4TU.CEE@TU/e 2019-2022

4TU. CENTRE FOR ENGINEERING EDUCATION


teaching excellence
educate
future engineers
4TU.CEE
TU/e
innospace
esoe
webinar
mathematics
challenge based learning
applied physics
innovation map
ict enhanced education
responsible engineering
educational ecosystems
entrepreneurial learning
interdisciplinarity
projects

Table of contents


innovation map
educate future engineers
teaching excellence
TU/e
activities
events
projects
esoe
mathematics
interdisciplinarity
entrepreneurial learning
4TU.CEE
webinar
challenge based learning
innovation map
responsible engineering
innospace
educational ecosystems
applied physics
ict enhanced education

Introduction

This report is a summary of the 4TU.CEE projects and activities at TU/e over the period 2019-2022, leaning on the 4TU.CEE progress report 2019-2021. During those years, the 4TU.Centre for Engineering Education (4TU.CEE) has continued to grow into a recognised centre of expertise in educational innovations in engineering education. The visibility and reputation of 4TU.CEE has grown vastly within the teaching community of the four Universities of Technology and at the international level. Dutch and international partners are eager to collaborate, either in the implementation of innovations or in their evaluation and dissemination of results. The number of activities, such as workshops and webinars for 4TU teachers, has been growing steadily, also at 4TU.CEE at TU/e. International scholars were invited to enrich the 4TU teaching community and share best practices.

Moreover, the centre has become a national leading example with its work on career frameworks and teaching excellence based on a longstanding collaboration with Ruth Graham. The 4TU.CEE Innovation Map has been recognised as good practice of knowledge infrastructure. Over the years, both practical tools as well as scientific publications have been produced. 31% of these publications on the Innovation Map originate from and have been supported by TU/e.

4TU.CEE project topics at TU/e varied widely from teaching excellence to challenge-based learning in engineering education. The COVID-19 pandemic brought all kinds of challenges for lecturers and students and gave a boost to online engineering education and research in this field.

Personnel

In 2017 prof. Pepin took over, as leader of 4TU.CEE at TU/e, from prof. den Brok who accepted a new position at our 4TU partner university WUR. Prof. den Brok subsequently became chair of 4TU.CEE. This report is a summary of the 4TU.CEE projects and activities at TU/e during the second half of the period of her leadership, 2019-2022. At the end of the 2022 prof. Pepin will step down as the leader of 4TU.CEE at TU/e due to retirement. The new leader of 4TU.CEE at TU/e will be prof. Ventura-Medina.

Future Perspective

At the end of 2021, 4TU.CEE launched its strategic plan for 2022 - 2025. During this period, 4TU.CEE focusses on five themes:

1. Entrepreneurial learning or academic entrepreneurship,
2. Educating for responsible engineering or the ethical and responsible engineer,
3. ICT enhanced education and the digital literate engineer,
4. Challenge Based Learning, and
5. Teaching excellence in engineering education.

At TU/e, projects have started on every theme and exciting proposals have been submitted for this period. 4TU.CEE at TU/e works closely together with TU/e policy makers to ensure that the projects that are supported are in line with the TU/e Strategy 2030. Together we generate new insights to innovate engineering education at TU/e. 4TU.CEE at TU/e considers it important to share the outcomes of the projects with the broader TU/e and the 4TU community as well as on an international level through events, publications and conference contributions.

4TU.CEE at TU/e continues to closely co-operate with the other three technical universities, either by bringing together findings of separate projects or initiatives,

or by initiating joint projects. Moreover, it continues to organize joint professional development activities, such as the CBL webinars and Learning Spaces tours. In parallel, 4TU.CEE at TU/e organizes and contributes to local events such as the innoXchange day 2022, always with an open invitation to all 4TU members.

Together with its 4TU.CEE partners, 4TU.CEE at TU/e is in the process of further expanding its international activities. Whereas in prior strategic periods 4TU.CEE at TU/e mainly focused on establishing 4TU.CEE locally and nationally, in recent years it has become more active internationally, e.g. by writing peer-reviewed articles in international research journals. As the other 4TU partners, 4TU.CEE at TU/e continues to actively participate at CESAER, SEFI, CDIO meetings and conferences, and contributes to and is involved in the international PhD symposium for engineering education together with KU Leuven and the University of Western Australia. At the same time, our longstanding collaboration with Ruth Graham on rewarding teaching excellence grows stronger.

Research on IT in engineering education continues to remain an important topic. 4TU.CEE at TU/e will continue to innovate and conduct research by supporting small-scale projects of individual teachers or courses, as well as large-scale, more complex and long-term projects conducted by postdocs or PhD candidates.

Reading Guide

In the pages that follow, an overview will be given of 4TU.CEE at TU/e initiated and supported projects and activities, conducted during the period 2019-2021 and ongoing projects in 2022, leaning on the progress report 4TU.CEE 2019-2021

These projects and activities are structured under the following themes:

From the strategic period 2019-2021:

1. Educating future engineers,
2. Interdisciplinary engineering education,
3. Engineering educational systems; and

Current strategic period 2022-2025:

4. Teaching excellence in university engineering education,
5. Entrepreneurial learning or academic entrepreneurship,
6. Educating for responsible engineering or the ethical and responsible engineer,
7. ICT enhanced education and the digital literate engineer,
8. Challenge Based Learning.

For each theme, a short description of the theme is provided as this has been defined in the shared 4TU.CEE progress report and new strategy. Moreover, only those projects are included that are conducted under that theme at TU/e.

A more detailed overview of activities and projects, as well as people involved, can be found in the 4TU.CEE Innovation Map.

The 4TU.CEE team at TU/e wants to thank all the project members for their contributions to the innovative developments realized at TU/e. To keep track of interesting 4TU. CEE activities and project results, more information can be found in the newsletter and the 4TU.CEE blog.


responsible engineering
interdisciplinarity
ict enhanced education

1. Educating Future Engineers

Introduction

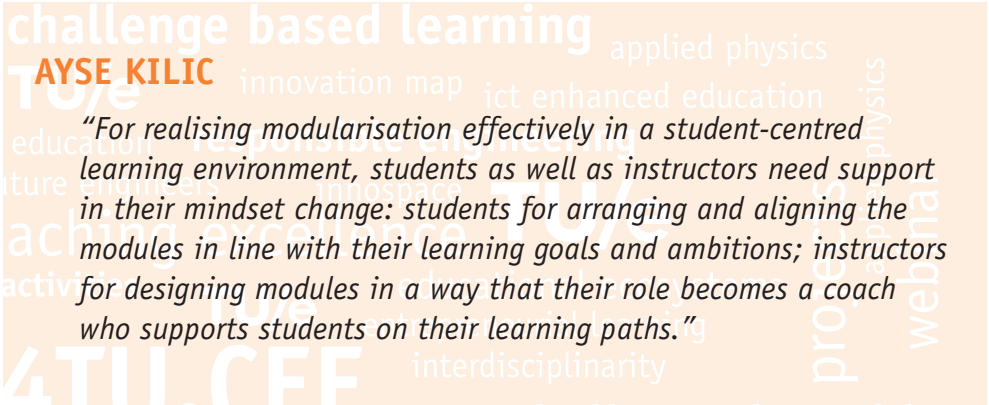
This theme deals with different engineering profiles and the development of the professional identity of engineers needed to develop future-proof engineers who are able to contribute to the sustainable development goals. It also deals with the new skills and competencies that future engineers need. At TU/e the following projects were conducted under this theme in the period 2019-2022.

USE Learning Lines

At TU/e the USE (User, Society and Enterprise) learning lines are essential courses in educating future engineers. These courses are under continuous development. After intensive research funded by 4TU.CEE at TU/e the basic course on ethics was fundamentally redesigned using flipped-classroom and Challenge Based Learning. Results show that intrinsic motivation, autonomy and competence were significantly higher in the co-creation case compared to the other approach not using Challenge Based Learning. More information can be found on the project page on the Innovation Map.

Modularisation

Modularisation of the curriculum is part of the TU/e strategy 2030 to enable students 'to pursue their individual interests and ambitions, while providing rigorous academic engineering education.' However, students often do not know on which criteria to base their choice of modules: how to connect the knowledge from previous and future modules to present module knowledge. A modular system can result in significant benefits for students (e.g., flexibility, choice, access, mobility), but to realise these gains, students need to be able to act autonomously when 'making a whole of different parts'. In the modularisation project of TU/e, a framework has been developed that supports course designers to develop appropriately connected modules, and that connects student learning and knowledge, in particular in the areas of mathematics in/for engineering education. This is to support students to benefit from these connections and to develop suitable individual learning paths. More information can be found on the the project page on the Innovation Map.



AYSE KILIC

"For realising modularisation effectively in a student-centred learning environment, students as well as instructors need support in their mindset change: students for arranging and aligning the modules in line with their learning goals and ambitions; instructors for designing modules in a way that their role becomes a coach who supports students on their learning paths."

C-mode-Constructing knowledge based on modular on-demand digital education

Modularisation is an important topic and digital education provides a unique opportunity to reshape educational practices in order to optimally use the limited resource in terms of human capital and continue to provide excellent education to students. However, education at most universities is still organized around monographic stand-alone topic courses, offered in a predetermined sequence and taught in plenary lectures. At the same time, it is known that the ingredients needed for (deep) learning are: boundaries (context), resources, and a question that triggers our imagination. The goal of CMODE project was to develop a course design strategy based on these three pillars that can be extended to curriculum design. Its subsequent project; CMODE-UP used the results of CMODE, and aimed towards creating evidence-based design principles for teachers to design their courses in engineering education with online modules.

The project adopted three distinct phases to create design principles for modular courses in higher engineering education. Phase 1 included a systematic literature review to get an overview of important principles in the instructional design of modular courses. In Phase 2, based on the findings from Phase 1, an initial version of the design principles was presented to experts in modular course design at the TU/e. In Phase 3, think-aloud interviews were conducted to finalize the design principles. The results produced the design principles and an overarching conceptual model. The generic instructional design model, ADDIE, was used to structure and organize the results into logical design principles.

Essential characteristics of modular approach are highlighted in the design principles: time and location flexibility, self-paced learning experiences, and self-contained modules with different components. The design principles are now revised based on: a) data collected at a workshop where teachers tested the design principles, and b) a descriptive review to further highlight aspects such self-paced learning, voluntary modules, CBL courses. More information can be found on the project page on the Innovation Map.

COVID-19 Pandemic Research into Student Learning and Wellbeing

All interaction between students and teachers shifted online with the start of the COVID-19 pandemic. The consequences for student learning and staff teaching were monitored in a TU/e project that started shortly after the transition. The focus was on monitoring student learning and well-being. The project delivered progress reports and three sets of hands-on recommendations for teachers to use in their courses to improve student learning and well-being. The project results provide useful input for the post-pandemic period when teachers are likely to aim for an optimal mix of blended learning. More information can be found on the project page on the Innovation Map.

TU/E PROJECT TEAM

"This natural experiment has given us valuable insights into the (long-term) effects of online education on student well-being."

This TU/e project team has also contributed to a joint 4TU.CEE white paper on the impact of COVID-19 on higher education. This was published in 2021. With this white paper several studies from the 4TUs were combined, presented and discussed at the 4TU board. The aim was to benefit from four excellent studies realized at each institution and to bring together the different results to generate policy advice and new research questions.

The white paper has been followed up by two webinars in 2021 and 2022. In the first webinar preliminary results were presented and discussed; in the second webinar follow-up research was considered. An interesting complementary report regarding this topic is the report by Ruth Graham 'crisis & catalyst'. 4TU.CEE at TU/e has part-financed and contributed case studies to this research.

Enhancing Bachelor Students' ownership in hands-on education: the case of mechanical engineering

In order to further develop the OGO-projects (in Dutch 'ontwikkelings-gericht onderwijs' - 'development focused education') in the direction of CBL , the department of mechanical engineering identified the importance for their students to increase their ownership of learning processes and learning outcomes. The need for this was based on experiences of teachers with ownership among their students in the ongoing OGO-projects: they experienced almost no increase in ownership among students over the years of the bachelor program. Despite the various attempts to make changes to this, for example, by carefully increasing the complexity of the projects (from less to more complex) and at the same time gradually decreasing support, students in their second and third year hardly changed towards more ownership when compared with first year students. More information can be found at on the project page on the Innovation Map

MEMI: Measurable effect of mini-lectures on improving student engagement and outcomes

Learning mathematics is a complex process, requiring many conceptual lenses and rich data sources to document and understand students' construction of knowledge. In particular within the context of learning mathematics at university, using online videos in university mathematics modules has been shown to benefit student learning. Perceived benefits of videos include flexibility of scheduling and pace, and avoidance of large, long lectures. Research has also shown that although videos provide a useful resource, they should be used in conjunction with lectures in this context. Findings show that students use videos as either a complement to or substitute for the lecture, and time spent using either or both resources has a significant impact on learning.

In this project, these findings were tested in the context of a newly redesigned course at master's level. The course was an established master's course in the core programme of the department. It comprised three distinct topics in stochastics. The current design involved 4 lecture hours per week, 4 guided self-study instruction hours, three midterm examinations (one on each topic), and a final examination. The material currently offered to students included lecture notes, one single book covering all topics, instruction sets, sketches of solutions to the instruction exercises, low-level comprehension quizzes per lecture, videos of the complete series of lectures from previous years, and practice exam sets for the final examination.

For the project, new videos of mini-lectures were created to complement this material. A light board was used, which mimicked the experience of a teacher writing a proof in class in terms of pacing, visualisation, and level of information. A third of the videos worked through material already offered to the students but not explained in class, and two thirds presented new notions (that were not part of the assessment of the course). The objective was to measure whether this intervention increased the students' engagement with the course and/or improved their outcomes (in the specific context of a specialised and rather challenging first year Master course of the IAM curriculum). More information can be found on the project page on the Innovation Map.

Structural scaffolding via diagrams to teach students syntactic proof production

With the project focus on developing exercise sets, the research question was: What are the effects of structural scaffolding on students' learning of syntactic proof production? The project aimed to develop exercise material that realizes diagram-based scaffolding to facilitate students in proof production by making logic and proof structures explicit. Accordingly, the project activities were located in the framework of educational design research, where the developed exercise material was trialled, evaluated and improved in iterative cycles.

A literature study was conducted to assess the best way to introduce students to syntactic proof production. Based on this study an initial assignment set for 'proof by contrapositive' was developed. This assignment set was trial run in the course 'Algorithms and Data Structures'. Students made the assignment in groups of four with only minimal intervention. The process in which they tackled the exercise set was recorded and the outcome was used to improve the set further. Based on the perceived problems the exercise set was further refined, and the team once again ran a brief evaluation in a later iteration of the course 'Algorithms and Data Structures'. Overall, the conclusion was that it is likely that the self-study material supports students in formulating the contrapositive in everyday situations. However, more work is needed to understand how to improve the self-study material with respect to extending this proficiency into the realm of mathematics. More information can be found on the project page on the Innovation Map.

Multimath

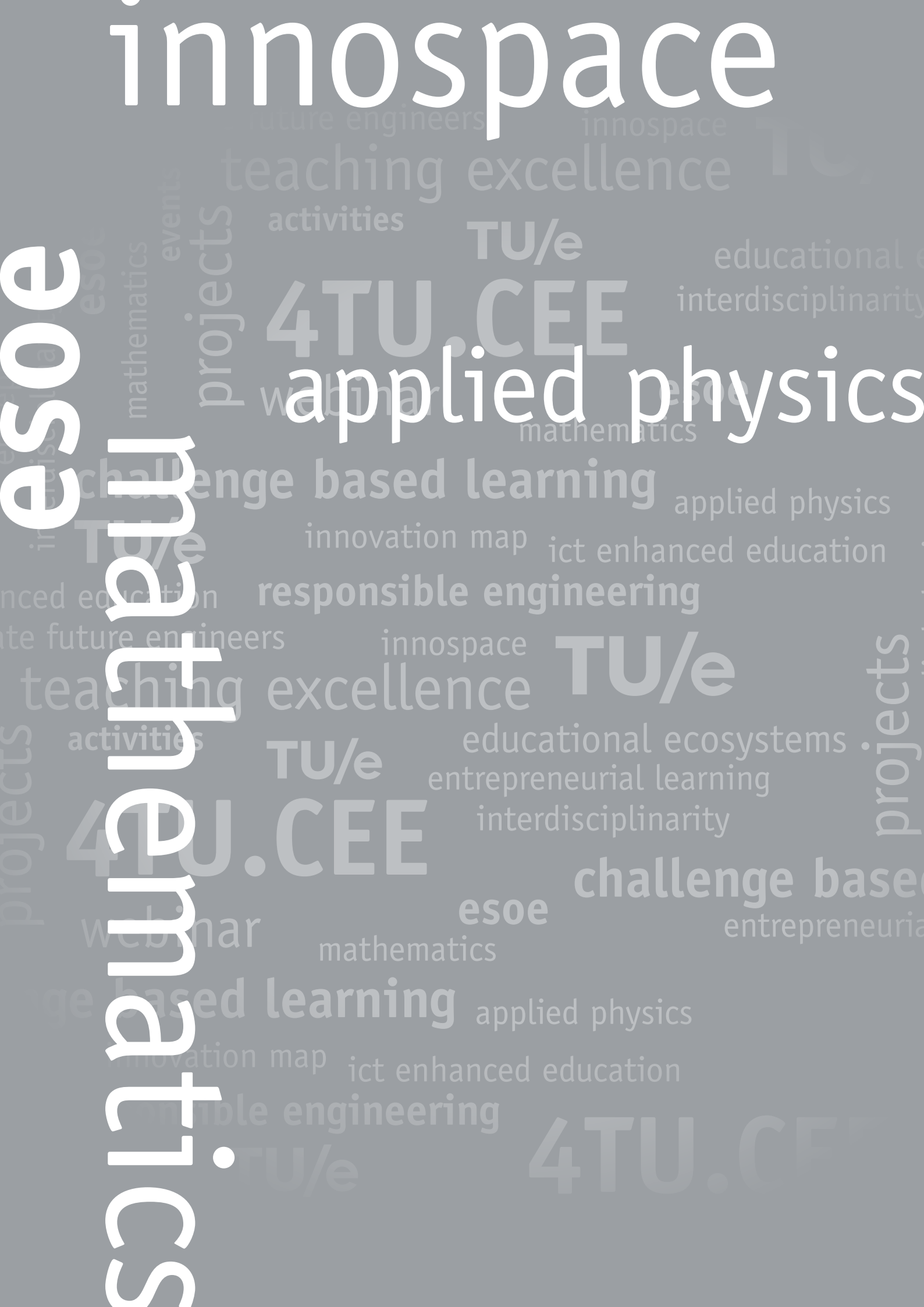
In traditional group work in mathematics, handwriting is a relevant element to enable reasoning, e.g. by supporting the generation of ideas or the storing of information. However, as COVID-19 has forced students to learn mathematics over distance, traditional handwriting could not be used anymore during group work. To address this issue, this exploratory study investigated the question of how students could use handwriting in a mobile-learning setting via Zoom, in which students used tablets and smart pens to collaborate over distance. It was found that, compared to traditional group work with pen-and-paper, the distance collaboration setup allowed for handwriting to become a syn¬chronous collaboration tool, for example, for enabling the individual development of ideas that can be extended by peers. More research is needed to investigate the particular epistemic role of handwriting and, particularly, the role of handwriting with smart pens in distance collaboration settings.

Effective learning and student-team collaboration in the international classroom at TU/e

The development of the 'international classroom' at TU/e has been supported by several projects. Since group work is a cornerstone of CBL, one of the projects focused on student collaboration and learning in internationally heterogeneous student groups, and how teachers and students could be supported in this context.
It was noted that the general atmosphere at TU/e demonstrates openness, inclusiveness and a positive attitude towards diversity. However, contacts between international and domestic students are still limited.

The first sub-study (using questionnaires) provided a path model that explained group outcomes in terms of the various group variables. This showed that in international groups, mutual trust may be lower (initially), and it is more difficult to build a shared vision of the task and possible solution directions. At the same time, positive beliefs and expectations about the benefits of team diversity were found to more than offset the aforementioned disadvantages. Such so-called 'diversity beliefs' should be promoted, and international groups should be encouraged to really get to know each other at the start of group work by exchanging backgrounds, competencies and expectations.

The second sub-study followed a selection of student groups and provided detailed insight into the dynamics of international group work. It showed that 'token members' (students who are the only international student in a group, or the only woman in a group, or both) are at risk of being marginalized, and often report being unhappy with group work. More information can be found at the project page on the Innovation Map.


innospace
applied physics
esoe
mathematics

2. Interdisciplinary Engineering Education

Introduction

Interdisciplinary education continues to be one of the key themes of 4TU.CEE, and at TU/e engineering education has become more interdisciplinary by nature. It is about solving problems that draw on multiple disciplines, either within or between the engineering domain and domains outside of engineering. It also involves learning to collaborate with teammates with a different cultural background or ethnicity. Research has been conducted on how interdisciplinarity can best be organised in learning activities, curriculums and assessment. At TU/e the following projects were conducted on this theme in the period 2019-2022.

Preparing students for tomorrow's engineering challenges

Societal challenges that call for a new type of engineer suggest the need for the implementation of interdisciplinary engineering education, to bring together expertise from different disciplines in a single context. Together with the other TUs, TU/e has conducted a review on interdisciplinary research with a focus on characterising vision, teaching practices and support. This resulted in a publication in the Journal of Engineering Education. In the project 'preparing students for tomorrow's engineering challenges', interdisciplinarity has been studied within challenge-based courses in the TU/e Innovation Space. Results suggest that students in interdisciplinary groups learned to understand each other's language, and showed a combination of high motivation and anxiety for the challenges. They also showed a hands-on approach, rather than a learning approach. Furthermore, as challenges were rather open-ended and ill-defined, students asked for clear signposting and structure for their learning process. Teachers required support for scaffolding and assessing interdisciplinary student efforts. More information can be found on the project page on the Innovation Map.

Assessment Practices in Inter-Programme Challenge Based Learning

At TU/e research has been conducted on interdisciplinary engineering education assessment, using the TU/e Innovation Space Bachelor End Project (ISBEP) as a case study. ISBEP is the alternative for students at TU/e who wish to finalise their bachelor programme in an interdisciplinary project. The ambition of the research project was to investigate assessment practices in a context such as ISBEP (i.e., interdisciplinary, inter-programme, CBL), and to propose assessment practices that are congruently aligned. The project has highlighted the challenges in the design and implementation of assessment within this context. It has also defined a set of intended learning outcomes for ISBEP, to be used as starting points and inspiration for the design and implementation of assessment practices and learning activities in these contexts. The project was focused on the design and evaluation of assessment tools (e.g., rubric) and procedures for ISBEP, emphasising assessment as learning, and on a tool to foster the development of students. More information can be found on the project page on the Innovation Map.

ANA VALENCIA

"This project has allowed me to combine my passion for design and research. It has been truly inspirational to witness the impact educational design can have on the development and growth and students. The engagement of educators and students throughout this project has been remarkable too, and key in better understanding the needs regarding assessment in interdisciplinary, inter-programme, Challenge Based Learning."

Interdisciplinary Presentations in Bachelor End Projects

The main objective of the project was that students learn to communicate about their work to peers with different backgrounds. In order to achieve this, students need to be given the right tools and support that helps them develop this new skill. The main three takeaways from the project were: (1) When students are to present their work in front of an interdisciplinary audience, the best way to prepare them for this is by actively making them perform an audience analysis, to think about who is going to be in the audience and what role they have. (2) Assessment of presentations that students give in front of an interdisciplinary audience should focus on both form and content; they should be understandable by people from different disciplines, showing that the audience analysis had the desired effect. (3) Analysing an interdisciplinary audience and connecting one's own disciplinary work to that audience provides opportunities for fitting one's disciplinary knowledge in a larger network, showing the value of interdisciplinary presentations for engineering students. More information can be found on the project page on the Innovation Map.

Deepening multi-disciplinarity within Signals & Control

In this project the two departments, Applied Physics (AP) and Mechanical Engineering (ME), collaborated to create a joint challenge-based course (CBL). The present project was an accompanying research linked to the 'CBL - Systems and Control' project. This accompanying study focused on multidisciplinary aspects of the course. This was a key point in the set-up of the project that required in depth development, and it was of fundamental value for the development of CBL at TU/e. The project investigated the factors that influence multidisciplinary teamwork and student learning outcomes connected to working in multidisciplinary teams in the context of the first pilot of the 'CBL - Systems and Control' course.

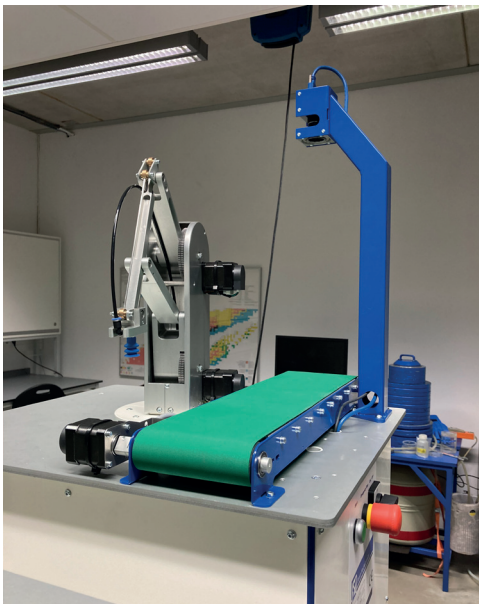
Among the AP and ME students who submitted a motivation letter, 30 students were selected to which this study relates. Data included interviews, reflection reports, observations, and design posters. The results indicated knowledge acquisition, application, and an awareness of other disciplinary approaches as the learning outcomes with some differences for engineering and physics students.

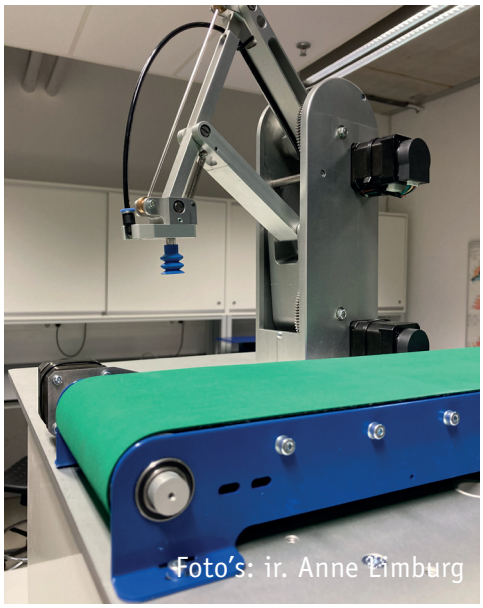
The findings also yielded individual (e.g. knowledge of control theory), team (e.g. disciplinary perspectives), and course factors (e.g. disciplinary connections to the challenge) that influenced multidisciplinary teamwork.

The second pilot of the same CBL course has been set up to understand how learning happens in multidisciplinary teams of AP and ME studentsFirst results indicate that the main disciplinary expertise of AP and ME interacted and connected respectively were: 'organization and project planning skills' and 'communication and teamwork skills, experience in theory and applications of control'. Students engaged in the following practices during teamwork to get the added value of both disciplines in their problem solution: 'creating mini-teams of AP and ME students around identified tasks, organizing multidisciplinary group discussions, and explaining the perspective of one's own discipline'. Moments of generative tension in the context of mini-teams and group discussions were identified.

It is found very positive that the students of both teams were responsive to the expertise of AP and ME disciplinary communities, and they were able to reflect this expertise in construction of their solutions. It appears that students tried to first understand each other's' disciplinary expertise and strengths. This was followed by making use of expertise to get the necessary benefit from both disciplines in the project.

The findings of both projects collectively have the potential to provide empirical support to enhance learning and collaboration in multidisciplinary teams in CBL courses. More information can be found on the project page on the Innovation Map.





Foto's: ir. Anne Limburg


ict enhanced education
ict enhanced
education
4TU.CEE
TU/e
esoe
challenge based learning
responsible engineering
mathematics
applied physics
ict enhanced education
interdisciplinarity
entrepreneurial learning
educational ecosystems
webinar
activities
projects

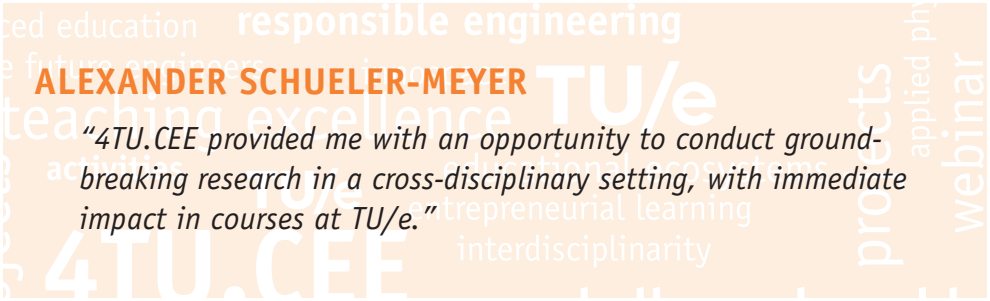
3. Engineering Educational Ecosystems

Introduction

Modern engineering education contexts allow for the involvement of multiple stakeholders, links to society, learning at multiple locations, and for using ICT in a smart way to support for this. 4TU.CEE at TU/e was involved in several studies to find out how educational ecosystems can best be organised, which learning outcomes are realised, and how they can be assessed. Furthermore, in the field of engineering educational ecosystems, various projects have been conducted on the digitalization of education at TU/e in the period 2019-2022.

Distance Collaboration with Mobile Technology

The mobile learning project of TU/e focused on distance collaboration with mobile technology. Several case studies have been conducted for this project. Faced with the pandemic situation the focus changed to exploring whether mobile learning could help students to collaborate over distance to maintain students' communication and collaborative learning activities despite the lockdown. In a study with the biomedical technology department, mobile technology was used to facilitate group work during experiments in the lab. It allowed students to stream the experiment activity to their peers in real-time, making direct interaction possible, such as discussing problems during experiments or solving technical issues collaboratively. In a study with applied mathematics students, smart pens and tablets allowed the students to collaboratively work on a proof, while being seated in different rooms. This study, see project MultiMath above, reveals that proof writing over distance could be beneficial also as a regular setup, because the students spend more time on discussing their overall planning, and use handwriting as a reasoning tool for communicating ideas. More information can be found on the project page on the Innovation Map.



ALEXANDER SCHUELER-MEYER

"4TU.CEE provided me with an opportunity to conduct ground-breaking research in a cross-disciplinary setting, with immediate impact in courses at TU/e."

Graph Checker-Tool support for structured drawings in automated feedback and assessment

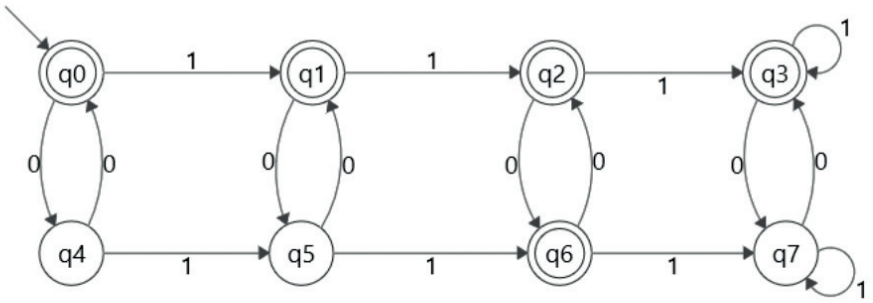
Many fundamental concepts, design methods, and transformational techniques in Computer Science and related disciplines are based on discrete combinatorial structures. Examples of these include graphs and finite-state machines in Computer Science, Markov chains and polyhedrons in Mathematics, business process languages and entity-relation diagrams in Economics, or even concepts like evolutionary trees in Biology.

The key idea of the GraphChecker project was twofold. First, in order to offer an intuitive way to test the learner's understanding of structured drawings, the ability to physically

Enter a DFA for the language $\{ w \in \{0,1\}^* \mid \#_0(w) \bmod 2 = 0 \vee \#_1(w) = 2 \}$, i.e. the language of strings of 0's and 1's with and even number of 0's or exactly two 1's.

Answer:

Reset answer



Check

	Test	Result
✔	Language equivalence (to word list)	Correct!
✔	Is deterministic	Correct!

Passed all checks! ✔

Correct

Marks for this submission: 1.0/1.0.

manipulate them as drawings was required. Second, due to the structured nature of the drawings itself it has been possible to create open-ended exercises with the automated grading accuracy of closed-format questions such as multiple-choice questions. More concretely, in the project the team could provide a graphical user interface within the learning management system where learners could directly draw their solutions. The structure of the drawings was captured behind the scenes and the answers of the learner could be encoded for subsequent automated processing. In particular, the researchers focussed on the case of finite state machines as taught in the course Automata, Language Theory & Complexity in the Bachelor Computer Science & Engineering at TU/e. The end product offered options for automated testing in both the formative and summative setting. Compared to more traditional methods such as multiple-choice exercises, the development of open-ended exercises based on structured drawings required teachers to be less concerned with the effects of guessing and weak distractors, and required a higher level of cognitive understanding of learners.

The plugin was and is maintained by the Education Innovation group (EdIn) of the Department of Mathematics & Computer Science, to maintain the plugin for structured drawings in OnCourse, thus assuring sustained availability. Within the scope of the project, the system has been used in the automata course and for learning and assessment by students and staff involved. Beyond the project scope, there is interest in the system from several courses of the Computer Science and Mathematics curricula. After a successful trial in the academic year 2021 in the automata course, the use of GraphChecker was continued and extended. More information can be found on the project page on the Innovation Map.

BULB: Bright Use of the Light Board

Learning to do mathematical proofs requires examples of good practice as well as guidance to the learner in attempts to construct a proof independently. In written material the construction directions are often either mingled with the proof itself or simply missing. With a video, these two threads could be kept separate. However, filming a person writing on the blackboard (or whiteboard for that matter) is not easy, not only because of lighting but also because of the uninviting position of the person writing on the board. Also writing on paper or a tablet makes the learner to feel distant from the teacher. The so-called light board, recently acquired in the web lecture studio of TU/e, is a viable alternative for filming a teacher writing on the blackboard. The light board avoids expensive post-processing of footage, but didactically speaking more importantly, allows to mimic the proximity of teacher and student. An additional advantage of the approach is that the teacher is in her normal modus operandi, standing in front of the board. More information can be found on the project page on the Innovation Map.

Activities regarding engineering educational ecosystems: the Learning Spaces Tour

Next to projects and research on engineering educational ecosystems, TU/e also contributed to joint 4TU.CEE activities on this topic. In January 2019, 4TU.CEE started the Learning Spaces Tour cycle with visits to AMS/UT/TUe/WUR and ended with an online session in 2020 with the Aalto Design Factory (hosted by TU Delft).

The goal has been to learn more about learning/maker/innovation spaces within higher education. Each institution has shown a strong integration of science, education, government, business partners and social organizations to create inter/ transdisciplinary and sustainable solutions for complex challenges in the metropole of Amsterdam, Wageningen, Eindhoven, Enschede or Helsinki. Learning spaces tend to spur the rapid development of innovation ecosystems. This is all realized in a non-hierarchical, constantly developing collaborative environment in which students, teachers, researchers and business practitioners across hierarchical, professional and disciplinary boundaries work together. TU/e has developed the innoSpace and a challenge-based education vision. Different frameworks of learning space learning have evolved, some learning outcomes have been identified, and staff training is being considered. The Learning Spaces Tour has inspired teachers, support staff and policy makers on how to realize their best possible learning space ecosystems. In total, the Learning Spaces Tour has been attended by around 200 participants.


webinar
educate future engineers
projects
events
activities
4TU.CEE
TU/e
challenge based learning
responsible engineering
innovation map
ict enhanced education
applied physics
educational ecosystems
entrepreneurial learning
interdisciplinarity
mathematics
esoe
innospace
teaching excellence

4. Teaching Excellence in University Engineering Education

Introduction

Teaching quality is said to be key for achieving the ambitious goals of student-driven and student-centred (interdisciplinary) education. Teachers need to be facilitated in their professional development to achieve these goals. Moreover, educational excellence is often confined to 'pockets': good practices are confined to one programme or department and very often not shared amongst departments and universities. This means that creating opportunities for teachers to collaboratively reflect on, further develop and share knowledge and practice-based research to promote educational innovation is very important. At the same time, teaching and other education-related activities also need to be recognized and rewarded.

At TU/e, recognizing and rewarding of teaching staff is an important theme, and 4TU. CEE at TU/e has actively contributed to local, regional, national and large international projects (e.g., those led by Ruth Graham). All the projects in this progress report are an outcome of stimulating teacher development and creating opportunities for teachers. 4TU.CEE at TU/e contributes financially to these projects, e.g. by coaching, creating dissemination opportunities and connecting projects at TU/e and beyond between the 4TUs. The project below started in 2019 and continues into the current strategic period. It is different from the other projects as that it is part of a large (inter)national research project (led by Ruth Graham).

Teaching Cultures Survey

(amended from the Graham 2022 report)

The Teaching Cultures Survey (TCS) is a global collaboration of universities committed to improving how university teaching is supported and rewarded. The TCS has been conducted in 2019 (TCS 2019) and 2022 (TCS 2022); a third survey is scheduled for 2024/25. Through an online survey administered at the participating universities, the TCS captures perspectives of the academic community on: (i) their institution's teaching and learning environment; (ii) the institutional commitment to university teaching; (iii) the status of teaching in key institutional processes; and (iv) expectations and desires for change.

Eindhoven University of Technology (TU/e) is one of 16 universities participating in the TCS 2022. Nearly 500 members of its academic community took part in TCS 2022, ranging in seniority from PhD students to university leaders. The report summarises findings from TU/e's 2022 survey; and comparisons are made with findings from its TCS 2019. Additionally, TU/e's findings were compared with the amalgamated findings from all 16 universities participating in TCS 2022, and with the smaller group of 13 universities that participated in both TCS 2019 and TCS 2022.

Overall, findings from TU/e compare favourably with global peer institutions in most areas of focus for the TCS. In addition, TU/e findings point to positive signs of change since 2019 in the status of teaching in key institutional processes and in the support for change. However, perceptions of the institutional culture as one that does not reward university teaching persists amongst many academics.

challenge based learning

educational ecosystems

responsible engineering

5. Entrepreneurial Learning or academic entrepreneurship

Introduction

This theme is about the entrepreneurial context of engineering, an entrepreneurial mind-set/attitude, and entrepreneurial or innovation skills: skills such as creativity, opportunity seeking, creating value, risk taking, leadership and self-management skills. 4TU.CEE at TU/e stimulates the embedding of entrepreneurial skills in teaching and assessment. TU/e is currently participating in the joint 4TU.CEE project headed by Frido Smulders (TUD, in collaboration with Isabelle Reymen, TU/e) through the projects below.

Educating the Entrepreneurial Engineer

4TU.CEE started up the joint Entrepreneurial Engineer project team in 2020. The aim is to ignite the entrepreneurial mindset among all 4TU engineering students by entrepreneurship education, and to challenge them to be flexible and create multiple value (i.e., economic, social and/or ecological) in close collaboration with stakeholders. The project team works on three concrete activities: (1) developing a theoretical framework as conceptual ground for defining entrepreneurship education; (2) formulating fitting learning goals; and (3) conducting an inventory of existing entrepreneurship education programmes at the 4TUs. In 2021 a brochure has been made of the inventory, showing inspirational practices. In 2022, the project team is eager to develop and investigate educational interventions, progression lines, and a train-the-trainer programme on entrepreneurial teaching. The team has started a joint PhD project as well as a joint post-doc project around these ambitions. Moreover, the team is considering creating a platform for discussing ideas in order to use and expand the materials. More information can be found on the project page on the Innovation Map.

Entrepreneurial learning

This PhD project is conducted together with WUR and emerged from 4TU.CEE's ambition (see earlier) to educate future engineers with an entrepreneurial mindset, to enable them to deal with grand societal challenges as recognized by the United Nations in the Agenda 2030 and specified towards the Sustainable Development Goals (SDG). These grand societal challenges require that engineering students are educated as T-shaped and responsible, so they develop skills not only focused on technical expertise but also on developing an entrepreneurial mindset allowing them to shape solutions with different actors (e.g. peers, teachers, stakeholders) in an iterative process of multiple value-creation that is spiced by uncertainties. The value that is being created to address the SDGs should be sustainable per definition and can be economic, social, environmental, cultural, or a combination of these.

To embed the development of an entrepreneurial mindset in engineering degrees, technical universities require education materials, modules and courses on entrepreneurial engineering for sustainability. These need to be designed using a wide entrepreneurship approach, which is focused on learning through entrepreneurship - providing entrepreneurial skills and attitudes in the context of multiple value creation. The main purpose of this PhD project is to develop evidence-based materials for education, facilitating the students to develop towards the entrepreneurial engineer for societal impact. Different steps have been outlined to reach this goal. First, based on the literature and via interviews, the profile of the entrepreneurial engineer will be created. Second, the effects of existing (wide) entrepreneurship education interventions for engineers will be tested. Third, new interventions to foster the entrepreneurial engineer will be developed, tested and monitored. More information can be found on the project page on the Innovation Map.


webinar
entrepreneurial learning
activities

6. Educating for responsible engineering/ the ethical and responsible engineer

Introduction

This theme was initiated in 2022 and is focused on ethical and sustainable behaviour competences in engineering education. The goal is to motivate engineering students to deal with ethical issues. Engineering and technology specific topics (e.g., social media, AI, robotics) are challenged with ethical questions; this is done in collaboration with other 4TU initiatives (e.g., 4TU.Ethics; 4TU Sustainability Challenge for honours students 22/23). For this theme 4TU.CEE at TU/e works closely together with the TU/e ambassador for sustainability.

Sustainability in TU/e education

The need to educate TU/e students for sustainability is emphasised by the university. The project team plans to enhance curricular education on sustainability and global challenges for all TU/e students. The overarching goal is to provide students with theoretical knowledge, practical skills and critical thinking regarding systemic change and sustainability. Students are expected to integrate these aspects in their studies, projects and later careers. The project is ongoing.

The first phase (= first year) of the project has focused on an investigation of how the current state of the university is in terms of sustainability education, and to outline the possible courses that contain Sustainable Development Goals (SDG) to students. Moreover, a study is being conducted on what students of the future need to learn in their education. More information can be found on the project page on the Innovation Map.


interdisciplinarity
interdisciplinarity
interdisciplinarity
interdisciplinarity

7. ICT enhanced education and the digitally literate engineer

Introduction

This theme consists of two strands: (a) ICT enhanced engineering education: this includes flexible and personal learning paths of learners, blended or online solutions for teaching and learning, especially for engineering specific activities such as lab education, excursions, collaboration in augmented or virtual reality, post Covid-19 hybrid education; (b) digitally literate engineers: this includes digital literacy and information skills, using digital tools to design or test solutions, and digital collaboration; the future role of computer science and mathematics; relevance of data security and privacy.

At TU/e, 4TU.CEE has worked closely together with the 'BOOST' program for this theme. The BOOST program supports ICT-related course innovations by teachers and 4TU.CEE at TU/e complements this by focussing on research by teachers with respect to ICT enhanced engineering education in their courses and in terms of digitally literate engineers. This theme has been initiated in 2022 and is ongoing.

PAELLA

The PAELLA (Personalized Activation in Education leveraging Learning Analytics) project is still ongoing. It develops and tests a new learning design in different bachelor courses. Within these courses, the team uses click-stream data from the Learning Management System (LMS) to push forward personalized educational interventions in the bachelor program. For selected students with a backlog in their online learning, the team will offer appropriate (mindset) interventions that are expected to stimulate students' self-regulation in learning. For this, the following challenges are addressed:

1. How can the LMS data be utilized in a scalable way to differentiate between students who are on track and those who lag behind in their learning?
2. How can personalized interventions be designed, and applied personalized interventions in LMSs be conducted that activate students and stimulate them to better self-regulate their learning in an engineering context without increasing the teacher's workload?
3. How can students be tracked in a way that students' privacy is guaranteed and that they do not feel threatened during online and blended learning?

More information can be found on the project page on the the Innovation Map.

challenge based learning

8. Challenge Based Learning

Introduction

An important change at TU/e has been the emphasis that Challenge Based Learning (CBL) has taken as an educational method at TU/e. 4TU.CEE has contributed to several projects concerning the development of and research in CBL, and it will continue to do so in the coming years. Together with colleagues from TU/e innoSpace and different departments at TU/e, 4TU.CEE at TU/e supports projects that investigate the benefits, affordances and constraints for students, teachers and other stakeholders in our society.

These projects vary from a framework for measuring learning gains in CBL courses, to research on CBL educational practices in hard-core engineering studies like mathematics and physics. Other examples include defining challenge-based tasks for fundamental knowledge acquisition, and the development of associating professional skills, of (interdisciplinary) Challenge Based Learning courses, and research on learning experiences of students.

Student Learning Experiences

In the TU/e vision on education in 2030, CBE plays a central role in educating the engineers of the future. There have been several studies on this issue, TU/e wide and within selected departments/faculties (see Innovation Map). It appears that for some faculties CBE is the natural next step in their education innovation, whereas for others innovating their curriculum towards CBE seems to need more time, consultation and experimentation. The reasons for that might be varied, but it is clear that some disciplines find it harder to prepare their education along the CBE line than others.

Until recently, this situation also applied to the applied mathematics and physics departments. At the same time there are at present many promising master courses in the applied mathematics and physics departments that lean on a CBE approach. Moreover, in the large first year courses, mathematics and physics are trialed (within a small group) along CBE lines.

Here it is where the student learning experiences project connects: to support the mathematics and physics engineering disciplines to provide their education in terms of CBE. In order to do so, it is necessary not only to listen to the TU/e-wide vision statements, but also to the instructors' and designers' voices (airing their perceptions in terms of affordances and constraints of CBE and its enactment/implementation within the university system), and most importantly, to the students' voices concerning their learning experiences, including benefits and needs, on CBE courses.

As there is already much experimentation with CBE from teachers in specific courses in mathematics and physics, it is important to understand the participants' experiences, in particular student experiences, in these innovative learning environments. This is done in order to know how students can be better supported in these environments. In other words, this research seeks a bottom-up approach, in order to turn the visions into sustainable reality.

In this study a case study approach has been used, and mixed methods within the cases, to investigate students' learning experiences in three selected TU/e courses and environments: (1) a course for mathematics and/or physics students in an early stage of their Bachelor programs; (2) a course at the end of the Bachelor program; (3) a Master

course for mathematics students, the mathematics 'Modelling week'. These courses (and environments) have been purposefully chosen, as (a) they all use a CBL approach; and (b) they are courses at different levels of students' education trajectory.

As preliminary results corresponding to the Modelling week, the following has been highlighted: (a) the crucial importance of human resources (e.g. problem owner and tutors) for such learning environments to link the mathematics to an authentic situation, and (b) to develop the skills of an 'applied mathematician in the real world'. Moreover, an analysis of the degree of achievement of learning and professional objectives (based on the interaction between problem owners and tutors with students) has been conducted. More information can be found on the project page on the Innovation Map.

Control & Semi-autonomous driving as Challenge Based Education

In this project Challenge Based Learning for Control & Semi-autonomous driving has been explored with interdisciplinary groups. Students were enabled to learn about, and to get hands-on experience, with real-life challenging control problems present in semi-autonomous driving. The pilot has been embedded into the curriculum of students who were doing their master's in either the Electrical Engineering, Automotive Technology, or the Systems and Control master's program. For this group of students, working in a team on a complex control problem that interfaces with real societal issues has been be a valuable addition to their curriculum. More information can be found on the project page on the Innovation Map.

Design your CBL: online reflective support to design CBL education

The second 'design your Challenge Based Learning' project (dyCBL-II) is currently coming to an end. The goal has been to support teachers in their thinking, reflecting and designing Challenge Based Learning ´courses´. While the first project offered a rich and very open but unstructured online and 'paper and pencil' tool, the second project offers the possibility of more structure and targeted support.
Like a classic computer game, the product of this second dyCBL project offers several 'levels.' Each level presents a scenario of CBL design focused on an aspect that teachers found difficult. The scenarios varied in complexity and some fitted specific interpretations of CBL in different departments.

The scenarios followed a structured approach to designing CBL instruction. However, this structure wass less strict for the advanced levels. For the different steps in CBL design, the tool offers a series of alternative choices for each of the key functional elements of CBL instruction, such as learning objectives, scaffolding, teacher guidance, and assessment. Teachers could play with these different options offered, or add new ones of their own, enhancing their thinking about CBL and student learning. In particular, the tool gives experimenting teachers open feedback about the potential impact of these design choices on student learning, and suggestions for how to proceed. Feedback and suggestions were always formulated in an open and inviting manner, as the goal was to support teachers' thinking about CBL and their design of CBL. The tool's release is planned for in January 2023. More information can be found on the project page on the Innovation Map.

Scaffolding challenge-based teaching in different educational contexts through Lesson Study

In this project, the aim was for teachers to collaboratively design, redesign and evaluate lessons based on ideas of scaffolding student-regulated learning, thereby boosting the adaptation of mostly teacher- centred lessons or courses into more personalized, student-centred learning paths stimulating students to developing their talents. To achieve these goals, five lesson study teams of teachers in the context of higher education as well as secondary education have worked collaboratively on their shared goals, supervised by a facilitator from the project. Results show how increasing student regulation is related to increased student ownership and motivation.

An ongoing learning process from secondary to higher education was found particularly in the scope of the activities students could regulate, moving up from a single activity within a lesson to working on a project to guiding ones learning process in general. To support students' learning process of increasingly being able to regulate their own learning, teachers are well advised to keep some teacher regulation, while slowly fading it out. For teachers, this is a learning process in itself, for which lesson study seems to be a relevant tool. However, for lesson study to be successful, time proved to be essential, as well as a team of teachers who preferably teach the same or similar subjects. More information can be found on the project page on the Innovation Map.

Challenge Based Learning Webinar Series

In spring 2021, 4TU.CEE started a webinar series on Challenge Based Learning at the 4TUs. Each of the 4TUs researches different questions related to CBL realized at their institution, and CEE at the four universities brought these together in the webinar series on CBL best practices, to share the mutual knowledge within the 4TUs and beyond. The CBL research community at TU/e has actively contributed to several of these webinars and has always been well represented as participant of the webinars. The series will be continued with a mix of national and international guests on embedding CBL from a policy perspective sin the months to come. A spin-off of the initiative has been the close collaboration and knowledge exchange between the 4TU. In July 2021, the 4TUs have given a joint seminar at the Dutch Educational Research Days.

Publication: Eindhoven University of Technology - Authors: 4TU.CEE team at TU/e (prof. dr. B. Pepin, drs. C. Vonk) - Cover photo: Bart van Overbeeke Photography - Design and layout: H. Slingerland BNO