Jaakma, Kaur; Kiviluoma, Panu

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Nine Years Of Systematic CAD Course Development: What Did We Learn?

Kaur JAAKMA
Aalto University, Finland, kaur.jaakma@aalto.fi

Panu KIVILUOMA
Aalto University, Finland, panu.kiviluoma@aalto.fi

NINE YEARS OF SYSTEMATIC CAD COURSE DEVELOPMENT: WHAT DID WE LEARN?

Kaur Jaakma [1]
Aalto University, School of Engineering, Department of Mechanical Engineering
Espoo, Finland

Panu Kiviluoma
Aalto University, School of Engineering, Department of Mechanical Engineering
Espoo, Finland

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ABSTRACT

Computer-Aided Design (CAD) plays a vital role in the curriculums of mechanical engineering degree programs, empowering students to conceptualize and visualize their designs, thus enhancing their abilities as engineers. This abstract presents the implementation of a multi-CAD course conducted between 2014 and 2022, catering to hundreds of students from diverse disciplines, including mechanical and civil engineering. Throughout the course, student feedback was systematically collected to assess learning outcomes and measure the effectiveness of different learning tools and methods.

The course employed a range of tools, including automatically graded quizzes and a dedicated CAD model assessment system, which not only lightened the workload of teaching assistants in terms of assessment but also allowed them to focus on guiding and supporting students. Additionally, surveys conducted at the beginning and mid-term stages provided valuable insights into students' initial proficiency levels and their study patterns during the course.

[1] *Corresponding Author*

Kaur Jaakma

kaur.jaakma@aalto.fi

Significantly, the course successfully transitioned to fully online teaching during the period of remote instruction from 2020 to 2022. Lessons learned during this time were integrated into the regular practicalities of CAD course teaching, ensuring continued effectiveness and adaptability.

Improvements in student performance and feedback, observed during the implementation of the multi-CAD course, demonstrate the impact and success of the teaching methods employed.

1 INTRODUCTION

Computer-aided Design (CAD) has become a fundamental tool for mechanical engineers, resulting in the inclusion of CAD courses in university curricula worldwide. In certain countries, the prescribed amount of CAD instruction is even specified at the national level [1].

Traditionally, CAD education has focused on mastering software tools, and assessment has primarily relied on computer exercises or project work. Lectures are often provided alongside these courses to support students in completing the exercises and developing a comprehensive understanding of CAD model creation and its applications in areas such as simulations and manufacturing.

The primary objective of CAD education is to equip students with the necessary tools to support their future studies and professional endeavors. CAD courses are typically conducted during undergraduate studies, with the expectation that students pursuing master's level studies already possess these skills. The CAD modeling software commonly used is commercially available (such as Creo, Inventor, Solidworks, Solid Edge, NX), designed for professional use, which poses a challenge for students to learn. Although there have been attempts to develop CAD tools specifically for educational purposes[2], commercial tools remain prevalent due to their relevance in summer work, internships, and post-graduation employment.

Due to the critical nature of CAD knowledge for early-stage mechanical and civil engineers, the enrollment in basic CAD courses can be substantial, reaching as high as 400 students. This presents challenges in terms of available study spaces and the assessment process. Several studies have explored automating the grading process for 3D CAD models [3,4] aiming to expedite assessment and provide students with timely feedback on their learning progress.

This study outlines the structure of a CAD course, its evolution over the years, the feedback received, and how systematically collected student feedback has been utilized to enhance the course. To accommodate the large number of enrolled students, this course was progressively developed with a wide array of online tools, alleviating the burden of assessment for instructors and enabling a comprehensive overview of student progress. These tools and methods played a pivotal role in addressing the challenges posed by the COVID-19 restrictions from 2020 to 2022, facilitating a successful transition of the course to an online format. Subsequently, as restrictions eased, the course was gradually reintroduced in face-to-face teaching.

Additionally, this paper presents a new CAD course tailored specifically to mechanical engineering students, built upon the learning outcomes derived from the nine years of course development

2 STRUCTURE OF THE COURSE

The *Computer-aided Tools in Engineering* course is mandatory for three different majors offered by the School of Engineering: Mechanical and Civil Engineering, Energy and Environmental Engineering, and Built Environment. In addition to covering CAD tools for mechanical engineering, this course also introduces CAD tools specific to civil engineering and Geographic Information System (GIS) tools used in land surveying. The course attracts an average of approximately 350 students annually.

The course aims to achieve the following learning outcomes:

- Familiarize students with the basics of computer-aided tools, enabling them to implement these tools in their respective fields and evaluate their suitability for various subjects.
- Develop students' understanding of the characteristics and limitations of computer-aided modelling, as well as the practical methods of applying these tools in industrial and research contexts.

Spanning a duration of 14 weeks, equivalent to 5 ECTS credits, the course is divided into two seven-week periods. It incorporates weekly lectures covering different topics and weekly computer exercises conducted in computer labs. The course grading is based on a pass/fail system where 80% completion of each exercise is required. During the exercise sessions, students submit their completed computer exercises by demonstrating their models to teaching assistants, who then assess their work. Feedback from students is collected through an end-of-course survey, which gathers input on their overall satisfaction with the course grade, teaching organization, workload, and perceived benefits from the knowledge gained.

By adopting this structure and assessment approach, the course provides students with practical hands-on experience and allows them to apply their skills under the guidance of teaching assistants. Furthermore, the feedback survey serves as a valuable tool for continuous improvement and refinement of the course content and delivery

3 NINE YEARS OF COURSE DEVELOPMENT

This chapter highlights recent changes in the course syllabus, focusing on structural and tool-related modifications. The course has been part of the curriculum since 2014. *Table* ***1*** presents numerical data from the course feedback survey, starting from 2015. The feedback survey used a grading scale from 1 (fair) to 5 (excellent) for categories such as General Grade, Teaching Methods, and Usefulness. The Workload category had a scale of 1 (less work), 3 (expected amount), and 5 (too much work). The data from 2014 was excluded due to changes in the feedback survey form and scales, making it incomparable.

These changes aim to improve the course's learning experience and align with evolving educational practices. The feedback survey data provides insights into the effectiveness of these modifications, guiding further course development and refinement.

Table 1. Numerical data from yearly feedback surveys

Year	Number of respondents	General Grade	Teaching methods	Workload	Usefulness
2015	82	3,49	3,63	3,54	4,34
2016	69	3,87	3,96	3,42	4,66
2017	147	3,90	3,95	3,35	4,66
2018	107	3,94	4,08	3,52	4,64
2019	118	3,97	4,16	3,63	4,64
2020	120	3,83	3,81	3,54	4,59
2021	149	4,11	4,14	3,39	4,62
2022	122	3,49	3,89	3,39	4,50

3.1 Initial course (2014)

The initial course structure, depicted in *Fig. 1* , comprised a Common module and a choice of two modules from a selection of five. The Common module covered general topics such as data storage techniques and advanced computer model utilization, including learning diaries as part of the assessment.

Students selected one module in each period, participating in lectures and practical computer exercises held in computer labs. The modules introduced various software tools, including Autodesk AutoCAD (2D-CAD), Siemens Solid Edge (3D-CAD), PTC Creo (Mechanical Engineering CAD), Trimble Solutions Tekla (Civil Engineering CAD), and Esrin ArcGIS (Land Survey GIS).

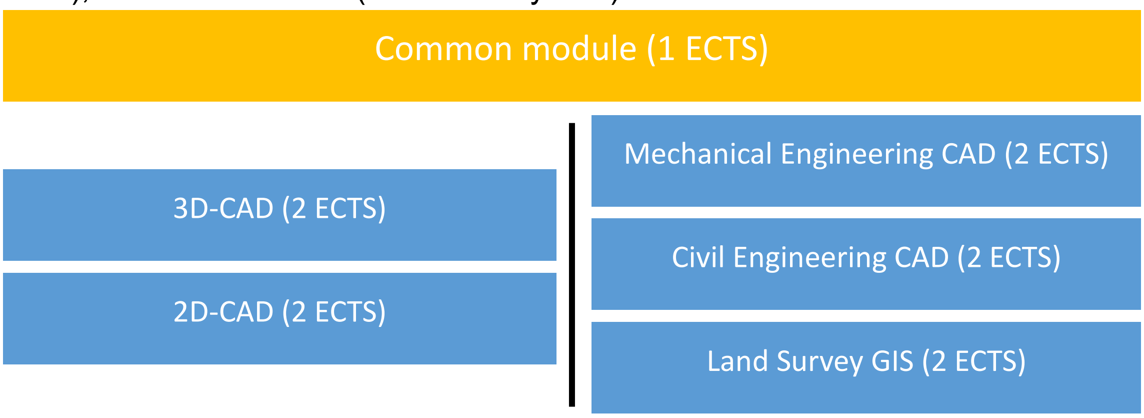

Fig. 1. Structure of the initial course

3.2 First iteration (2015)

In the first iteration of the course in 2015, the course structure was streamlined. The Common module was removed, and clearer module selections were introduced (*Fig. 2*). Now, students participated in two modules focusing on 2D and 3D CAD tools in the first period, followed by one selective module in the second period.

This change aimed to ensure that all students developed essential skills in both 2D and 3D CAD tools, which are crucial in fields like energy technology where layouts are in 2D and components are in 3D. As a result, the learning diaries were removed to allocate more time for practical training and hands-on experience with computer tools. This decision was strongly supported by student feedback.

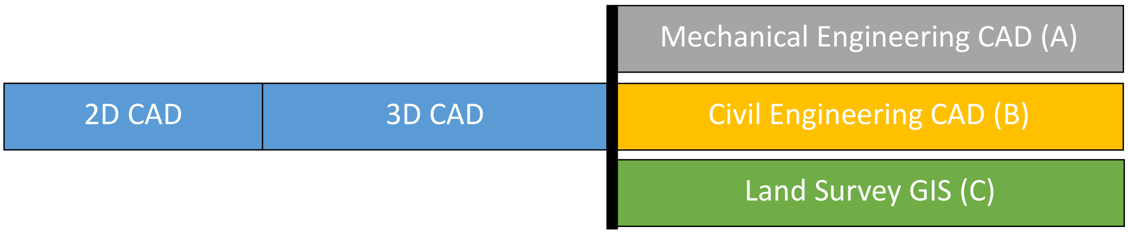

Fig. 2. Streamlined course structure

3.3 Quizzes (2017)

Creating engineering drawings according to standardized rules can pose a significant challenge for students. These drawings are intricate, requiring the memorization and recognition of numerous symbols, the creation of cross-sections and projection views, and the completion of header information fields. To support students in mastering these skills, an Engineering Drawings Symbols quiz was developed within the Moodle platform.

The quiz provided students with an opportunity to practice applying projection rules (as shown in *Fig. 3*) and recognizing various symbols used in engineering drawings. By engaging in interactive quizzes, students could enhance their understanding of these critical elements.

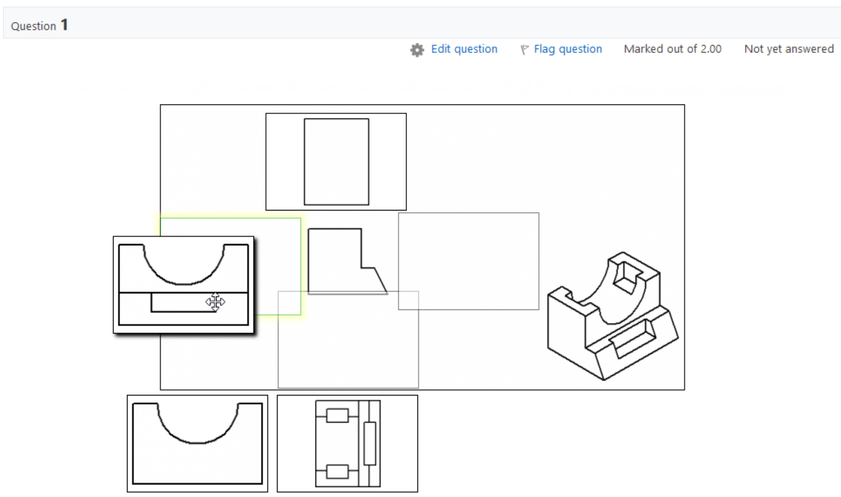

Fig. 3. An example question about projection rules, where a correct projection is needed to drag on its correct location

The quiz was automatically graded, and student had several attempts to get the required 80% right. The questions were randomized and selected from the pool of questions.

3.4 Additional Surveys (2017)

In 2017, two mandatory surveys were introduced: the starting survey and the mid-term survey. These surveys aimed to collect more comprehensive feedback throughout the course, enabling timely adjustments and enhancing the student experience.

The starting survey gathered information on students' backgrounds, computer usage experience, general computer skills, and attitudes towards learning CAD. This data provided valuable insights into their starting point, allowing for tailored course adjustments.

The mid-term survey assessed students' progress in learning CAD and their attitudes towards computer-aided tools. By collecting feedback during the course, instructors gained a better understanding of students' experiences, identifying areas that required additional support or clarification.

3.5 Automatic Assessment Systems (2018)

The assessment of CAD models is a time-consuming task, often with variations among teaching assistants and teachers in the assessment process and criteria. To ensure the accuracy of engineering drawings, it is crucial to verify the correctness of the CAD models before proceeding further.

To streamline the assessment process, two automatic assessment systems were implemented in the course. The first system compared the shape of the model with a reference model (*Fig. 4*), while the second system modified the CAD model's parameters and evaluated its response to changes [3].

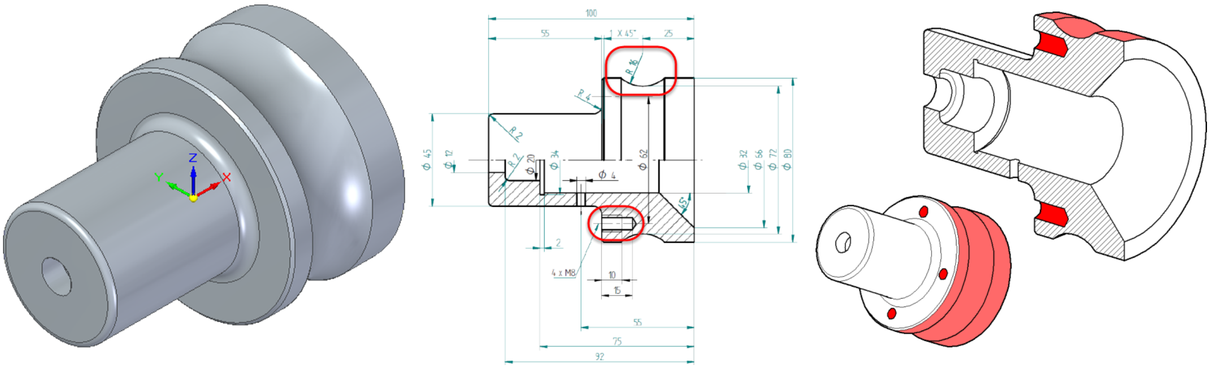

Fig. 4. From left to right: Student's returned model, comparison to reference model and mistakes made, feedback picture from the system highlighting errors in the shape [3]

By incorporating these automated assessment systems, the need for exercise demonstrations during computer sessions was reduced. This provided students with the convenience of submitting their CAD models independently, at their preferred time and location, which was well-received by the students.

3.6 Remote Teaching (2020-2022)

The year 2020 presented significant challenges for universities, with the sudden transition from in-person to remote teaching. Fortunately, the CAD course had existing online materials and tools in place for distributing and grading student work, making the transition surprisingly smooth. An online version of the course had also been developed beforehand [5].

The main challenges arose from installing necessary computer tools on students' personal computers. This was resolved by providing virtual computers with remote access, where all required tools were pre-installed. Exercise sessions were conducted via MS Teams, allowing students to share their screens and seek assistance from course staff.

The shift to remote teaching also impacted the submission of larger exercises. Previously, most modelling tasks were automatically assessed, with only a few more creative assignments demonstrated during computer exercises. However, in the remote setting, students were asked to create demonstration videos showcasing their models and their performance, as creative tasks without predetermined correct answers could not be assessed automatically.

4 CURRENT INPLEMENTATION

Following the renovation of the bachelor program, the previous common CAD course was replaced with two discipline-specific courses: mechanical engineering and civil engineering. The new mechanical engineering CAD course continues to utilize the tools discussed in the previous chapter. With this change, the number of students decreased from over 400 to approximately 250. Since it is now a single-discipline course, only one mechanical engineering CAD software, PTC Creo, is utilized.

This shift in discipline provided an opportunity to enhance the mechanical CAD teaching by incorporating more advanced modelling techniques, including skeleton and surface modelling. Consequently, the grading system was modified from pass/fail to a scale of 0-5 (0 representing fail and 5 representing excellence). This change was requested in the feedback received, as it allows for better recognition of students who invest time and effort in learning the tools and methods, rather than simply aiming to pass the course with minimal effort.

5 DISCUSSION

The CAD course received positive feedback from students since its inception. While there were concerns about the course's relevance to land survey and real estate economics students, the increasing demand for 3D models and evolving industry trends justified the inclusion of CAD skills in their education.

The introduction of quizzes and additional surveys in 2017 had a minor impact on feedback grades. The engineering drawings quiz aided students in completing their tasks, resulting in a slight reduction in perceived workload.

The implementation of automatic assessment in 2018 improved classroom guidance by allowing teaching assistants more time to assist students during computer exercises. However, it increased the workload for responsible teachers as the system identified more modeling mistakes, necessitating additional effort to address and rectify them. Clearer guidelines for automatically assessed models can help mitigate this issue.

The experience of remote teaching in 2020-2022 yielded varying feedback grades. The initial drop in 2020 can be attributed to the sudden transition, while the subsequent increase in 2021 reflects familiarity with remote teaching methods. The decline in feedback grades in 2022 may be attributed to the hybrid nature of teaching, causing confusion among students.

Future development of the course includes creating self-assessment quizzes on key tools and methods and providing in-depth knowledge on advanced CAD modeling techniques.

The learnings from the CAD course development include the need for careful assessment planning, as more precise assessment methods can increase the workload for course staff. Manual checks are still necessary despite the implementation of automatic systems. The previous pass/fail grading system, while ensuring uniform learning, posed challenges in managing missing assignments and caused prolonged course completion. The new course addresses these issues through a wider grading range, recognizing that students may have diverse learning preferences.

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