

CONCEIVING, DESIGNING AND IMPLEMENTING THE MECHANICS TEACHERS SOCIAL CLUB

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ABSTRACT

As part of the Delft University of Technology's (TU Delft) bachelor programmes, mechanics courses are provided across 7 out of its 8 faculties by more than 70 mechanics lecturers. Yet, mechanics is considered a difficult subject to teach, with lecturers reporting that they have limited time and resources to assess and improve their teaching practice. Moreover, these lecturers are seldom connected. The lack of collaboration and exchange between the mechanics lecturers has resulted in limited peer-to-peer support and hindered the development of shared mechanics teaching competence. To tackle these challenges, the PRogramme for Innovation in MECHANics education (PRIMECH) was launched at TU Delft in 2021. In this paper, PRIMECH's solution is discussed: the introduction of the Mechanics Teachers Social Club, an inter-faculty Community of Practice (CoP), built around the shared domain of interest of teaching mechanics and improving students' conceptual understanding. The CoP aims to enhance lecturers' awareness of best teaching practices and foster collaboration on new educational projects. Within this CoP, lecturers are encouraged to share teaching materials, discuss pedagogical approaches, and share advice towards achieving this goal.

KEYWORDS

Community of Practice, Enhancement Teaching Competence, Mechanics, User-Centred Design, Standards 1, 2, 4, 7, 8, 9, 10, 11, 12

INTRODUCTION

Mechanics is a core subject of study in most bachelor curricula of engineering, architecture and industrial design programmes. By mechanics we refer to the disciplines that study the effects of loadings on physical bodies and structures, such as statics, dynamics and mechanics of materials. These disciplines provide fundamental knowledge for the development of product-, process-, and system-building skills. Therefore, as part of the Delft University of Technology's (TU Delft) bachelor programmes, mechanics courses are provided across seven out of its eight faculties by more than 70 mechanics lecturers. mechanics courses are provided across 7 out of its 8 faculties by more than 70 mechanics lecturers.

Given the wide spread of mechanics disciplines across campus, the TU Delft Central Student council initiated the PRogramme for Innovation in MECHANics education (PRIMECH) in 2020. The PRIMECH project was then further supported by the Education and Students Affairs office of TU Delft, which dedicated extra Nationaal Programma Onderwijs (NPO) funding to the project (Minister van Onderwijs, Cultuur en Wetenschap, 2023). The PRIMECH project was officially launched at TU Delft in October 2021 and funded till August 2024. Afterwards, the project is expected to be self-sustained, and the initiating team will be dissolved.

The goal of the Student Council in initiating the PRIMECH project was to replicate the success of PRIME (Programme of Innovation in Mathematics education; Cabo & Klaassen, 2018; Cabo & Klaassen, 2019) in the field of mechanics courses. The PRIME project, which began in 2014, aimed to develop an alternative method of teaching mathematics to engineering students. Prior to 2014, mathematics courses were already taught by many lecturers belonging to the same group, the Delft Institute of Applied Mathematics (DIAM). With the implementation of PRIME, these lecturers became part of a larger project team. Together, they develop teaching material, and they maintain and teach approximately 45 courses belonging to various TU Delft bachelor programmes.

During the initial stages of the PRIMECH project, it became evident that replicating the PRIME approach was not feasible. Unlike mathematics education, the teaching of mechanics is decentralised, with each faculty responsible for its own mechanics curriculum. The current TU Delft organisational structure is based on each faculty being a completely independent entity, responsible for its own research and educational activities. Therefore, centralising mechanics education would require a structural reorganisation across multiple faculties, resulting in a significant amount of time, resources, and buy-in from various stakeholders. Thus, it was deemed a high-cost and low-priority change to implement.

Consequently, the PRIMECH team, initially comprising an educational project manager, an educational advisor, and a system architect, re-evaluated the project's goals while retaining the interfaculty character of the initiative. The PRIMECH team conducted an exploratory analysis to identify the underlying needs and opportunities for innovation. Based on the findings, the team proposed the introduction of the Mechanics Teachers Social Club, an interfaculty community of practice (CoP), built around the shared domain of interest of teaching mechanics and improving students' conceptual understanding. This ongoing intervention aims to promote community-based professional development, in accordance with CDIO standard number 10: Enhancement of Faculty Teaching Competence. This standard calls for creating a supportive environment that encourages and enables faculty members to continuously improve their teaching practices, leading to better quality education for students (Malmqvist, Edström & Rosén, 2020).

The enhancement of faculty teaching competence is widely regarded as a major challenge in the implementation of the CDIO curriculum or any active learning approach (Loyer & Maureira, 2014). The Mechanics Teachers Social Club is a key example aimed at enhancing the teaching competence of faculty members with an interfaculty approach. This paper presents the first three phases of the ongoing PRIMECH project, namely Conceiving, Designing, and Implementing, along with the initial steps and plans for the Operating phase. While it is not yet possible to accurately measure the impact of the intervention on students' learning, the aim of this paper is to share insights and experiences gained thus far, with the hope of providing useful information to others attempting to implement similar projects.

CONCEIVING

As replicating the PRIME approach was not feasible, the PRIMECH team had to re-scope the project. The team began by analysing the initial requirements, which included the intervention being inter-faculty, aiming at improving mechanics education at TU Delft, not requiring a structural reorganisation within the university faculty, and being led by the PRIMECH team until the end of academic year 23/24. Thereafter, the aim is for PRIMECH to be self-sustainable. To further define the project requirements, the PRIMECH team conducted an exploratory analysis of the mechanics educational system, following the Design-Based Educational Research approach (McKenney & Reeves, 2018). The goal was gaining a comprehensive understanding of the educational context and potential areas for improvement, as well as determining and managing the expectations of stakeholders.

Exploratory analysis

In the exploratory phase of the study, two data collection methods were utilised: unstructured interviews and document analysis. More than 30 interviews were conducted with various stakeholders, including teachers from three distinct faculties, the student council, faculty study associations, learning developers, academic counsellors, directors of education, and directors of studies. The questions asked were aimed at gaining a comprehensive understanding of the educational context and desired outcomes, specifically with regards to the current teaching methods and systems in place in the different faculties, the challenges faced by the mechanics teachers, and the current status of student learning in mechanics.

In the document analysis, a comprehensive review of various written materials was conducted, including the university's vision on education, the organisational structure, materials from the mandatory teaching qualification course, mechanics course descriptions, outlines, and slides, as well as statistics on student performance in previous years, and students' feedback on the mechanics education they received. The insights gained from this analysis were integrated with the outcomes from the interviews to form a comprehensive picture of the mechanics education context.

The exploratory analysis yielded several key findings, such as the stakeholder map of the university's organisational structure, a comprehensive list of TU Delft's bachelor mechanics courses and respective teachers, a detailed representation of the teaching system, personas, and the problem statement. However, to preserve privacy and ensure brevity, certain findings, such as the stakeholder map, the list of mechanics courses and teachers, and the in-depth personas were not included in this paper.

Representation of the teaching system

At TU Delft, mechanics is taught across seven of its eight faculties, with over 70 mechanics lecturers providing instruction. These lecturers are generally affiliated with the faculty in which they instruct. Mechanics courses are present in various bachelor's degree programmes, including Civil Engineering, Mechanical and Maritime Engineering, Aerospace Engineering, Applied Physics, Architecture, Geoscience, Electrical Engineering, and Industrial Design. In many cases, these programs offer mechanics as a series of sequential courses and often link mechanics courses to design projects. The curricula of Aerospace, Civil, Mechanical, and Maritime Engineering are most closely aligned in terms of mechanics instruction. Despite the similarities in the theoretical content taught across faculties, the specific applications and contexts of this content vary. The pedagogical approach and delivery strategies used by

mechanics lecturers vary as well, ranging from traditional lecture-style teaching to flipped classroom environments. Additionally, the number of credits awarded for completing a mechanics course differs among faculties.

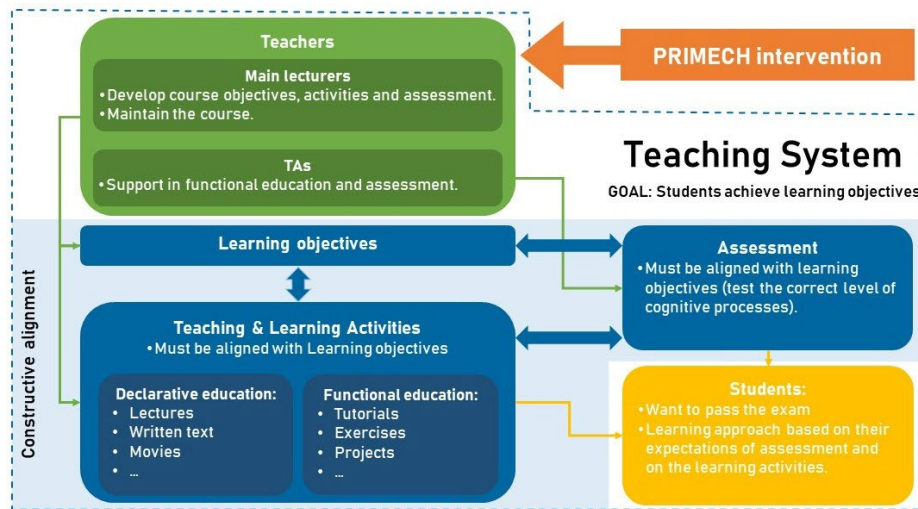




Figure 1 - Teaching system of bachelor-level mechanics courses at TU Delft

The teaching system at the course level has been visually represented in Figure 1. This model displays the use of the constructive alignment triangle as the main educational principle in developing courses at TU Delft (Biggs, 1996). The principle of constructive alignment is centred around the idea that teaching and learning should be designed in a manner that facilitates the achievement of desired learning outcomes by students. Figure 1 highlights the impact of the different components of the triangle on students' understanding and study attitude and underscores the primary role of teachers in teaching as well as shaping the course content, structure, objectives, methods, materials, and assessment.

Personas

Table 1 – Simplified personas of the intended users of the intervention

Persona	Frustrations, needs and wants
<p>I hope students will follow the path I created, so they can appreciate all the beautiful details, and deeply understand the subject.</p>  <p>Teacher of Mechanics</p>	<p>The mechanics teacher</p> <ul style="list-style-type: none"> Highly values the job of teaching to the next generation of engineers, they want to be good at it. Has limited time, balancing education and research duties. Wants to collaborate and share material with other teachers and align their courses, ... but wants to keep their teaching freedom.
<p>If I pass the exam, it means I learnt the subject and I can move on in my studies. Just show me the quickest way to do it!</p>  <p>Student</p>	<p>The first-year mechanics student</p> <ul style="list-style-type: none"> Has a “hectic schedule” between courses and extra-curricular activities. Wants to pass the exam with minimum effort, still has a “high school” study mentality. Tends not to understand fundamental concepts properly. Sees their curriculum of studies more as an obstacle course than a learning experience.

PRIMECH created personas to summarise the findings from the interviews conducted and to insure the alignment of the final solution with the identified users' needs. A simplified version of the personas for mechanics teachers and students can be found in Table 1; however, as noted above, the detailed personas cannot be shown due to privacy concerns. The personas were developed based on different teacher types, including those hired as full-time lecturers, tenure trackers, and a range of professors from assistant to full. From the interviews, it emerged that the teacher's role influences their time availability for teaching and their level of experience and willingness to learn from and share their experience with others.

Problem statement

Teachers reported difficulties in creating an effective course structure, in incorporating active-learning activities, and in developing appropriate assessments, particularly with large class sizes. They also reported limited time, resources, and discipline-specific support to assess and improve their teaching practice. Moreover, these lecturers are seldom connected within and across faculties. This decentralisation of mechanics instruction resulted in a lack of peer support, hindering the development of shared mechanics teaching competence and leading to a sense of isolation and duplication of efforts: teachers feel like they are often "reinventing the wheel" when developing teaching material and activities for their mechanics courses.

Insufficient conceptual understanding in mechanics was identified as a major challenge for students, who often resort to memorisation of formulas rather than forming a deeper understanding of core mechanics concepts and their interrelationships. Poor study attitudes, including a lack of metacognitive skills, self-directed learning, and limited awareness of desired learning outcomes, were also observed, resulting in low passing rates for mechanics courses. Furthermore, students often struggle to transfer and retain learned mechanics content, causing frustration among subsequent course instructors.

PRIMECH objectives

PRIMECH's primary objective is to innovate mechanics education at TU Delft. Based on the insights gained in the exploratory analysis, PRIMECH decided to intervene within the teaching system by collaborating with the teachers, as illustrated in Figure 1. Accordingly, PRIMECH has further defined its objectives in a two-fold manner:

1. Providing (domain-specific) support for the mechanics teachers:
 - Facilitating the alignment between mechanics courses within each Bachelor programme.
 - Promoting the interfaculty collaboration and exchange of material, good practices, and peer-to-peer support.

In the long term, this support would aim at innovating the mechanics teaching system and, consequently,

2. Helping more students adopt a deep approach to learning:
 - To better understand and acquire mechanics concepts.
 - To help the development of an effective studying mentality.

DESIGNING

After defining the project objectives, a co-design process was initiated to delineate the intervention strategy. Three statics teachers from different faculties (Mechanical and Maritime Engineering, Aerospace Engineering, and Civil Engineering) were selected to participate in the co-design process. This is as statics is taught similarly in the first quarter of the first-year bachelor programme in these faculties and served as the students' initial exposure to engineering after high school. Five workshops were conducted over five months to explore the solution boundaries further. Figure 2 showcases the statics teachers during two of the workshops.



Figure 2 – Statics teachers during two of the PRIMECH workshops

The first step in the co-design process was establishing a shared vision for the intended learning outcomes of the statics courses among the participating teachers. This allowed for an in-depth examination of the course components. Then, the teachers identified possible improvement areas, such as teaching for conceptual understanding, promoting self-directed learning and accommodating diverse learning paces. The teachers found that they were spending a significant amount of time developing teaching materials and assessments, feeling like they were “reinventing the wheel”, leading to a decision to share resources and investigate the use of an online repository tool. It also became apparent that the frequent co-designing meetings were alleviating the sense of isolation experienced by teachers, allowing them to engage in meaningful discussions with their peers. Consequently, PRIMECH decided to extend these activities to all TU Delft mechanics teachers by implementing a CoP: the Mechanics Teachers Social Club.

Community of Practice (CoP) and community-based professional development

“Communities of practice are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly” (Wenger-Trayner, 2015).

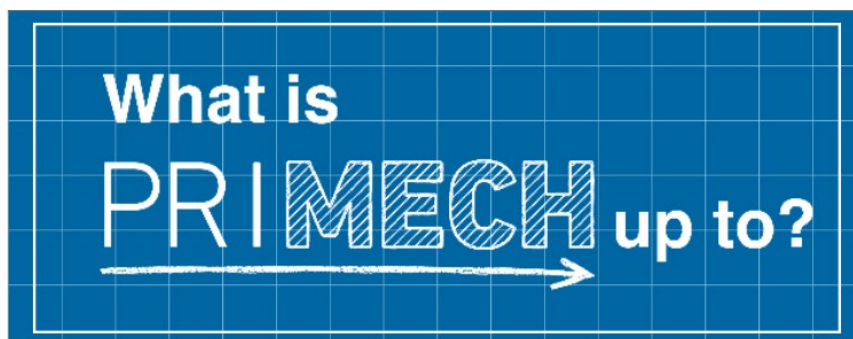
CoPs typically form around a shared domain of interest and are characterised by social interaction and collaboration between members (community) to improve their expertise in a particular area (practice). These groups are frequently utilised to support community-based professional development for teachers. Although the CDIO community has previously addressed this intervention through various publications, such as Kilstrup, Hellgren, & Andersson (2011) and Cárdenas, Martínez, & Muñoz (2013), there is still a need for further investigation into its effects and implementation.

PRIMECH CoP: the Mechanics Teachers Social Club

The PRIMECH team took the role of initiating the Mechanics Teachers Social Club with the responsibility for organising and operating the community for the first two years, as well as fostering ownership of the CoP among the teachers with the aim of promoting its continuation after the PRIMECH central team dissolves. The CoP was designed around the shared domain of interest of teaching mechanics and improving students' conceptual understanding, with all TU Delft Bachelor-level mechanics teachers as intended members. The CoP was designed on two levels in alignment with PRIMECH objectives: 1. supporting teacher professional development (teacher level) and 2. collaboration on new educational projects aimed at improving students' conceptual understanding and studying mentality (student level).

To achieve these objectives, it was planned that the CoP activities should include networking events and guest expert events. The networking events aim to encourage collaboration and discussions among teachers, leading to a rethinking of the learning objectives, course structures, learning activities, and assessments in mechanics courses, as well as to new teacher-led mechanics education projects. The guest expert events are designed to share information about teaching tools and provide a platform for members of the community to highlight their educational initiatives. Additionally, a Microsoft Teams group was established, providing a virtual space for teachers to meet, share material and discuss their teaching practices across faculties. It was decided to constantly monitor the CoP success based on the perceived value it added for teachers. To do so, surveys are conducted after each event to assess if PRIMECH is on track towards achieving the various goals outlined in this paper.

PRIMECH could not mandate participation in the CoP for TU Delft bachelor-level mechanics teachers, so they developed a communication strategy to encourage teachers to join. The strategy included sending a monthly newsletter to all mechanics teachers and using a LinkedIn page. The aim of the newsletter is to keep the community informed of the latest CoP developments and encourage their participation, as clearly stated in the newsletter header shown in Figure 3. The monthly newsletter was designed to feature the “teacher-of-the-month” column, a series of interviews with active members of the community. This serves multiple purposes, as it demonstrates the value of being in the CoP to non-participants, it creates a reputational platform that values teachers for their teaching competence, and it fosters a sense of ownership through teacher integration. The LinkedIn page was created to increase the Social Club's visibility by taking advantage of the vibrant LinkedIn network that extends throughout TU Delft.



Hi there, Engineers!

Figure 3 – The header of PRIMECH Newsletter

IMPLEMENTING

In June 2022, PRIMECH launched the Mechanics Teachers Social Club by organising the first networking event, a social lunch where all TU Delft mechanics teachers were invited, with the aim of convincing them to join the CoP. Strategic partners were also invited to inform them of PRIMECH's results up to this point and collect their feedback. Around 25 people participated in the event. Through the three hands-on activities displayed in Figure 4, attendees had the opportunity to get to know each other, discuss mechanics education in TU Delft Bachelor programmes and the challenges faced in teaching this subject.



Figure 4 Hands-on activities of the mechanics teachers social lunch event

The hands-on first activity, "After all, what is Mechanics really all about?" challenged attendees to define the essence of mechanics in just one sentence. The second activity, "Mapping Mechanics," involved creating a mind map of the fundamental concepts of the discipline, providing a comprehensive view of mechanics, and helping attendees discuss how the concepts are interconnected. The third activity, "Teaching Mechanics," was a plenary discussion centred on the challenges of teaching the fundamental concepts of mechanics. These hands-on activities served as a networking platform, promoted collaboration between teachers, and helped the development of a common vision on mechanics education at TU Delft.

During the final plenary session, teachers also expressed their enthusiasm for joining the Mechanics Teachers Social Club. The teachers were determined to continue working together to develop a shared vision for mechanics education and new educational projects. To achieve these goals, they agreed to meet every six weeks during lunch breaks in the upcoming academic year. They expressed interest in delving deeper into the fundamental concepts and skills of mechanics, with a focus on the challenges and best practices of teaching them. In addition, the teachers committed to continuing the development of the open repository of mechanics learning materials.

OPERATING

In the 2022/2023 academic year, the Mechanics Teachers Social Club is operating as planned. As of April 2023, the club has published fourteen monthly newsletters that feature reports on CoP activities, "teacher of the month" interviews, and insights into useful educational theories. Four key activities have been hosted, including 1) the co-development of concept maps using an in-house TU Delft concept-mapping tool to aid students in navigating their learning, 2) a networking event to gather teacher feedback and aspirations for the community, 3) a guest-expert lecture on designing and implementing in-class demonstrations for mechanics, and 4) a lecture by two members of the community sharing their approach to formative assessment and their insights from creating a shared question bank using an e-learning assessment tool.

Through the after-event surveys, teachers have reported that they are eager to implement the new discussed strategies in their courses and that they have been meeting new colleagues, with some teachers even beginning to collaborate on new educational projects without the direct involvement of the PRIMECH core team. These preliminary results are encouraging and in alignment with the PRIMECH objectives.

DISCUSSION AND CONCLUSIONS

When the preliminary goal for PRIMECH was deemed unachievable, the project had to be re-scoped. During the conceiving phase, PRIMECH conducted an exploratory analysis across faculties to gain a better understanding of the educational context. In retrospect, approaching this phase without a preconceived solution in mind was the right decision. This allowed the PRIMECH team to thoroughly analyse the contextual needs and realise the importance of collaborating with teachers for the success of the intervention. During the designing phase, PRIMECH held frequent workshops with a small group of statics teachers to design the intervention project collaboratively. Based on the outcomes of these workshops, PRIMECH identified the students' insufficient conceptual understanding of mechanics as a potential domain for developing a CoP, which would provide (domain-specific) support for the teachers and promote the implementation of new teaching strategies to help more students adopt a deep approach to learning, in accordance with the two PRIMECH objectives. In June 2022, PRIMECH launched the Mechanics Teachers Social Club, and several mechanics teachers joined the CoP. The development of the Mechanics Teachers Social Club took a total of 9 months, starting from the conceiving phase to the implementing stage. Since September 2022, the club has been operating according to plan. The team's future focus is to foster even more ownership and active involvement in the CoP operations among teachers, to ensure the sustainability of the club after the PRIMECH team dissolves.

In conclusion, the Mechanics Teachers Social Club is tackling the need for innovation in mechanics education at TU Delft by fostering collaboration and enhancing the teaching competence of mechanics teachers, in accordance with CDIO Standard 10. The teacher-centred approach allowed the team to develop a solution that is valued by the teachers and has already shown promising results in innovating their teaching practice. The authors believe that the insights and experiences shared in this paper can be of great value for universities and faculties looking to enhance the teaching competence of their members by implementing a CoP.

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BIOGRAPHICAL INFORMATION

Marta Gavioli holds an MSc degree in Electrical Engineering, and she is currently a PhD candidate in the field of Engineering Education. Her research project focuses on conceptual understanding of mechanics. Since October 2021 she leads PRIMECH: PRogramme of Innovation in MECHANics education at TU Delft, a university-wide initiative to innovate mechanics education together with the mechanics teachers. As such, she is involved in developing tailored educational projects, workshops and events, and coordinating a growing group of people involved in the process.

Grant Penny holds an MA degree in Online and Distance Education. He is an educational advisor, working at TU Delft in Education and Student Affairs on educational innovation and student success. His current focus areas include transferrable skills, peer-to-peer development, and future education policy. Since 2022 he has been working on PRIMECH: PRogramme of Innovation in MECHANics education at TU Delft, a university-wide initiative to innovate mechanics education together with the mechanics teachers.

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