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Re-imagining engineering education through addressing interdisciplinary course design challenges

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1 INTRODUCTION

There has been a shift in higher education as universities began to re-evaluate their teaching and learning to ensure that students are well-prepared for the global challenges. Especially in the field of engineering, future graduates are expected to address complex issues such as sustainability and consider the societal impact of their solutions (Hadgraft and Kolmos 2020). These expectations require engineers to collaborate effectively with others from different disciplines and backgrounds (Borrego et al. 2013). However, interdisciplinary collaboration and learning from different disciplines can introduce challenges, as team members often have vastly different perspectives, experiences, methodologies, and even different languages (Feng et al. 2023). This dynamic can be especially challenging for students who are accustomed to discipline-specific collaborations.

Universities have responded to this challenge by creating various opportunities for engineering students to engage in interdisciplinary collaboration projects. Internationally recognized frameworks and accreditations, such as the CDIO (Conceive – Design — Implement — Operate) framework (Crawley 2001) and ABET (Accrediting Board for Engineering and Technology 2021), highlight the critical role of multidisciplinary collaboration for engineers.

Despite these initiatives, developing and implementing courses that integrate multiple disciplinary perspectives remains a challenge for educators. Research indicates a need for pedagogical training in course design to help educators navigate the complexities of interdisciplinary projects and ensuring that students receive appropriate support (Kjellberg et al. 2023; Van den Beemt et al. 2020; O'Connell et al. 2023). Therefore, this workshop aims to assist educators in designing multi-, inter, and transdisciplinary courses that leverage available resources and align course design with intended learning outcomes, effectively preparing students for their future roles in addressing societal challenges. We introduce a toolkit that can be utilized by all engineering educators regardless of their expertise. Novice engineering educators will find the toolkit an accessible starting point for designing multi-/inter-/transdisciplinary courses, while seasoned educators can use it to explore new aspects in their course designs.

2 RATIONALE

Interdisciplinary courses can take various forms, such as incorporating students from diverse backgrounds, introducing interdisciplinary problems or projects, or involving non-academic stakeholders to collaborate with students (Feng et al. 2023). Navigating these characteristics of interdisciplinary teaching and learning is not straightforward. Hurdles have been found among teachers collaborating across different departments and schools (Dym et al. 2005; Feng and Hölttä-Otto 2021). Engineering educators often struggle with how to optimally use resources while balancing the need for disciplinary breadth against depth (Holt et al. 2017).

The aim of this workshop is twofold. First, it introduces a toolkit that provides a platform for engineering educators to re-imagine and co-create course designs for various multi-, inter-, and transdisciplinary teaching scenarios. Second, it offers an opportunity to test the course design toolkit presented in Figure 1, gathering insights for its further development to better meet engineering educators' needs. After the

workshop, the participants are equipped to pilot the toolkit in their own course design and to facilitate course design workshops within their respective institutional contexts.

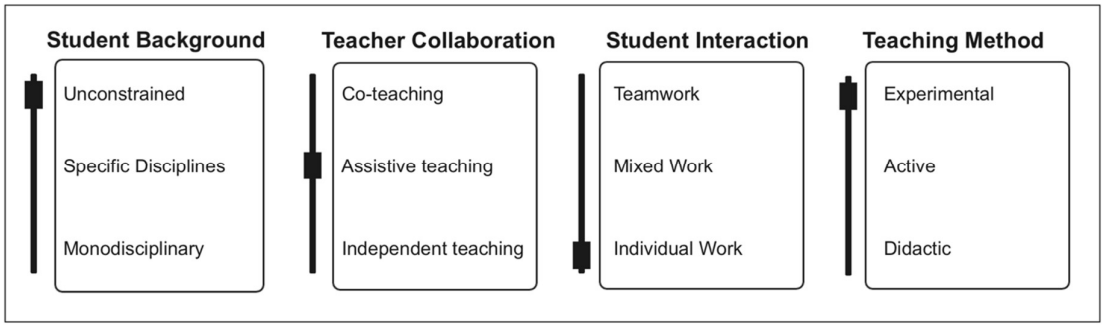

Fig 1. Multi-, inter-, transdisciplinary course design framework. The tool works like a mixing board with a slider; by finetuning the settings, course designers achieve an optimal outcome

In theorizing this workshop, we recognized various relevant terminologies of disciplinary integration, and distinguished between multidisciplinary, interdisciplinary, and transdisciplinary. A multidisciplinary course exposes students to various disciplinary perspectives, offering a broader view. An interdisciplinary course goes a step further by integrating different modes of thinking and methodologies from various disciplines. A transdisciplinary course transcends traditional academic boundaries by involving societal stakeholders in the co-creation of solutions (Lattuca et al. 2017; Klein 2015).

Building on a previously developed course design framework on multi-, inter-, transdisciplinary course design (Feng et al. 2023), the workshop covered four aspects (Figure 1):

- ***Student Background*** refers to the disciplinary backgrounds of the students participating in the course. Students may come from only one discipline, specific sets of disciplines, or any discipline.
- ***Teacher Collaboration*** relates to the mode of working among course teachers. Teacher(s) may teach alone or invite guest lecturers for assistance. Co-teaching represents the highest level of collaboration, including joint course design and teaching efforts throughout the course.
- ***Student Interaction*** pertains to the nature of students' work during the course, ranging from purely individual work, a mix of teamwork and independent tasks, to team-based work throughout the course.
- ***Teaching Method*** refers to method employed by the teacher. Didactic method involves traditional lectures, imparting knowledge to students; active learning method emphasizes experiential learning with, for example, Problem-Based Learning; experimental teaching adopts creative teaching methods, such as writing, drama, debates, role play, etc.

3 METHOD

The workshop was implemented as a course design challenge aimed for engineering educators of all experience levels. It was particularly appealing to those new to or with varying degrees of experience in interdisciplinary teaching who wish to explore the implications of their course designs more deeply. Structured as a 60-minute session, the workshop was comprised of three sections: a 15-minute introduction, a 30-minute group work activity, and a 15-minute conclusion.

First, the workshop provided the participants with an overview of the different aspects of course designs (Figure 1). Then, the participants worked in teams to solve course design challenges. The participant groups were given hand-outs to familiarize themselves with course scenarios and toolkit materials. In the workshop's final part, participants shared their designs and formulated their take-home messages.

The workshop provided several different course design challenges. Three course scenarios were provided, each included three course design challenges. Two to three participants worked together in each group to tackle one challenge. The exemplar course scenarios and challenges are introduced below in Table 1.

When designing their course, participants were asked to consider the four aspects described in the course design framework (Figure 1), which include student background, teacher collaboration, student interaction, and teaching pedagogy. They were also required to justify their course design considering the intended learning outcomes.

Table 1. Engineering course scenarios and design challenges

Course scenarios	**Course design challenges**		
	Multidisciplinary	Interdisciplinary	Transdisciplinary
1. Water governance course	Design a *multidisciplinary* water governance course	Design an *interdisciplinary* water governance course	Design a *transdisciplinary* water governance course
2. Product development course	Design a *multidisciplinary* product development course	Design an *interdisciplinary* product development course	Design a *transdisciplinary* product development course
3. Course on developing sustainable living spaces	Design a *multidisciplinary* course on sustainable living spaces	Design an *interdisciplinary* course on sustainable living spaces	Design a *transdisciplinary* course on sustainable living spaces

4 RESULT SYNTHESIS

There were approximately 25 faculty members who participated in the workshop. The participants collaborated in ten small groups of two or three persons in each. They were asked to tackle a course design challenge with an aim to create a multi-, inter-, or transdisciplinary course. The three given course design scenarios included product development, water governance, and sustainable space design. Once the

ten small groups completed their designs, they merged into larger groups to compare and discuss each other's course designs. There were four larger groups, each comprising 4 to 9 participants, who engaged in these comparisons.

The comparisons between the groups revealed that while participants often adopted similar overall approaches to course design, the details and underlying rationales varied significantly. For example, both the multi- and transdisciplinary course design groups tailored their courses for students with specific disciplinary backgrounds, such as architecture, energy, and civil engineering. However, the transdisciplinary group extended their course to include more diverse students, such as sociology students, bringing a broader and more diverse range of perspectives than in the multidisciplinary group. Moreover, while both multi- and transdisciplinary groups incorporated guest lecturers from various disciplines as part of their assistive teaching strategies, the transdisciplinary groups also involved stakeholders, either as guest lecturers or as to provide real-world challenges for students to address. For interdisciplinary groups, their course designs emphasised more on the disciplinary integration regarding co-teaching and students' teamwork throughout the course.

5 SIGNIFICANCE

The workshop provided a valuable opportunity for engineering educators to reflect and collaborate on interdisciplinary course designs. As the current global challenges often demand interdisciplinary approaches, engineering educators are at the forefront of crafting educational experiences that span across disciplines. This workshop, by focusing on the intricacies of designing courses that accommodate diverse student backgrounds and interdisciplinary content, addressed a critical need within the academic community. It encouraged educators, regardless of their experience level with interdisciplinary teaching, to explore and critically evaluate the implications of their course designs. The importance of peer learning was also highlighted in the wrap-up discussion.

Through a structured exploration of course design aspects and tackling exemplary teaching challenges, participants were equipped with the tools and insights necessary to enhance their pedagogical strategies. This not only enriched the learning experience for students but also contributed to the broader goal of fostering a more integrated, holistic approach to engineering education. Through dialogue and sharing of course design ideas, this workshop can help shape the future of engineering education, making it more responsive to the needs of multidisciplinary students and ultimately, a rapidly evolving world.

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