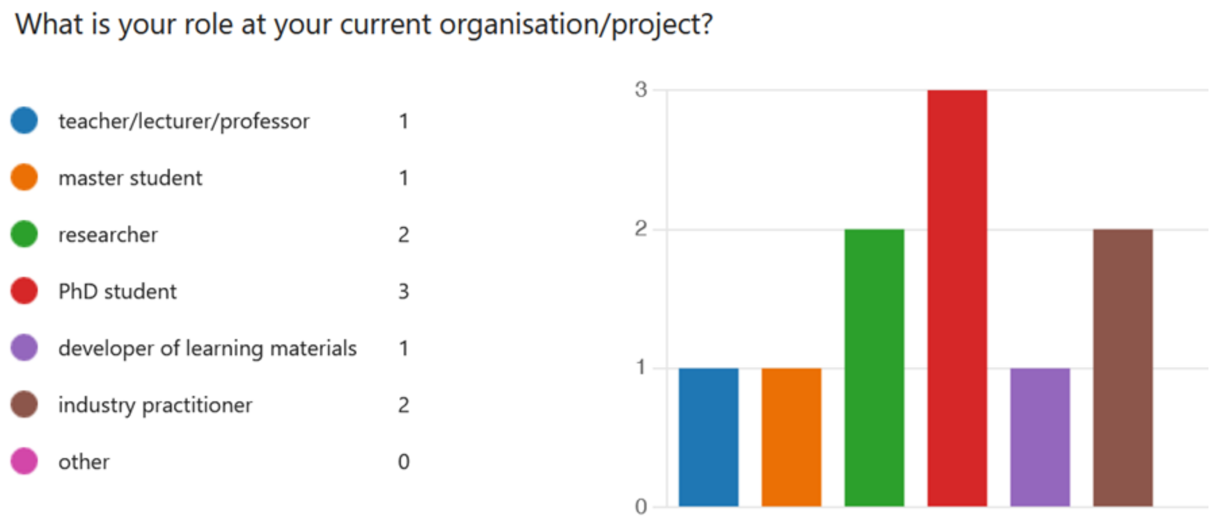

Fig. 2. Profile of respondents

Only 38% of respondents experienced special tools for assigning specific team roles to people in the project settings.

Table 1. Insights into means of soft skills' development

What were the means or approaches applied to train these particular deficit skills?	What would be your suggestions to improve soft skills development?
• Creative challenges, daily social conflicts between technical opinions encountered • Project-based learning on real-world problems • Meeting and collaborating with disciplines outside of mine • Through having sufficient knowledge about the topic • Practice	• The implementation of more workshops and to invest on team working innovation on the industrial businesses • Learning by doing • Exposure to different disciplines early on in education • Make a lot of real situation practical experiences, even better do them in industry • A holistic understanding of how the whole enterprise functions • Project-based tasks within all subjects of the curriculum

3. Limitations

While organising the workshop, we were informed on appr. number of participants for the workshop as 20. Since we had about 50 participants, we did not have enough materials and capacity to help all participants with Part 2. At the same time, we were positively surprised with this attendance rate, and believe that this shows a high demand and importance of our research and education focus.

Since the evaluation took place before Part 3, and due to the remark above, this limited the response rate of our evaluation.

4. Conclusion

If you want to help our research, and managed to check the materials via the link mentioned above, please fill in the evaluation/feedback form: https://forms.office.com/r/JfGg92HRAA

Several discussions proceeded after the workshop, and defined future research collaborations. To conclude this report, we want to use one of the statements a participant shared: "*The development of soft skills is required to complement the development of technical skills*."

5. Acknowledgement

The workshop was organised in frames of Erasmus+ KA2 Knowledge Alliance project 621745-EPP-1-2020-1-DE-EPPKA2-KA "ProDiT- Projects for the Digital Transformation".

References:

[1] Wolff, C. *et al.* (2022) *Cross-Border Projects in Digital Education Ecosystems*. Springer International Publishing. doi: 10.1007/978-3-030-93904-5.

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Promoting Active Learning in STEM Subjects

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Conference Key Areas: *Student Engagement, Teaching methods, Assessment*
Keywords: *active learning, assessment, digital tools, learning and pedagogical technologies*

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Literature does not provide a universal definition of active learning. Bonwell & Eison (1991) defined active learning as "instructional activities that involve students in doing things and thinking about the things they are doing". Active learning can be considered as anything but passive listening to a lecture. Most typically the concept of active learning encapsulates methods that activate students during in-class sessions (Prince, 2004).

Several research studies have advocated active learning methods in teaching and learning STEM subjects (see e.g. Freeman et al. (2014), Theobald et al. (2020) and Prince (2004)). Many benefits of active learning have also been highlighted. Meta-analysis of Freeman et al. (2014) revealed increased course scores and passing rates in STEM courses under active learning. The effects seemed to be greatest with small group sizes (under 50) even though active learning methods appeared to work across all group sizes (Freeman et al., 2014)

The drop-out rates are high in the field of engineering throughout Europe. In Finnish universities of applied sciences the percentage of graduates in ICT engineering after 5 years of studying is 40 % and in engineering 48 % (Vipunen). These figures are quite low. Engaging students in their learning process seems to promote retention rates. One way to engage students in their studies seems to be using active learning methods.

The objective of this proposed workshop is to enhance educators' competence of such instructional design that improves students' active learning. The workshop aims to promote digital and pedagogical competence of engineering educators by introducing methods and tools for promoting active learning. By increasing such competences of educators, it gives them tools and knowledge to redesign their teaching and implement digital resources and activities (e.g. TPACK, active learning, self-regulated learning, digital languaging and assessment) for different personalized learning scenarios.

The content of the proposed workshop will be twofold. On one hand, it presents DigiSTEM project results, and on the other one, participants will share their experiences and expertise related to using digital tools and pedagogy in STEM education. The session itself utilizes active learning methods. Participants will keep small pitches of their best pedagogical practices in teaching/learning of STEM subjects and participate in group working. Hence, participants will actively construct content for the workshop. Working activities in the groups will be focused on the following issues:

- Many forms of assessment - In what ways is it possible to reduce the amount of teacher's assessment work?
- What kind of learning technology / digital tools do you use in teaching? Share your best experiences.
- What kind of active learning methods are you using?

The authors will collect a list of participants. As a result of the workshop, a collection of best practices, examples of using digital tools, pedagogical solutions and summary of workshop ideas will be created and sent to the session participants. Aim is to create a collection that includes elements among others e.g. innovative pedagogies, utilizing digital assessment, promoting self-regulated learning and using online resources for STEM subjects' learning purposes. This collection seeks to support pedagogical and digital learning methods that activate students and promote self-regulated learning.

The workshop focuses on the pedagogical issues and also on concrete actions and examples of usability of technology. At the end of the workshop participants are expected to experience for example the following outcomes:

- Reflect on how their courses support pedagogical and digital learning methods that activate students and promote self-regulated learning.
- Share concrete actions and examples of usability of technology and pedagogical solutions in STEM education.
- Discuss how using digital tools and pedagogy in STEM education could be designed to optimize learning outcomes in engineering studies.

- Obtain relevant information about various possibilities of online tests used for assessment of acquired knowledge and competencies by means of both - formative and summative testing
- Learn about available software options and solutions for digital (online) testing and receive practical advice on good experience with the development and use of online tests (suitable topics, design of questions, choice of answers, ways to insert answers, automatic evaluation, etc.)
- Analyze the impact of digital learning scenarios (on-line, distance, blended, hybrid, …) on the quality and sustainability of acquired knowledge and competencies

References:

Bonwell, C. C., & Eison, J. A. (1991). Active learning: Creating excitement in the classroom. 1991 ASHE-ERIC higher education reports. ERIC Clearinghouse on Higher Education, The George Washington University, One Dupont Circle, Suite 630, Washington, DC 20036-1183.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the national academy of sciences, 111(23), 8410-8415.

Pelkola, T., Rasila, A., & Sangwin, C. (2018). Investigating Bloom´s Learning for Mastery in Mathematics with Online Assessment, *Informatics in Education*, Vol. 17, No. 2, pp. 363-380. Available at: https://files.eric.ed.gov/fulltext/EJ1195654.pdf

Prince, M. (2004). Does active learning work? A review of the research. *Journal of engineering education*, *93*(3), 223-231.

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., ... & Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences*, *117*(12), 6476-6483.

Vipunen - Education Statistics Finland. The education administration's reporting portal. Retrieved 3rd May 2022. Available at: https://vipunen.fi/en-gb/

Responsible Innovation as a vehicle for teaching ethical and social dimensions of technology

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Conference Key Areas: *Ethics in Engineering Education, Social and Service Learning, Curriculum Development*
Keywords: *Responsible Innovation. Ethics. Social Responsibility.*

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This session is designed for anyone with an interest in teaching ethics, Responsible Innovation (RI) or both. We aim for a lively session in which participants leave with new ideas on how they might embed RI in their modules or curricula. The session will be of interest both to those who involved in teaching modules and to those who are responsible for higher level curriculum design.

Workshop leads are also interested in understanding more about how members of the engineering education community are using RI in their programmes and we hope that this will be a forum for the exchange of ideas all round. Is RI (or elements of it) part of an already existing curriculum or module that you run? From our experience, RI is used most often in areas of the curriculum where sustainability is considered and the two endeavours do have synergies, which will be discussed in the workshop.

Background and relevance?

Over the past two decades there has been a growing emphasis on incorporating social and ethical perspectives in engineering education, and at the same time the concept of Responsible Innovation (RI) has emerged in the UK and Europe as a way of ensuring new technologies align with societal needs. The outcome is that RI frameworks are growing in popularity as a vehicle for teaching ethical and societal dimensions of technical innovation.

At its most fundamental, RI holds that moral values are embedded in technologies and that normative deliberation should be part of all stages of technological innovation [1]. RI is an ethical construct. Indeed, many educators treat it as a special case of ethics [2] but here we present our own on-going experience of using RI and its practice as a tool for teaching and addressing curriculum development. Using a framework (AREA) that is widely employed in the UK we will demonstrate how we can map curricula and modules in search of opportunities to embed RI within our engineering modules and student projects.

One advantage of using RI frameworks over teaching classical ethics is that RI is explicitly future oriented. Where ethics classes often focus on retrospective case studies, RI can be used in real-time in design projects. The AREA framework prompts practitioners to ask questions that will help to anticipate the impacts of research and innovation before they occur [3]. It encourages the engineer to understand how it is possible to innovate *with* and *for* society and it creates opportunities both for two-way dialogue and for co-creation. RI is especially helpful in the upstream phases of project development but in iteration it can also aid in assessing and responding to downstream technological impacts. In the broadest sense RI is a set of tools and techniques that enable engineers to probe the social world.

What is RI? And what is RI for you?

RI is often criticised for its vagueness, but this mistakes its purpose. RI is not a theory or a discipline and as such it does not have long held or rigid epistemic boundaries. RI is a process designed for use in knowledge production and technical innovation that can aid producers and innovators to embrace ethical, contextual and sustainability issues upstream and downstream of innovation. Key to this process is the opportunity it affords for making changes in designs in response to engagement with stakeholders.

Participants who join this workshop will take away -

- An understanding of the RI AREA framework and how to use it as a means of identifying normative material in the curriculum
- Ideas on how they might embed RI into modules and programmes.
- Ideas on the competencies that educators may need to teach RI effectively
- Going forward, an opportunity to build a network of educators who are interested in developing RI in engineering curricula

Workshop Format

Presentation on using RI and the AREA framework.

The aim is for participants to learn about the four steps of the RI framework – anticipation, reflection, engagement, action – and the ways they can be used for teaching.

(15 mins)

Activity 1: Mapping your module or your programme using AREA.

The aim for this group activity is for participants to identify where ethics, social context, value and impact are taught in their own modules and curricula – is your provision mostly about, through or for RI?

Sum up and introduction –

(30 mins)

Activity 2: Ways to teach RI using AREA

Using the output of the previous activity participants will explore opportunities to embed and extend ethics provision perhaps by including elements of RI in active-learning or PBL activities.

Sum up and introduction –

(45 mins)

Activity 3: Brainstorming the competencies that educators need to have within themselves to include this material in curricula

This is a chance to think through how we as teachers need to develop in order to teach this kind of material and a chance for discussion and reflection on the learning and how we would like to take it forward.

Sum up.

(60 mins).

The results of this workshop will be outlined in the final workshop report.

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REPORTS

SEFI 2022 AWARDS

Every year, SEFI uses the unique opportunity of its Annual Conference to SEFI acknowledges the commitment and hard work of many professionals through awards.

Leonardo Da Vinci Medal:

The Leonardo da Vinci Medal is the highest distinction SEFI can bestow. The SEFI Board of Directors awards the Medal to living persons who have made an outstanding contribution to engineering education and have been of international significance.

This year, SEFI awarded the SEFI Leonardo Da Vinci Medal to **Dr Faraón Llorens Largo,** a full professor of Computer Science and Artificial Intelligence at the University of Alicante (UA) as well as the Santander-UA Chair of Digital Transformation, for his outstanding and innovative approach to engineering education, pioneering efforts in digital transformation and his international impact in Spanish-speaking countries.

Fellowship Awards:

The SEFI Fellowship Award acknowledges meritorious service to engineering education in Europe. The awardees may use the expression "Fellow of SEFI" (F. SEFI) as a postscript to their name. Additionally, the nominees are individual members of SEFI who have worked in the field of engineering education for at least five years.

Therefore, during the annual conference, SEFI granted the Fellowship Award to three outstanding academics:

- **Prof. Jonte Bernhard**, Linköping University, a leading figure for many years in the creation of the SEFI Special Interest Group for Engineering Education Research, as well as the Nordic Engineering Education Research Network. In addition, another essential defining quality is that he elevates younger talents and encourages renewal.

- **Prof. Mike Murphy**, Dublin Technological University, is the second awarded with the SEFI Fellowship for his diligent work as SEFI President and Vicepresident, Chair of the SEFI Dean’s Council as well as after his mandate ended. His dedication ensured the much-needed continuity within our organisation and major development in several areas, notably the SEFI Special Interest Groups.

- **Prof. Şirin Tekinay**, George Mason University, was also honoured with the SEFI Fellowship 2022 due to her meritorious service to engineering education. Besides her core area of research and teaching, she has focused on different aspects of Higher Education and Engineering Education, such as diversity with particular emphasis on women in engineering, professional identity, multi-disciplinarity in teaching and research, design thinking and convergence research, technology-based learning platforms, sustainability, and engineering for peace. Moreover, Professor Tekinay initiated and contributed to many SEFI activities, including the Susan Ihsen Best Paper Award Programme, the Maffioli Award and relations with the Global Council of Engineering Deans.

SEFI Francesco Maffioli Award:

The SEFI Francesco Maffioli Award is granted to individual teachers, or a team of teachers, from SEFI member institutions of higher engineering education. This award aims to recognise the open development of open curricula, learning environments or tools, novel didactics, methods, or systems in engineering studies.

As a recognition of the extraordinary social impact of this project, this year's SEFI Francesco Maffioli Award for Excellence in the Development of Learning and Teaching in Engineering Education has been awarded to **Dr Joost Vennekens** of KU Leuven, in recognition of the extraordinary social impact of his project. Dr Vennekens' work involves Service Learning as a pedagogical means to enhance the creativity and empathy of students in the Bachelor of Engineering Technology: Electronics-ICT. The project was featured as an example in an EU report on Service Learning and on several Service-Learning platforms across Europe.

FACE TO FACE AGAIN – REPORT FROM THE DOCTORAL SYMPOSIUM IN ENGINEERING EDUCATION RESEARCH AT SEFI 2022

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Keywords: Engineering Education Research, doctoral education, networking

ABSTRACT

The 6th Doctoral Symposium at SEFI 2022 attracted 20 doctoral students and 17 senior researchers. After two years as an online event during the pandemic, it was organised as a fully in-person event. In preparation, the doctoral students wrote extended abstracts to introduce themselves and their PhD projects, while the seniorsprovided reading recommendations and advice. The intense, full-day program was based on group discussions and interactive plenary sessions. The Doctoral Symposium was concluded by a session in which each participant presented their take-home message. This paper outlines how the Doctoral Symposium was organised and summarizes some of the documentation.

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1 INTRODUCTION

1.1 The SEFI Doctoral Symposium

With the exception of a few larger research centres, doctoral education in engineering education research (EER) is often organised in relatively small scale at each institution – this is not least true in Europe. Therefore, it is important for PhD students to network outside their own research environment, in order to enhance the doctoral student experience, support their development as researchers, and increasetheir understanding of the EER field as a whole. Creating and maintaining connections between researchers, and regional and international networks, are then strategies for strengthening the research field (Borrego & Bernhard, 2011; Edström etal., 2018).
The European Society for Engineering Education (SEFI) recognises the EER field and its importance for furthering engineering education. Through the Doctoral Symposium in Engineering Education Research, SEFI offers PhD students opportunities to share their work with peers and with senior researchers, to build theirpersonal network and exchange feedback. The aim is that participants will:

- meet other students and supervisors to extend their network and view of theEER field,
- present and discuss their own work and the work of others,
- get perspectives from scholars outside their own institution,
- contribute to the conference and the SEFI EER community, and
- promote collaborative research and elaborate future research directions.

In five previous SEFI conferences, a Doctoral Symposium in Engineering Education Research (DS) has been held as a full-day pre-conference event: before the SEFI Annual Conference 2016 in Tampere, 2018 in Copenhagen, 2019 in Budapest, 2020in Twente (online), and 2021 in Berlin (online).

The purpose of this paper is to document and share some insights into the process and products of the DS 2022. In the following, we discuss recruitment of participants – both the doctoral students and experienced researchers, and explain the activitydesign. We present parts of the rich material that was created, in particular the advice from seniors and the individual reflections from all participants.

1.2 Back to a face-to-face Symposium

Due to the Covid-19 pandemic the DS had to be arranged online in 2020 and 2021.This year, the SEFI annual conference as well as the DS were back to in-person meetings. As organizers, we had very much been looking forward to arranging the DS as a face-to-face event again. There was however still a risk for new outbreaks which could force us to transfer the DS, and indeed the whole conference, to an online event again. Another risk which could cause low attendance was if the intended participants would be afraid to start travel internationally again, or not allowed to by their universities. Luckily, both these fears were unfounded and the participation at the DS was back to similar numbers as before the outbreak of the pandemic. The only disturbance due to the aftermath of the pandemic was that airlines and airports could not handle the return of traffic post-pandemic. This had, unfortunately, as consequence that a few accepted doctoral student and senior participants could not arrive in Barcelona in time for the DS.

1.3 Doctoral Student Participants

The doctoral students interested in participating were invited to send an extendedabstract, containing:

- *A general introduction* (background and interest in EER),

- *An outline of their research* (elevator pitch, research interest, thesis title,supervisors, current work),
- *Reflections* (questions, challenges, dilemmas, wishes and ambitions),
- *Preferences for networking* (at SEFI2022, and for keeping in touch).

The extended abstracts that were submitted showed that the doctoral students werein various stages in their PhD projects, representing various topics from policy level to fine-grained classroom studies. Twenty-four doctoral students were accepted, butfour of them had to cancel due to illness or flight problems. Finally, 20 students attended representing 10 countries: Belgium, Denmark, Germany, India, Ireland, theNetherlands, Norway, Sweden, the UK, and the US.

1.4 Senior Participants

A number of experienced researchers in the field – here called senior participants – were invited to provide the PhD students with feedback, coaching and guidance. It isimportant for the quality of these discussion that there is a high number of seniors.
Just like in the previous symposia, the organisers wanted to keep the ratio of seniorsto students very high, aiming at approximately 2 seniors per 3 doctoral students. Theinvitations were apparently very attractive, as almost every person agreed to extend their travel to volunteer their time, on a Sunday. This year there were in total 17 seniors, including the organising team (the authors of this paper). They came from Australia, Belgium, Denmark, Ireland, the Netherlands, Portugal, Sweden, Switzerland, South Africa, the UK, and the US. Hence, the seniors were even slightlymore geographically diverse than the doctoral students.

1.5 Groups

The core of the symposium consisted of group activities in which doctoral students and seniors worked together. Seven groups were formed, each containing 3 doctoralstudents and 2–3 senior participants. The groups were composed taking into accounta balance between diversity and similarity regarding: years of experience; research interests – both in terms of topics and methods; university and country. A compilationof all extended abstracts was sent out to all participants. The instruction was to prepare by reading the abstracts of the doctoral students, at least the ones in their own group. The groups were formed a week in advance, but some last-minute changes were made due to the late cancellations.

1.6 Event Outline

The event took place on Sunday September 18, as a pre-conference day before theSEFI 2022 Annual Conference. The program was designed to accommodate lively and deep discussions between PhD students and experienced researchers. The main parts of the program were group activities, interspersed with plenary activities:

09.30 – 10.00 Coffee & Tea
10.00 – 10.30 Introductions and instructions for the day
10.30 – 12.30 First group session
Lunch
13.30 – 14.15 Speed dating
14.15 – 15.30 Second group session
15.30 – 16.30 Plenary report: Take-home messages and final reflections

2 DOCUMENTED RESULTS

2.1 Getting to Know the Experienced Researchers

The senior participants were asked to submit some reading tips for the doctoral students. The first question was: *If a doctoral student wanted to read something byyou, what would you* *recommend and why?* In response, the seniors mentioned thefollowing selection of their own work (in alphabetical order).

Diana Bairaktarova

I would recommend my most current publication. It is a guest editorial and the article frames itself in the context of the Ukraine situation, which feels close to home for me. The editorial is one of the thingsthat I worked on, feeling the urgency to put concerns into action. The article offers an overview of key educational theories and how these can be utilize in educating more empathic engineers for their rolesas global citizens. In the editorial, I also cite the dissertational work of one of my graduate students, which makes this publication even more special for me:

- Bairaktarova, D. (2022). Caring for the future: Empathy in engineering education to empowerlearning. *Journal of Engineering Education*, *111*(3), 502-507.

Jonte Bernhard

My first choice is a paper with Caroline Baillie. We discuss issues related to quality in engineeringeducation research (EER):

- Bernhard, J., & Baillie, C. (2016). Standards for quality of research in engineering education.

International Journal of Engineering Education, 32(6), 2378-2394.

Next, this one discusses and reflects on the relationship between "pure" engineering research andengineering education research:

- Bernhard, J. (2015). Engineering education research as engineering research. In S. Hyldgaard Christensen, C. Didier, A. Jamison, M. Meganck, C. Mitcham, & B. Newberry (Eds.), *Internationalperspectives on engineering education: Engineering education and practice in context, Volume 1*(pp. 393-414). Springer.

This paper demonstrates how engineering thinking, indeed, can improve the methods of EER:

- Carstensen, A.-K., & Bernhard, J. (2019). Design science research – a powerful tool for improving methods in engineering education research. European Journal of Engineering Education, 44(1-2),85-102.

Shannon Chance

In this article we discuss differences between two major methodologies used in engineering educationresearch, and then they demonstrate how they applied each methodology to one qualitative dataset (transcribed interviews). Results of each analytical process aligned in this study, yet each method uncovered slightly different findings; a primary lesson is that the lens we view the world (data) throughinfluence what and how we see.

- Chance, S., Duffy, G., & Bowe, B. (2019). Comparing grounded theory and phenomenology as methods to understand lived experience of engineering educators implementing Problem-BasedLearning. *European Journal of Engineering Education, 45*(3), 405-442.

Inês Direito

Launching into any new topic in your PhD, you may feel overwhelmed. The available information may seem too vast and complex to synthesize and summarize. This is made more complex by EngineeringEducation Research being an emergent new field – one that draws from, and combines, expertise in multiple disciplines – which adds to the complexity of selecting and analysing literature. Using a structured approach to identify, select, and analyse the existing body of literature can help you build confidence by helping ensure consistency, quality, and reliability of your review. This paper presents asystematic literature review in a relatively unexplored area in Engineering Education (grit's influence on students' performance).

- Direito, I., Chance, S., & Malik, M. (2021) The study of grit in engineering education research: asystematic literature review. *European Journal of Engineering Education,*

46(2), 161-185.

Xiangyun Du

This work was led by one of my PhD students and exemplifies how a systematic review study servesas a start of a PhD project. It is a good example supporting how to get a PhD journey started.

- Chen, J.B., Kolmos, A. & Du, X.Y. (2020). PBL in Engineering Education – Forms of Implementation and Challenges: A Review of Literature. *European Journal of EngineeringEducation, 46*(1), 90-115.

Kristina Edström

In this paper I reflect on engineering education research, especially in relationship to engineering education development. I think we all need to consider our role as researchers along these dimensions. What is the purpose of our work: who do we want to be, and what do we want to achieve?

- Edström, K. (2020). The role of CDIO in engineering education research: Combining usefulnessand scholarliness. *European Journal of Engineering Education, 45*(1), 113-127.

Anette Kolmos

- Kolmos, A. (2021). Engineering Education for the Future. In *Engineering for Sustainable Development: Delivering on the Sustainable Development Goals* (p. 121-128). UNESCO.
- Kolmos, A., Holgaard, J. E., & Clausen, N. R. (2021). Progression of student self-assessed learning outcomes in systemic PBL. *European Journal of Engineering Education, 46*(1), 67-89.

Greet Langie

- Craps, S., Pinxten, M., Knipprath, H., Langie, G. (2021). Different roles, different demands. A competency-based professional roles model for early career engineers, validated in industry andhigher education. *European Journal of Engineering Education, 47*(1), 144-163.

Melissa Marinelli

This paper uses an interesting theoretical framework to understand how industry -university relationships are started and to provide recommendations for improved industry engagement. I thinkthe study is useful as it uses theory and empirical analysis to address a pertinent issue. It links to myresearch interests of bridging education and practice, student employability, and professional awareness and identity.

- Valentine, A., Marinelli, M., & Male, S. (2022). Successfully facilitating initiation of industry engagement in activities which involve students in engineering education, through social capital.*European Journal of Engineering Education, 47*(3), 413-428.

John Mitchell

An accessible study that looks to understand the development of in the context of an education change.

- Mitchell, J. E. & Rogers, L. (2020). Staff perceptions of implementing project-based learning inengineering education, *European Journal of Engineering Education, 45*(3), 349-362.

Mike Murphy

- Murphy, M., Chance, S. & Conlon, E. (2015). Designing the Identities of Engineers. In *EngineeringEducation and Practice in Context, Vol.2* . Springer.

Kate Roach

I chose this paper, because it came about through an unexpected opportunity. I collected student evaluations from a large scale module which I ran at the time and while preparing it for university processes, I noticed that there were some interesting trends and comments on authenticity and that was how the paper came about. The original data was simplicity itself in its conception and execution.The analysis was also straight forward. Even so the data reaches into some of the deeper debates and issues relating to authenticity in engineering education.

- Roach, K., Tilley, E., & Mitchell, J. E. (2018). How authentic does authentic learning have to be?,

Higher Education Pedagogies, 3(1), 495-509.

Corrinne Shaw

The reason for this selection is that this is my most recent publication with my research team exploringthe students' transition into undergraduate engineering. Our team has a long collaboration of reflexive practice and this article reflects a particular point in our journey of understanding and leveraging the resources that diverse students bring with them.

- le Roux, k., Ngoepe, M., Shaw, C., & Collier-Reed, B. I. (2022). Language and disciplinary literacies for accessing, learning and communicating meaning: students' experiences of the transition from school to first-year undergraduate engineering, *European Journal of EngineeringEducation*.

Roland Tormey

I'd recommend the following paper because it shows how conceptual and empirical work can come together to do something worthwhile. It is also a project of a scale that is similar to a doctoral project:

- Tormey, R. Rethinking student-teacher relationships in higher education: a multidimensionalapproach. *High Educ 82*, 993–1011 (2021).

Esther Ventura-Medina

This is a qualitative research based on naturalistic data analyzed with Conversational Analysis to capture the interactions that take place between members of a team to elucidate how they managetheir work:

- McQuade, R., Ventura-Medina, E., Wiggins, S., & Anderson, T. (2020). Examining self-managedproblem-based learning interactions in engineering education. *European Journal of Engineering Education, 45*(2), 232-248.

Pieter de Vries

I would recommend something that is about to be published, so cannot give you the reference yet. The title is: 'The Ethical Dimension of Emerging Technologies in Engineering Education' and it is aboutthe values and risks of using these technologies in Engineering Education. Emerging Technologies are part of the constituting datafication and digitalisation process that poses major challenges to the current educational infrastructure. Universities are challenged to respond to the demands that seem todevelop faster and become more complex. The complexity though is not just technical, it is the combination of technology, and specifically big data use, the link with job requirements, educational practices, ethical responsibilities, and socio-cultural aspects of education. The purpose of this paper is to analyze and discuss elements of those issues in trying to clarify the complexity and lower the threshold for those who are involved and looking for a better understanding of the opportunities and challenges.

Patric Wallin

I would recommend an article that I wrote together with three students on reclaiming higher educationas a space for play. I think it provides an interesting contrast to many other articles and challenges traditions on several levels. Furthermore, I think it illustrates how to write a piece where the research process, content and presentation all line up to create a whole.

- Wallin, P., Mariussen, K. L., Mogstad, H., & Sønderaal, M. (2021). A dialog on reclaiming highereducation as a space for play. *The Journal of Play in Adulthood, 3*(2).

Bill Williams

- Trevelyan, J., & Williams, B. (2019). Value creation in the engineering enterprise: an educationalperspective. *European Journal of Engineering Education, 44*(4), 461-483.

2.2 Reading Recommendations from the Experienced Researchers

Next, the senior researchers were asked to give input following the prompt: *Recommend one paper, not your own, for a starting PhD student?* This resulted in acomprehensive collection of publications.

Diana Bairaktarova

- Johri, A. & Olds, B. (2011). Situated Engineering Learning: Bridging Engineering EducationResearch and the Learning Sciences. *Journal of Engineering Education, 100*(1):151-185

Jonte Bernhard

- Case, J. M. (2019). A third approach beyond the false dichotomy between teacher- and student-centred approaches in the engineering classroom. *European Journal of Engineering Education, 44*(5), 644-649.

Shannon Chance

My primary recommendation is a textbook rather than a journal article:

- Major, C. H., & Savin-Baden, M. (2012). *An introduction to qualitative research synthesis: Managing the information explosion in social science research*. Routledge.

As for journal publications, I would recommend an excellent example of a systematic literature review:

- Campbell, A. L., Direito, I., & Mokhithi, M. (2021). Developing growth mindsets in engineeringstudents: a systematic literature review of interventions. *European Journal of Engineering Education, 46*(4), 503-527.

Tinne De Laet

- Fleur, D.S., Bredeweg, B. & van den Bos, W. (2021). Metacognition: ideas and insights fromneuro- and educational sciences. *npj Sci. Learn. 6*(1), 1-11.

Inês Direito

- Grant, M. J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information and Libraries Journal, 26*(2), 91–108.
- Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to Do a Systematic Review: A BestPractice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta- Syntheses. *Annual review of psychology, 70*, 747–770.

Xiangyun Du

- Borrego, M., Douglas, E. P., & Amelink, C. T. (2009). Quantitative, qualitative, and mixed researchmethods in engineering education. *Journal of Engineering Education, 98*(1), 53-66.

Kristina Edström

A special issue in EJEE should be a state-of-the-art collection of papers on a specific theme. Recentlywe published special issue on the theme "*Early Career Engineers and the Development of Engineering Expertise*". The editorial introduces the topic and the ten amazing papers:

- Buckley, J., Trevelyan, J., & Winberg, C. (2022). Perspectives on engineering education from theworld of practice, European Journal of Engineering Education, 47(1), 1-7.

Anette Kolmos

- Repko, A.F., Szostak, R., & Buchberger, M.P. (2013). *Introduction to interdisciplinary studies.*Sage, London.

Greet Langie

- Naukkarinen, J. & Bairoh, S. (2022) Gender differences in professional identities and developmentof engineering skills among early career engineers in Finland. *European*

Journal of Engineering Education, 47(1), 85-101.

Melissa Marinelli

Again, this is a paper that bridges engineering education and practice. It presents a way of thinkingabout early engineering careers that is new and different.

- Craps, S., Pinxten, M., Knipprath, H., & Langie, G. (2022) Different roles, different demands. A competency-based professional roles model for early career engineers, validated in industry andhigher education. *European Journal of Engineering Education, 47*(1), 144-163.

John Mitchell

- Case, J. M., & Light, G. (2011). Emerging research methodologies in engineering educationresearch. *Journal of Engineering Education, 100*(1), 186-210.

Mike Murphy

- Mitcham, C. (2014). The True Grand Challenge for Engineering: Self-Knowledge. *Issues in Science & Technology, 31*(1).

Kate Roach

This is an editorial rather than a research paper, but it is timely and important. It takes as its starting point the complexity of current global crises and raises theoretical lenses that may help us to think about how to deliver support for complex problem solving. This piece is very timely and speaks to theneed to help students develop the knowledge, skills and attributes they will need to live and work in a rapidly changing world.

- Chance, S. et al (2019). Guest editorial special issue on using enquiry-and-design-based learningto spur epistemological and identity development of engineering students. *IEEE Transactions on Engineering, 63*(3), 157-164.

Corrinne Shaw

- Kvale, S. (1983). The qualitative research interview. *Journal of phenomenological psychology,14*(1-2), 171-196.

Roland Tormey

A systematic literature review is a great starting place to develop a doctoral picece of work. This onewas done as part of a PhD project:

- Zhang, F., Markopoulos, P. & Bekker, T. (2020). Children's Emotions in Design-Based Learning: aSystematic Review. *J Sci Educ Technol 29*, 459-481.

Esther Ventura-Medina

This paper summarizes quite well different approaches to research in engineering education. Althoughthere are other perhaps more recent papers I always refer back to this one.

- Borrego, M., Douglas, E. P., & Amelink, C. T. (2009). Quantitative, qualitative, and mixed researchmethods in engineering education. *Journal of Engineering education, 98*(1), 53-66.

Pieter de Vries

A comprehensive analysis of Edtech development and policy under Covid:

- Williamson, B., & Hogan, A. *Pandemic Privatisation in Higher Education: Edtech & UniversityReform* (p. 80). 2021.

Patric Wallin

Time is an important concept in all types of research and this paper challenges the reader to thinkdeeper about it. While it is not situated within Engineering Education Research, I think it is highly relevant.

- Bennett, A., & Burke, P. J. (2018). Re/conceptualising time and temporality: an exploration of timein higher education. *Discourse: Studies in the Cultural Politics of Education, 39*(6), 913–925.

Bill Williams

- Passow, H. J., & Passow, C. H. (2017). What competencies should undergraduate engineering programs emphasize? A systematic review. *Journal of Engineering Education, 106*(3), 475-526.

2.2 Advice from Experienced Researchers

In their advance input, seniors were also asked to give one general tip for a startingPhD student.

Diana Bairaktarova

Expand on your professional network while in grad school to engage with scholars from other fields.

Jonte Bernhard

Think through your research question(s), i.e. find interesting problems you want to investigate. In myopinion the quality of the insights generated is more important than mechanically following a method.

Shannon Chance

Cultivate mentors. Find a range of people with varying expertise and perspectives who are willing to chat with you from time to time and provide you ideas to help you dream big. Make sure you let themknow when they've made a difference in your life.

Tinne De Laet

Talk to your colleagues, also the ones of other domains. They well help enrich your work and broadenyour horizons.

Inês Direito

Invest time in literature reviews - both before and after data collection. These help you to develop yourresearch aims and conclusions.

Xiangyun Du

The well-being of a PhD study is highly related to your passion, purposefulness, making milestones toobtain feelings of achievements, and being agentic in one's choices and actions.

Kristina Edström

The senior researchers are absolutely delighted that you have come to this field. They will offer support in so many different ways – here in the Doctoral Symposium, attending your conference talk,as reviewers of your manuscripts, in your doctoral defense, or just chatting with you during the conference dinner. Soon, much sooner than you think, it will be your turn to support others who comeafter you.

Anette Kolmos

Keep working on your research question and the purpose of the study.Be careful with review, methodology.

Work on your confidence - you are the one who knows most about the subject.

Greet Langie

Focus

Melissa Marinelli

Remember your 'why' - why did you choose to start your doctoral studies? Why is your work importantto you? In tough times, these motivations will get you through!

John Mitchell

Refine and be clear on your research question so that you can try to avoid being distracted from theinevitable interesting rabbit-holes that will appear - but always write them down for later.

Mike Murphy

It's a marathon, not a sprint; therefore be measured and not impatient.

Kate Roach

Keep research questions and data collection as simple as you can - complex data does not equalcomplex thinking!

Corrinne Shaw

Becoming part of a community of practice and write, write, write some more.

Roland Tormey

Write something every week. Writing is a skill that cannot be done judiciously unless it is done withpractice.

Esther Ventura-Medina

Take ownership of your project and make sure you have a clear research question.

Pieter de Vries

Go for the nuts that are self-explanatory!

Patric Wallin

Look beyond the Engineering Education Research literature and engage with literature from otherdisciplinary contexts, also look into education philosophy, critical pedagogy and theory of higher education.

Bill Williams

Identify one or two scholars whose work really speaks to you. Speak to them.

2.3 Group Notes

The six groups wrote collaborative notes during their time together, in total 3 hours. AGoogle Document was prepared with space for each group. The downloaded versionof the notes is 15 pages long in total, and it is outside the scope of this report to analyse this comprehensive material. However, the groups seem to have followed the suggestions in the instructions, as the notes contain generous amounts of:

- Interesting things that resonate with us
- Ideas and strengths that we have identified
- Problems, questions or issues we have identified
- Tips, things to do, read or think about

2.3 Take-home Messages

Each participant was asked to formulate a short nugget of wisdom during the day, asa take-home message from the DS. In the final plenary session, each participant hadone minute to present their take-home message. Below the messages of doctoral students and seniors are mixed and appear in no particular order.

Kate Bellingham: The dichotomy I am dealing with - to help universities improve their recruitment ofwomen while using a novel theoretical approach of a dating model - might be solved if I'm less ambitious: Keeping it smaller scale allows me to hear some individual stories, see if the model is useful, then hand that on for further research projects. I shouldn't aim to solve it all myself!

Mariana Velho: Do my research in collaboration with secondary schools in Portugal in order to get abetter and more diverse sample.

Nargiza Mikhridinova: I will check other methodologies and reduce my PhD project ambitions inorder to keep it feasible. Critical incident technique recommended sounds very promising to be applied.

Greet Langie: The EER-community is getting better interconnected, and this despite the fantastic factthat we are also getting bigger.

Bill Williams: I’m reminded once again of the value of finding connections between ideas, people indifferent contexts.

Melissa Marinelli: The power of diverse perspectives and backgrounds in discussing issues. The common threads that run through diverse projects. An observation - the many different backgrounds ofengineering education PhD students - psychology, philosophy, education science, engineering, computer science, industry experience… very different to my local context in Australia.

Marten Westerhof: be explicit

Vivian van der Werf: In an interview, each word of a sentence can be a data point, whereas in a questionnaire, only each question is a data point (mentioned by Patric). For my own research I will consider using additional individual interviews besides focus groups for interviewing teachers on developed curricula materials (tip by Esther). Reason: focus groups might not always provide additional information as people tend to agree on everything. Individual interviews may show people'sactual opinions better than in a group.

Max Vincent Uzulis: It is always good to discuss one's research with others to reflect upon our own methods and approaches. I learned a great lot about my own research and the interesting projects ofthe other group members.

Esther Ventura Medina: Nice to see Qualitative approaches becoming more prominent - excitingtimes ahead! Having said this, be mindful that your methodology should help in answering your research question(s).

Patric Wallin: It is important to find a balance between researching stuff within the education system and critically questioning that very system. This balance might be different depending on your positionand context, but reflecting on it and being aware of it is important. Never forget that systems can be changed and if you want work towards changing them.

Gitte van Helden: Even (or maybe especially) when your ideas are not yet fully clear and well-articulated, talking about it with others can be very helpful.

Elizabeth Rees Chin: Great to have advice, insights and perspectives on my project - adding in observations to interviews will also be helpful. Lovely to hear those with diverse/non-traditional backgrounds. Also super interesting to hear about everyone else’s projects and to share our experiences. A great event.

Diana Bairaktarova: I love the level of engagement in a small group gathering and I am fascinatedwith the quality of work of the doctoral students and their investment in engineering education research. Kudos to the organizers and to all Doctoral students from whom I learned so much todayand I am sure I will continue learning about the future of engineering education.

Mike Murphy: I am astonished with the variety of EER topics presented today. In addition to the variety, the practical nature of them is very encouraging.

Urša Benedičič: Make it simple and be critical. Be clear on what you will and what you will NOT do.

Mieke Cannaerts: Make sure you know why you make certain choices and if they contribute to answering your question, but also don't lose sight of what you are passionate about.

Panagiotis Pantzos: Critique of method (SDT)

Kate Roach: So lovely to hear the enthusiasm and to see the talent in the room. My main message iskeep it simple and stick with what you love.

Roland Tormey: Stop and think about what you are doing - don’t do something unless you can defend it. And make sure you can defend what you have done.

Melanie Herzig: Different sessions, experiences, perspectives, and methods shape my research

Sam Snyder: Practicing the discussion of my dissertation has helped me reaffirm my and critique mywork, and getting detailed feedback from other engineering educators has been indispensable

Wei Siqing: Limit or narrow down my research scope further to be easier to be answered and understood for others simply.

Anette Kolmos: Open education opens door for new era of education.

Styliani Malkogeorgou: Discussing my work with other PhD students and experienced researchersgave me a new perspective, made me think and reevaluate my research and approach.

Inês Direito: It has been wonderful to meet old and new colleagues who are so passionate about engineering education and research. We can learn so much from each other, listen to different perspectives - especially in informal contexts. To the PhD students: network as much as you can (andhave fun!)

Gouri Vinod: I learned about the importance of being clear about the definitions I hope to use in my thesis- an issue I mentioned I wanted to tackle during SEFI. I also learned that it is better for my PhD- level research to be more focused than it is for it to be broad, so I have thought about how I can narrow down my proposed research plans so it is more realistic to complete during the next few years.Being able to network with those I hope to work with during the data collection stage of my project hasalso been extremely helpful- in addition to hearing about everyone’s research interests :)

Luke Dokter: Fantastic diversity of very interesting people here that I am looking forward to getting to know better. It is good to be ambitious, but don’t be too ambitious! Focus on completing the doctorate rather than trying to investigate and solve all of the problems that I have identified in my work.

Acceptance of my doctorate within a more traditional engineering context could be a challenge, but being aware of my audience is important. Tailor the message in order to reach your audience. I have aunique opportunity to develop something of importance for the Norwegian Armed Forces and am lucky to have a position that allows me access to employers and former students, something that is almostimpossible at other Universities.

Ann-Kristin Winkens: Bill advised this morning, “Identify one or two scholars whose work really speaks to you. Speak to them.“ This is the most important message for me today, don’t be shy, talk topeople, ask questions – you are not alone. Everyone is faced with some kind of challenges.

Xiangyun Du: It is exciting to learn about the growing scope of EER, with so many new topics and stronger passion than ever before :-). This gives space for discussions on what a EER PhD project may mean. In particular, how to get a PhD project started? What questions to ask and what scope andambition can be feasible? This can be quite different if it is a monograph targeted or article-binded theses. It is also quite interesting to discuss with PhD candidates about their ambitions, goals and plans, how much insights they can go into research and how much change they can make in the real world.

Pieter de Vries: Very pleased to see so many EE enthusiasts. Even when most want to change theworld, it is promising. The diversity is challenging though and the tendency to caress the niche approach certainly has no future. More motivated students is part of the solution.

Shannon Chance: Use this face-to-face conference to build and strengthen your networks so you'll be able to collaborate more effectively online when you're back home. Find people who have interestssimilar to you or who you think can shed light on specific questions you have, and try to stay connected with them. We're a very warm and welcoming community. Don't be afraid to approach people at SEFI and in the EER community to ask questions and suggest topics to discuss.

Xiaoling Zhang: Limit the research scope, do more concrete work. Read more methodologies and theories. Start small and don't aim to save the "world" within a PhD project. There is a whole life formore work to be done.

Dimitri Eckert: 1. Read more about Methodology, Theories and Methods to get a more rigorous planfor my research. 2. See what tools already exist that I can use.

Abhijith Venugopal: 1. Importance of 'scope' 2. addressed the dilemma in methods 3. Narrow down the concepts to focus, and to complete the degree, 4. Need to have a look into the framework (evolving one), 5. Insights on recommended readings and projects, General: PhD is not the ultimate aim in life, students should narrow down and stick to the specific topics. These interactions are very helpful to ensure that the researcher moving in the right direction. First time seeing these many peopleworking in EE research!

Corrinne Shaw: I was struck by the nature of the research problems that PhD students have set themselves to solve, often as a consequence of their own experience in education or their observations of how others learn and experience education. Finding out how the problem came aboutand what contributes to its continuation can be enough for a research study. These are complex problems and the role of the PhD is to solve the research problem and perhaps not the practical problems that were initially observed.

John Mitchell: The range of topics being covered by the PhD students represented is inspiring. The questioning of the level of progress and the need for direction on methodologies and theoretical lens reminds me of the troubled times of my own PhD and just underlines how necessary sessions such asthis are and how much more we could be doing as a community to support our early career researchers.

Kristina Edström: The goal of a PhD education is to become an independent researcher. During yourPhD, take the opportunity to develop into a whole scholar. In addition to your thesis, learn to teach, give seminars and workshops, organise stuff, develop your networks, lead projects, apply for funding. And learn how to review manuscripts – see me after class!

Jonte Bernhard: I am glad that so many could participate in the symposium today and I am very happy we are back to face-to-face meetings again. I hope the meeting has inspired you and you have learned something. You can always learn something by extending your network and you get new perspectives from visiting other institutes and communicating with people outside your own close circle. Never stop to keep your mind open!

3 REFLECTIONS AND WAY AHEAD

The SEFI 2022 Doctoral Symposium was successfully carried out in a face-to-faceformat again. 20 doctoral students and 17 seniors worked together in shaping the future of the engineering education research community. Our impression is that participants were very pleased with meeting face-to-face again and making use of the advantages and affordances of such a meeting format.

On the other hand, we have successfully arranged online DS meetings in 2020 and 2021, and these experiences certainly showed that a remote format was feasible.
However, there are some trade-offs. One great advantage with the online format was that participants who, for various reasons, would not be able to travel to a conference could still attend. The downside is that quite many participants found a full day online quite wearying, and very much so for those located outside European time zones.
For those who are anyway travelling to the conference, a day of face-to-face meeting is less tiring, even energizing, and may also be more rewarding.

We believe that face-to-face and online meetings could complement each other in afavourable way. One way forward could be to use the online format to arrange meetings and webinars *between* an annual, face-to-face, SEFI conference and DS. As mentioned in the introduction, many doctoral students and senior researchers in engineering education in Europe work in small groups. The online format could enable shorter, more frequent meetings, in between face-to-face conferences and seminars, that could further strengthen the research community in engineering education research. Such initiatives are also underway in co-operation with SEFI special interest group for Engineering Education Research and different engineeringeducation research centres.

4 ACKNOWLEDGEMENTS

The authors wish to thank every single participant in the Doctoral Symposium over the years, doctoral students as well as seniors. The success of the activity is a directresult of your engagement and enthusiasm. We thank the organisers of the SEFI Annual Conferences for great hospitality during the pre-conference day. We thank SEFI for being entrusted with the stimulating task of organising this activity. Finally, we gratefully acknowledge how SEFI supports the EER field in many ways, among them the Doctoral Symposium.

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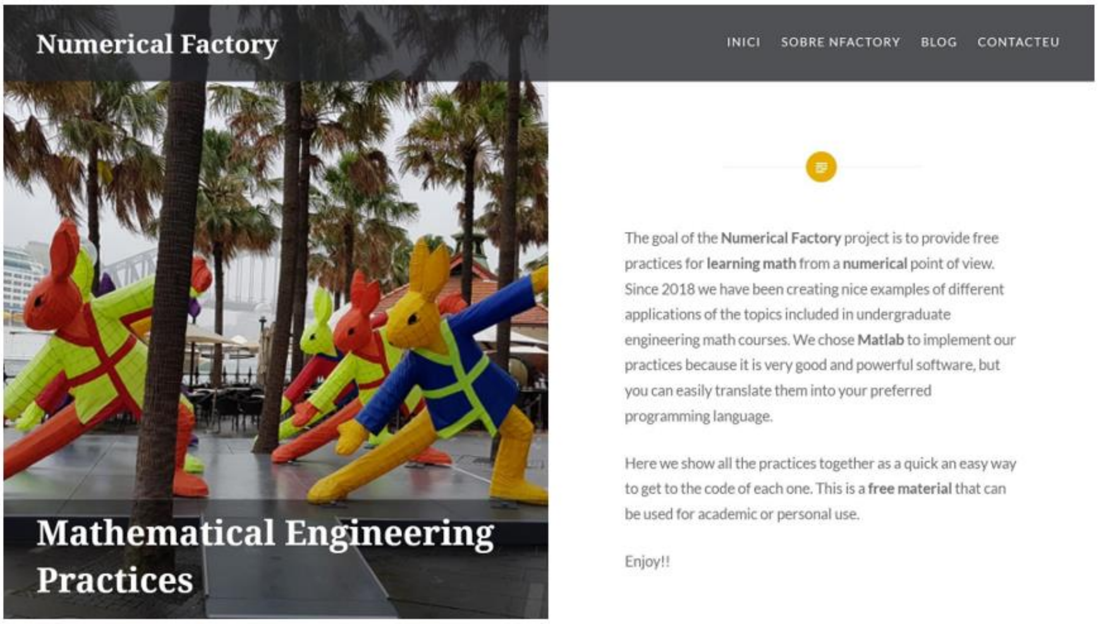

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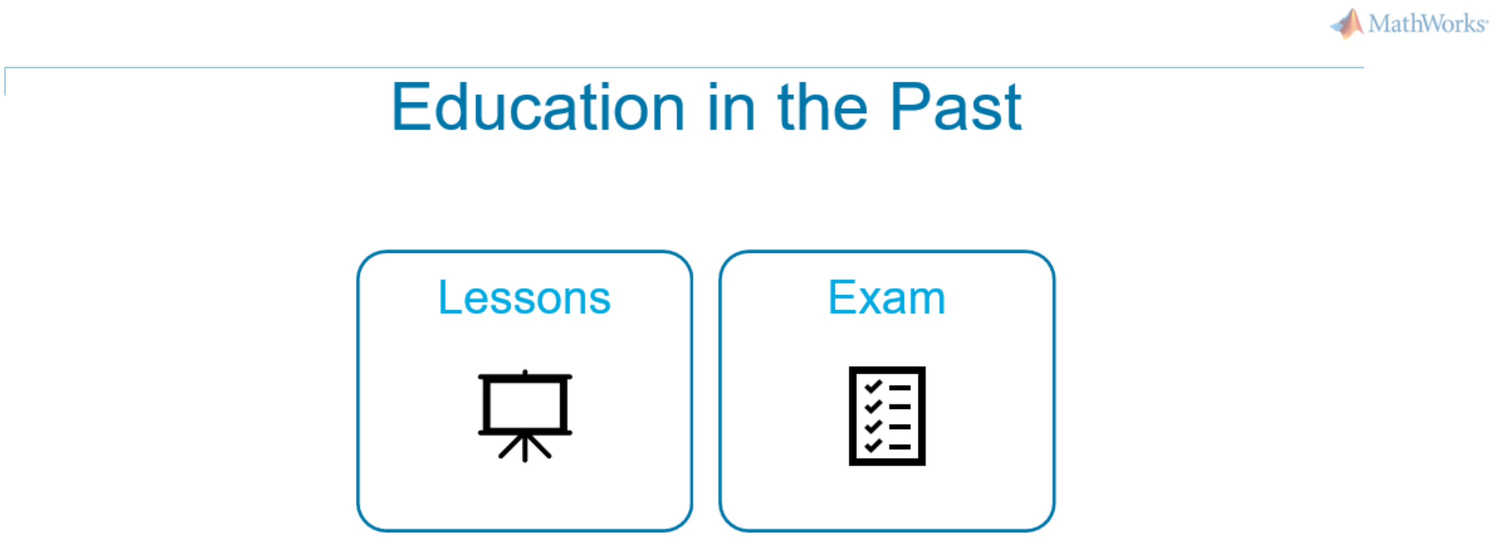
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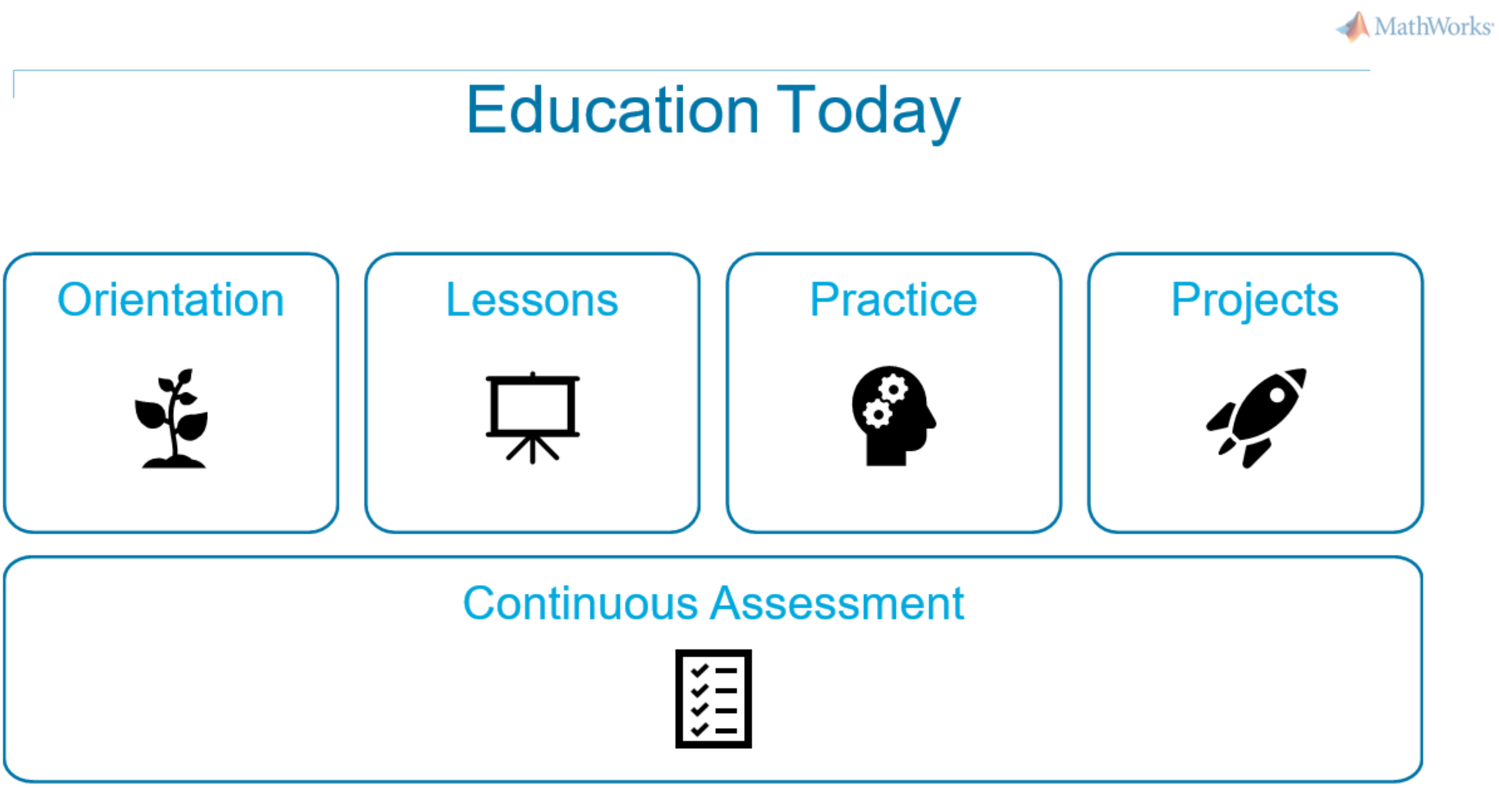
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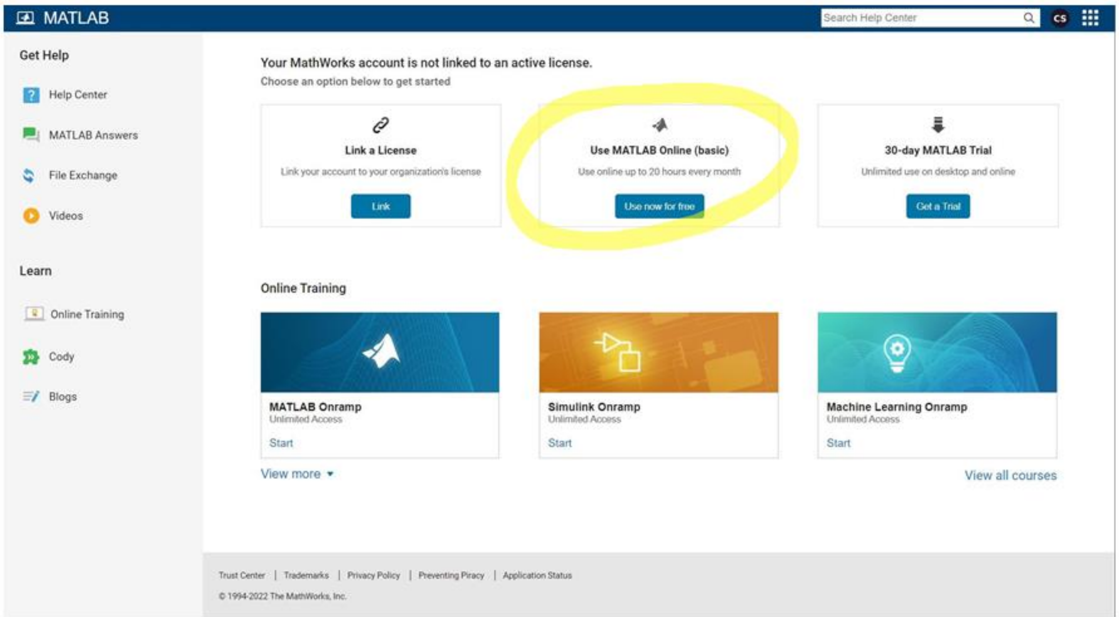

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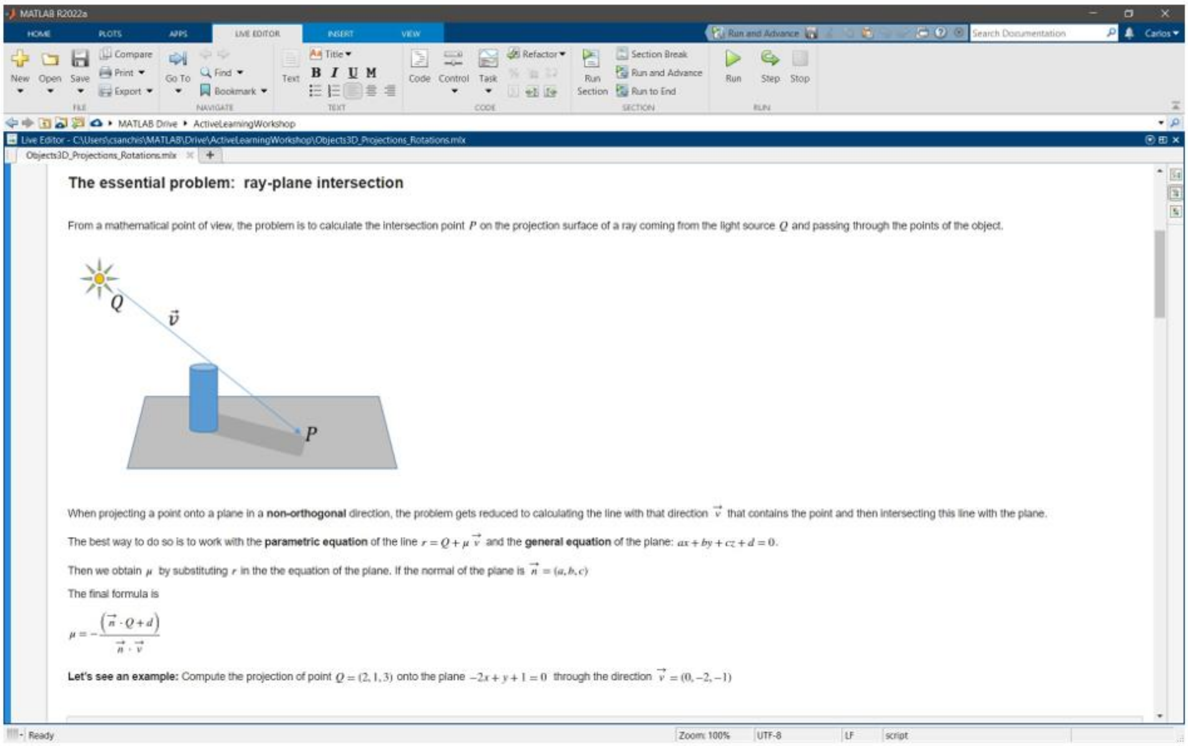

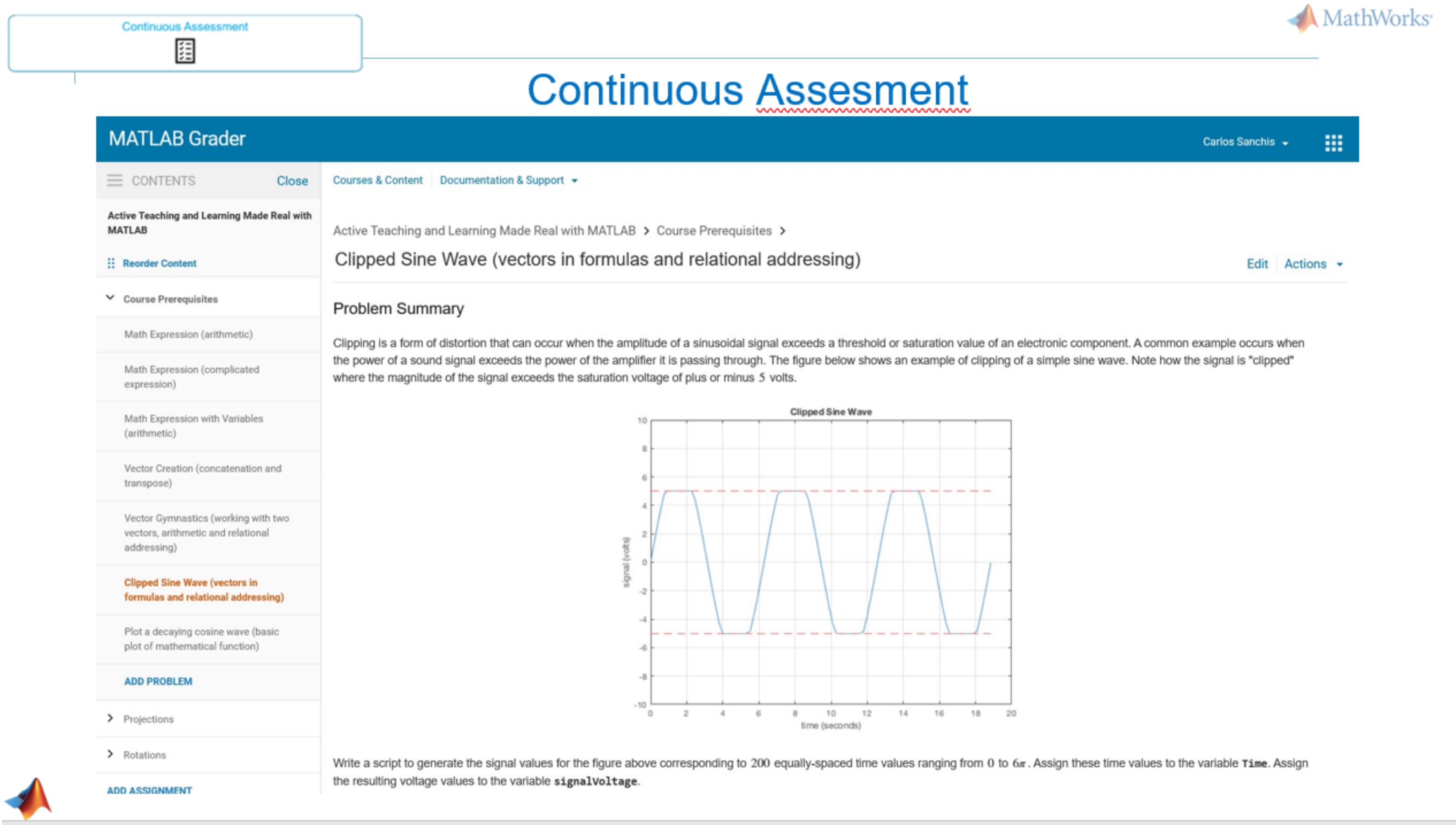
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Clipped Sine Wave (vectors in formulas and relational addressing)
Plot a decaying cosine wave (basic plot of mathematical function)
ADD PROBLEM
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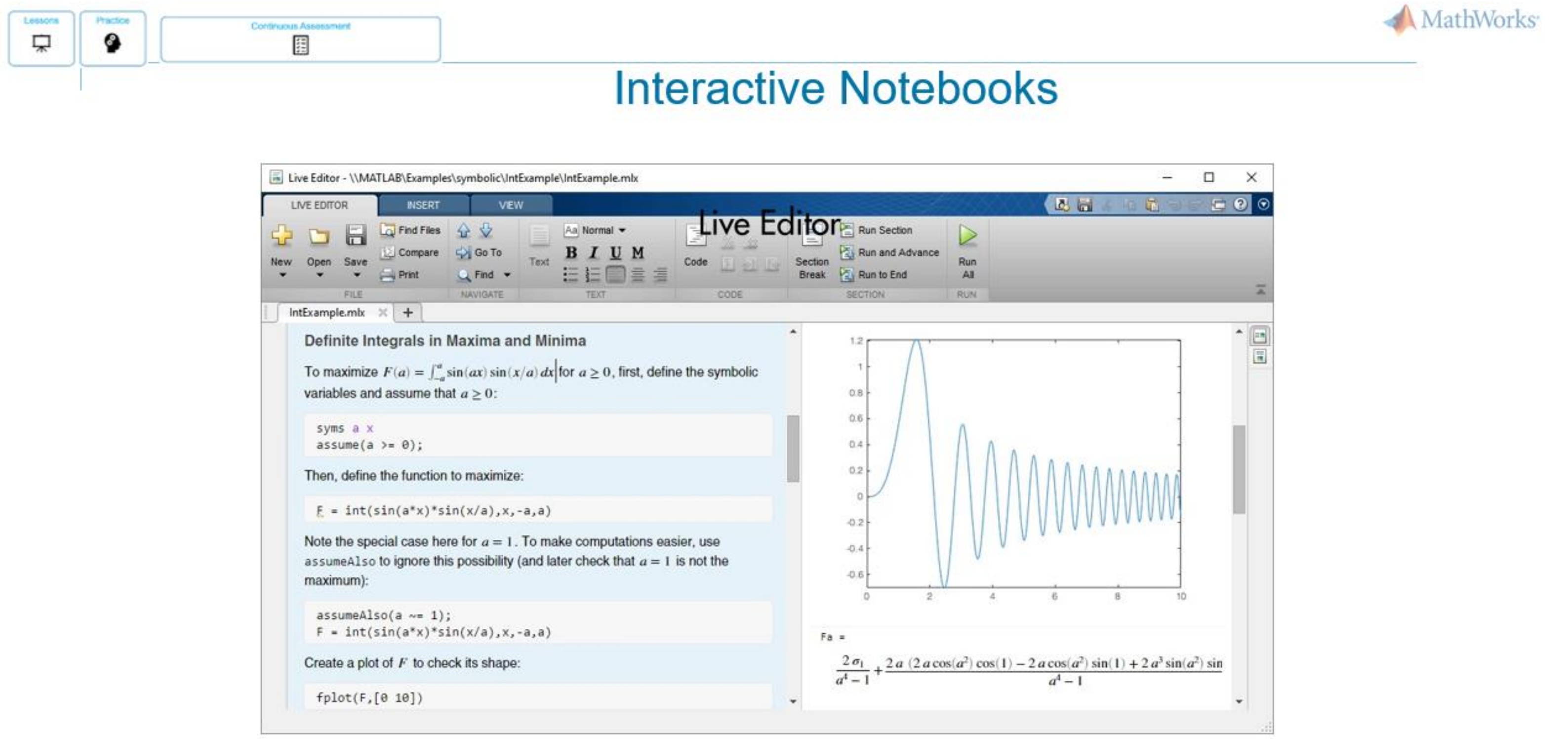
Active Teaching and Learning Made Real with MATLAB > Course Prerequisites >
Clipped Sine Wave (vectors in formulas and relational addressing)
Edit
Actions
Problem Summary
Clipping is a form of distortion that can occur when the amplitude of a sinusoidal signal exceeds a threshold or saturation value of an electronic component. A common example occurs when the power of a sound signal exceeds the power of the amplifier it is passing through. The figure below shows an example of clipping of a simple sine wave. Note how the signal is "clipped" where the magnitude of the signal exceeds the saturation voltage of plus or minus 5 volts.
Clipped Sine Wave
signal (volts)
time (seconds)
Write a script to generate the signal values for the figure above corresponding to 200 equally-spaced time values ranging from 0 to 6π. Assign these time values to the variable Time. Assign the resulting voltage values to the variable signalVoltage.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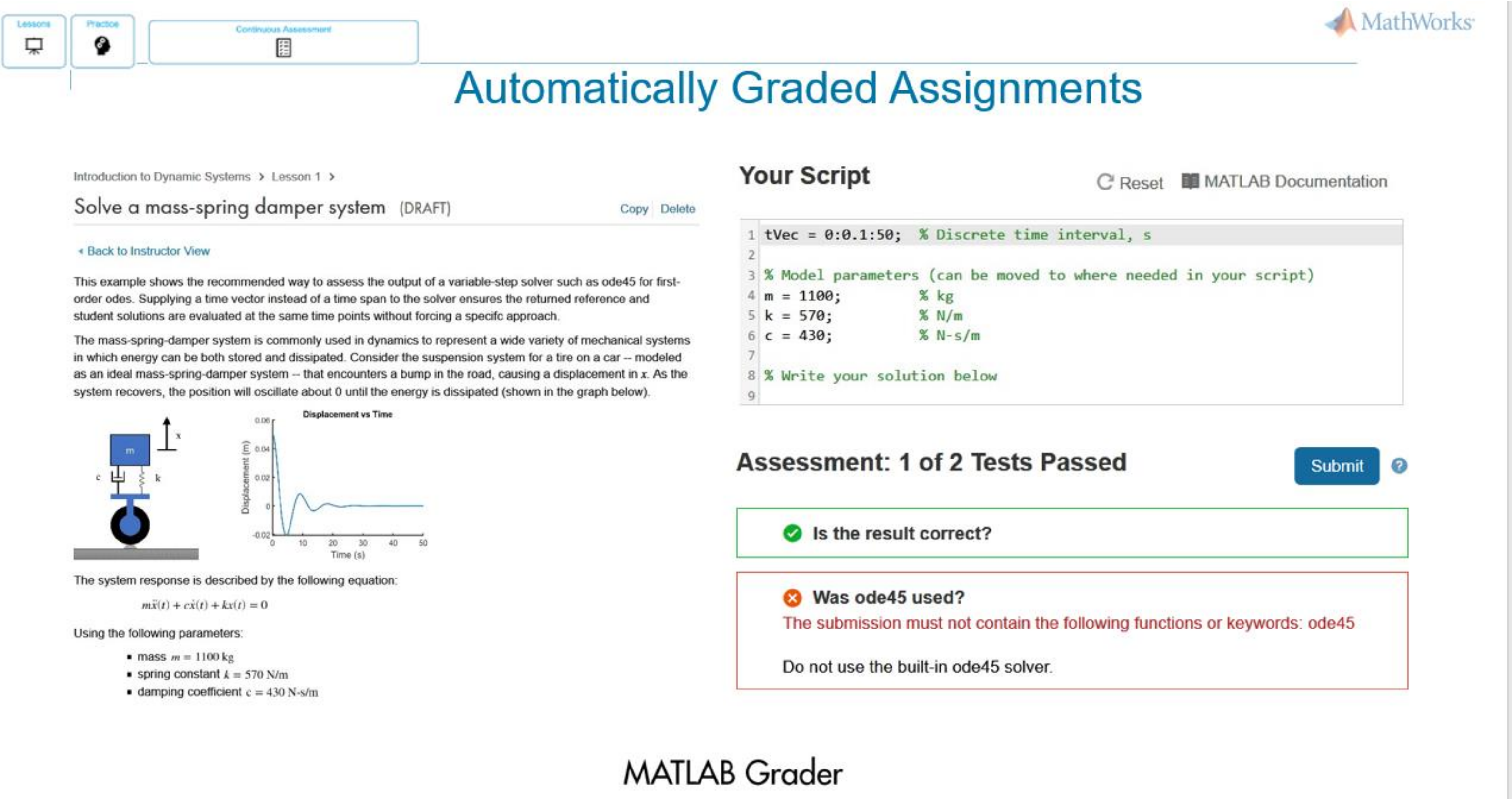
Normal
Code
Section Break
Run Section
Run and Advance
Run to End
Run All
FILE
NAVIGATE
TEXT
CODE
SECTION
RUN
IntExample.mlx
Definite Integrals in Maxima and Minima
To maximize F(a) = ∫ sin(ax) sin(x/a) dx for a ≥ 0, first, define the symbolic variables and assume that a ≥ 0:
syms a x
assume(a >= 0);
Then, define the function to maximize:
F = int(sin(a*x)*sin(x/a),x,-a,a)
Note the special case here for a = 1. To make computations easier, use assumeAlso to ignore this possibility (and later check that a = 1 is not the maximum):
assumeAlso(a ~= 1);
F = int(sin(a*x)*sin(x/a),x,-a,a)
Create a plot of F to check its shape:
fplot(F,[0 10])
Fa =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Introduction to Dynamic Systems > Lesson 1 >
Solve a mass-spring damper system (DRAFT)
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This example shows the recommended way to assess the output of a variable-step solver such as ode45 for first-order odes. Supplying a time vector instead of a time span to the solver ensures the returned reference and student solutions are evaluated at the same time points without forcing a specifc approach.
The mass-spring-damper system is commonly used in dynamics to represent a wide variety of mechanical systems in which energy can be both stored and dissipated. Consider the suspension system for a tire on a car -- modeled as an ideal mass-spring-damper system -- that encounters a bump in the road, causing a displacement in x. As the system recovers, the position will oscillate about 0 until the energy is dissipated (shown in the graph below).
Displacement vs Time
Displacement (m)
Time (s)
The system response is described by the following equation:
$m\ddot{x}(t) + c\dot{x}(t) + kx(t) = 0$
Using the following parameters:
mass $m = 1100$ kg
spring constant $k = 570$ N/m
damping coefficient $c = 430$ N-s/m
Your Script
Reset
MATLAB Documentation
tVec = 0:0.1:50; % Discrete time interval, s
% Model parameters (can be moved to where needed in your script)
m = 1100;   % kg
k = 570;   % N/m
c = 430;   % N-s/m
% Write your solution below
Assessment: 1 of 2 Tests Passed
Submit
Is the result correct?
Was ode45 used?
The submission must not contain the following functions or keywords: ode45
Do not use the built-in ode45 solver.
MATLAB Grader


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SIEMENS SKILLS FOR SUSTAINABILITY

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ABSTRACT:

Since the start of the industrial revolution, more than two centuries ago, the life of mass-produced goods our society has come to rely can be traced as a straight line from raw material, through manufacturing and usage, to end in a landfill. However, considering the climate crisis we face today, that is no longer a viable business model.

Rather than the line from raw material to landfill that exists now, when a product in a circular economy reaches end of life it is broken down, reused, retooled, and recycled as completely as possible. To truly realize the potential of a circular economy, the principles of sustainability must be ingrained in a design from the very conception of a product. While a circular economy does offer benefits in the areas of cost and sustainability, it does present new challenges when transitioning from our current economic model.

As part of an ongoing series of industry-faculty dialogues, we're excited to be holding this roundtable during SEFI 2022 to discuss: **'What mindset, skills and tools do students need to learn, and how, to bring and keep the circular economy in the workplace?'**. Through industry insights and peer exchange, we aim to facilitate the exchange of knowledge and ideas to help embed this topic within engineering curriculums.

Siemens skills for sustainability network

Formed in 2022, the Siemens Skills for Sustainability Network has the ambition to support educators in our common goal of enabling the global workforce of the future to develop innovative sustainable solutions that drive the circular economy – a pivotal discipline to deliver the SDG commitments.

This October, in two online roundtable discussions and one in-person session held at SEFI, we asked industry and faculty from around the world to discuss the mindset, skills, and tools that students need to drive circularity in industry. Together we explored the role of the faculty, students, and industry in creating a more sustainable and circular mindset.

The full report from this roundtable series is available here: https://blogs.sw.siemens.com/academic/skills-for-sustainability-network-october-roundtables/

What mindset, what skills, and what tools do students need to learn, and how, about the circular economy?

Participants came up with many ways that students can learn and practice circularity in their engineering programs. Several spoke about the mindset shift that needs to happen not only for students but also for university faculty and industry, as well. A major point was the importance of systems thinking – students need to be taught to look at the entire supply chain when making decisions about sustainability and circularity. Building solutions that use locally available resources and suppliers was another key theme, and multiple participants suggested project-based learning as a key to consolidating theoretical knowledge into actionable skill.

As well as these themes for addressing circularity in the classroom, participants returned several times to the importance of getting students involved in both existing industry and entrepreneurial activities. The consensus was clear that there’s no single road to sustainability and imbuing students with the skills, knowledge and mindset to change the way businesses operate is an all-hands effort.

Values and Mindset Changes

Participants discussed multiple ways of adjusting student mindsets. One major point was that sustainability mustn’t be ‘tacked on’ to all that we currently teach, rather, there needs to be a radical shift in how we teach problem solving. Students need not only to be taught a new approach to solving problems but also encouraged to help reshape the very values fundamental to the practice of engineering, so that they can champion sustainability in their careers.

“So, for manufacturers who've always received revenue and received value when they've changed ownership of a good, that model is not a sustainability-driven model. It's a take, make, dispose driven model. And if that's what you're optimized on, that's what it's going to drive you to.”

Eryn Devola, VP of Sustainability, Siemens DISW

Participants also felt very strongly that industry must change how they assign and derive value vis-à-vis sustainability and circularity. Companies often say they value sustainability in their messaging but ultimately select their materials and manufacturing practices without regard for the true cost to society or any negative, albeit unintended, externalities. Companies and markets need new ways to measure cost and value in order to get serious about sustainability.

Systems Thinking

Participants noted often that engineering has traditionally been a highly siloed practice and students often don’t understand the many steps that a product might go through before reaching a consumer, and the many factors that contribute to the sustainability or circularity of the final product. Students must be trained to think about all the resources and inputs required to design a product as well as the possibilities for the end of the product lifecycle. Environmental impacts in sourcing, testing, manufacturing, de- and re-purposing, as well as the social impacts like working conditions and living wages must be fundamental to product, process and system design. Students need to understand how to look at the ‘big picture’ and consider every step before and after a product is designed and manufactured.

"The knowledge of the materials from which products are made as well as the manufacturing processes they undergo before becoming products will greatly assist the students in understanding circularity and sustainability. It is necessary to change their mindset against the dangers of buy, use and dispose."

Mohammed Dauda, Professor of Mechanical Engineering, University of Maiduguri, Nigeria

Sustainability and Systems-Based Projects

Systems-based thinking should be introduced to students through real-world projects. Ideally, participants agreed that students should see these concepts as early as possible. First-year students should be immersed in projects that directly address circularity and sustainability, while project work done throughout the curriculum must incorporate systems thinking and sustainability as fundamentally as physics and mathematics. If students are to really integrate the importance of sustainability, it should be taught early and continually.

"With first-year engineering students, we try and present engineering as an endeavor that occurs within social contexts. Our approach is to introduce them to the concepts of production, of sustainable production, of their relationship with the environment."
Corrinne Shaw, Senior Lecturer, University of Cape Town, South Africa

Students as Drivers of Change

Students also need to gain the mindset needed to become advocates for sustainability. This can be through small projects using local materials, or through creating entirely new businesses. Either way, students are the future drivers of change. Part of the mindset students need to create a sustainable and circular economy is the knowledge that they can lead change themselves.

"So, what is the economic answer? Entrepreneurship. We need new businesses; we need new companies. And this is what we could teach our students, to say, 'Okay, I've got a new idea which is sustainable.' Well then, be a founder and make your own business out of it."

Jan Robert Ziebart, Professor of Applied Sciences, FH Bielefeld, Germany

Students will become business leaders and start-up founders and can take what they learn about sustainability into those companies. Sustainable companies will drive the future and current students will be the ones leading the way in creating them.

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