Progress Report 4TU.CEE 2019-2021

Innovating Engineering Education for the future

TU Delft Delft University of Technology

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

UNIVERSITY OF TWENTE.

WAGENINGEN UNIVERSITY & RESEARCH
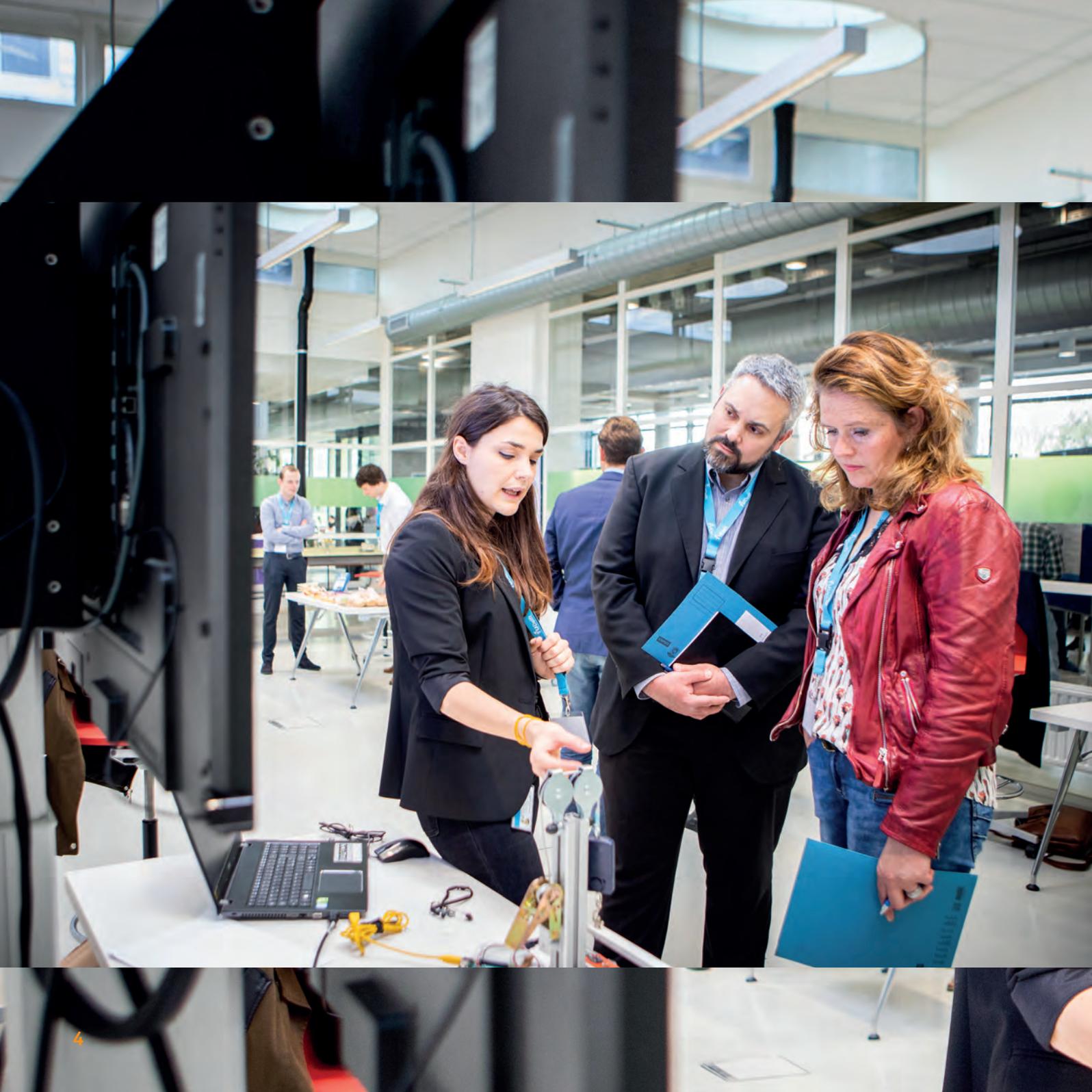
4TU.

4TU. CENTRE FOR ENGINEERING EDUCATION

4TU.CEE

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Introduction

Well-respected Partner

During the past years, the 4TU.Centre for Engineering Education (4TU.CEE) has grown into a recognised centre with expertise on 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 beyond. Dutch and international partners are eager to collaborate, either in the implementation of innovations or in their evaluation and dissemination of results. International partnerships were strengthened. 4TU.CEE was involved in the organisation of large conferences and workshops, such as the 2020 SEFI conference and the 2018 international CDIO meeting. At the same time, the number of activities, such as workshops and webinars for 4TU teachers, has been growing steadily. International scholars were invited to enrich the 4TU teaching community and share best practices.

4TU.CEE was successful in obtaining several research grants and during 2018-2021 the first 4TU.CEE funded PhD students finished their dissertations. The centre became a national leading example with its work in career frameworks and teaching excellence based on a longstanding collaboration with Ruth Graham. The 4TU.CEE innovation map was recognised as a good practice of knowledge infrastructure. Over the years, both practical tools as well as scientific publications have been produced.

4TU.CEE project topics varied widely from teaching excellence to interdisciplinary 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 on this topic.

Personnel Changes

Several changes have occurred over the past years in 4TU.CEE leadership. Dr. Jan van der Veen (University of Twente) stepped down as UT leader of 4TU.CEE in 2020. His leadership was taken over by dr. Cindy Poortman. Ineke ten Dam stepped down as 4TU.CEE coordinator at UT, and Chris Rouwenhorst returned in this position. At TU/e, prof. Birgit Pepin (leader of 4TU.CEE at TU/e since 2017) temporarily handed over leadership to dr. Antoine van den Beemt and dr. Alexander Schuler-Meyer between April-December 2020, then picked it up again in January 2021.

At TU Delft, ir. Aldert Kamp stepped down as 4TU.CEE leader, leaving the centre with a nice visionary document 'Navigating the landscape of higher engineering education'. Prof. Marcus Specht and dr. Remon Rooij have taken over as new TUD leaders.

Future Perspective

4TU.CEE has launched its strategic plan for 2022 - 2025. In this period, 4TU.CEE will focus on five topics:
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.

The 4TUs will continue to collaborate intensively either by bringing together findings of separate projects or initiatives or by initiating joint projects. We will organise joint professional development activities, such as (recently) the CBL webinars and Learning Spaces tours.

4TU.CEE will further expand its international activities. Where prior strategic periods mainly focused on establishing 4TU.CEE locally and nationally, in recent years we have become more active internationally by writing peer-reviewed articles in international journals. All 4TUs will actively continue participation in CESAER, SEFI, CDIO and our involvement in the international PhD symposium for engineering education together with KU Leuven and the University of Western Australia. Our longstanding collaboration with Ruth Graham on rewarding teaching excellence will continue.

4TU.CEE aims to organise at least one large conference or international meeting, and strives to apply for a European or international grant/project. Our collaboration may well extend to outside Europe, as we have good contacts in Australia, China, Singapore and the US. The University of Twente will organise the SEFI Deans convention 2023 together with 4TU.CEE.

Research on IT in engineering education will continue to remain an important topic. During the past strategic period, studies were started on the transition to online education during the COVID-19 period. The studies' findings have been merged into a white paper containing recommendations for higher engineering education. We will continue to innovate and conduct research through 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.

We aim to contribute more to university policy and leadership by providing input in strategic discussions, writing policy papers, or organising inspiration sessions around topics. Students will be involved in our projects as assistants, via lunch meetings and via theses or internships.

Finally, a word of appreciation goes to the dedicated 4TU.CEE leaders and programme coordinators. I would also like to thank all university staff and national and international partners of 4TU.CEE. We look forward to continuing our collaboration with you in the upcoming years!

Prof. Perry den Brok, chair of 4TU.CEE

In the pages that follow, you will read a selection of activities and projects, conducted during the period 2019-2021.

These activities and projects are structured under the following themes: *(1) educating future engineers, (2) interdisciplinary engineering education, (3) engineering educational systems and (4) teaching excellence in university engineering education.*

For each theme, we will provide a short description of the theme and a selection of flagship activities conducted under that theme. A more detailed overview of activities and projects, as well as people involved in them, can be found in the 4TU.CEE innovation map, and the TU Delft and WUR project overview reports.

In the appendices of this report, an overview of impact and output indicators is given, as well as an overview of 4TU.CEE postdocs, PhD researchers and master theses conducted in the last strategic period. To keep track of interesting 4TU.CEE activities and project results, we invite you to subscribe to our newsletter and visit our 4TU.CEE blog, as well as, of course, the 4TU.CEE website!

4TU.nl/cee

1 Educating Future Engineers

Introduction
This theme deals with different engineering profiles and the development of the professional identity of engineers (from technical orientation to more entrepreneurial or societal orientation) 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, such as digital literacy skills, boundary crossing skills, entrepreneurial skills and creative and critical thinking.

Skills Learning Trajectories at the Bachelor Level
At Wageningen University, bachelor programmes started implementing learning trajectories for academic skills. The university is in the process of implementing a much wider set of skills, ranging from 'dealing with diversity' to 'entrepreneurial skills'. In this project, postdoc Claire Goriot and her project team investigated what educational design choices were made in constructing learning trajectories, and what stakeholders' experiences with the trajectories are, by 1) conducting a systematic literature search and 2) interviewing skills learning trajectories coordinators and educational directors. Both activities showed that a variety of design choices and success and risk factors exist, relating to multiple domains of the educational programme. Also, teaching staff and students were interviewed about their experiences. The insights of this project may help to make recommendations for programmes inside and outside WUR that want to implement learning trajectories in the future.

The Entrepreneurial Engineer
4TU.CEE started up the Entrepreneurial Engineer project team. It is their aim to ignite the entrepreneurial mindset among all 4TU engineering students by entrepreneurship education. 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 is currently working 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. 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 is now preparing two joint PhD projects around these ambitions and thinking about creating a platform for discussing ideas in order to use and expand the materials.

PROJECT TEAM

"It is our aim to ignite the entrepreneurial mindset among all engineering students through entrepreneurship education."

USE Learning Lines
At TU/e the USE learning lines (User, Society and Enterprise) are essential courses in educating our future engineers. These courses are under continuous development. After intensive research funded by 4TU.CEE the basic course on ethics was fundamentally redesigned using flipped-classroom and challenge-based learning. Results show that intrinsic motivation, autonomy and competence are significantly higher in the co-creation case compared to the other approach not using challenge-based learning.

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.

Edu - Hackathon

In October 2019, an education hackathon challenge was organised by 4TU.CEE with support of LDE/CEL and the TU Delft Teaching Academy. In 24 hours, the future of education was co-created with students, innovators and educational enthusiasts. The hackers worked on four challenges introduced by lecturers of TU Delft. Educational and business mentors supported them.

The challenges were: 1) How can we ensure individual students pass all learning goals in group work? 2) How can we track the team performance of student groups with the input of students and coaches? 3) How can students take control of their learning process? and 4) How to support teachers in developing serious games good and quickly? The winning team designed a 'Teacher's Toolbox', a highly customisable online platform that lets lecturers create their educational games and share them with their peers. They explored start-up possibilities at YES! Delft. A handbook for organising similar hackathons is available on request at 4tu.cee@4tu.nl.

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."

FACILITATOR EDU-HACKATHON

"The students were also very positive about the hackathon experience. They found that the challenge opened up their minds to new ideas and learned that if you set a goal, nothing is impossible. They also highly valued the feedback from the mentors."

Well-being Strategies to Reduce Stress in Design Education

Teaching physical design skills has long been the main building block of the bachelor curriculums at the TU Delft faculties of Industrial Engineering (IDE) and Architecture & the Built Environment (ABE). We observe that the IDE and ABE students achieve high level (design) competencies during their study time at TU Delft. But we also observe that design education too often goes together with over aroused students and (over)ambitious teachers, leading to higher levels of student stress.

It goes without saying that this results in (the threat of) underperforming students, increased levels of student drop outs, and increased levels of student burnouts. This project contributes directly to the TU Delft agenda on study climate and student well-being, in which the executive board is looking for strategies to create both an ambitious and (mentally, physically and socially) healthy learning environment for students. This project will deliver a series of teaching guidelines for our staff and learning guidelines on Healthy Challenging Design Education.

Reflective Engineering

In 2021, TU Delft has started a project on embedding the vision of the future roles of engineers in the Challenge-based Education Master Programme of the Bio Medical Engineering Masters. The students make a reflective journey through their personal, educational and professional learning experiences in challenge-based education, based on their engineering role. The iterative reflective journey should result into a portfolio dashboard of their personal development and a network in the biomedical field.

The first course has started in September 2021 and will be evaluated on the development of professional skills and impact on personal growth. Additionally, a framework will be delivered with guiding principles on developing the entire master programme with the same principles. This project is a co-creation between the teaching staff of the Master BME, 4TU.CEE and Reframing Studio.

More background information is available in the report: Engineer of the Future.

SEFI2020 @ UT

Highlights of 2020 were the SEFI Doctoral Symposium on 20 September and the SEFI 2020 Annual Conference from 21-24 September, organised by the 4TU.CEE and hosted by the UT and Saxion University of Applied Sciences. The SEFI annual conferences are scientific conferences focused on engineering education and they are the largest events of this type in Europe. Engaging a growing group of young people to embark on an engineering career is what both the SEFI conferences and the 4TU.CEE aim for. Travel restrictions, national event rules and health considerations forced us to organise the event online.

Nevertheless, it was a huge success. Participation numbers were as in previous on-campus SEFI conferences and we had more participants from countries that otherwise could not have participated. We can conclude that we managed to keep the SEFI community very much alive.

The theme of the conference was 'Engaging engineering education'. Four keynotes set the scene: Greet Langie on student career development, Pierre Dillenbourgh on virtual and augmented learning environments, Gerard van der Steenhoven on what COVID-19 teaches us about climate change and Ruth Graham on rewarding teaching.

In addition to a variety of other international and national contributions, many of the 4TU.CEE funded projects were presented. In total, 4TU scientists offered 40 paper and poster presentations and organised or contributed to 11 workshops and 3 symposia (see appendix 4). The conference attracted 365 participants.

View the SEFI proceedings.

PARTICIPANT

"...I missed the informal contacts. But the pre-recorded presentations were fantastic (...). Also, some were so good they blew me away, and it will be very nice to have them online after the conference..."

2 Interdisciplinary Engineering Education

Introduction

Interdisciplinary education continues to be one of the key themes of 4TU.CEE. Engineering education is becoming 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 is also about learning to collaborate with teammates with a different cultural background or ethnicity. Research has been done how interdisciplinarity can best be organised in learning activities, curriculums and assessment.

Structuring Interdisciplinary Projects for Engineering Students (STRIPES)

The STRIPES Comenius Leadership project at UT supports teacher teams in designing and redesigning their inter-disciplinary (ID) modules in a structured and evidence-informed way. Students are involved via participatory design. The project is at the core of the UT strategy concerning interdisciplinarity and challenge-based learning.

Five interdisciplinary modules were thoroughly investigated. Three master students (Coralie Johnson, Nikola Petrova, and Niveditha Uthrapathi) focused on these modules in their final project. PhD student Xin Ming is also conducting case study research, focusing on the intersection of engineering and humanities. So far, the main outcomes of the research show that both staff and students experience the benefits of interdisciplinary competencies. However, while student-driven learning is advocated, support (scaffolding) remains necessary. Proper support of ID teamwork is important, as is the careful design of ID problems and challenges.

Teacher-team cohesion and acting as a role model for the student teams with respect to how interdisciplinarity can

be executed are also essential. An open-source ID toolkit with a collection of best practices, a handbook and other relevant information will be made available.

Photo Marte Hofsteenge

Boundary Crossing @ WUR

The Comenius Leadership project 'Boundary Crossing (BC) as modus operandi at Wageningen University' has been running since 2018. Project leader Arnold Bregt, a core team, and four Bachelor Pilot programmes (Animal Sciences, Environmental Sciences, Food Technology and International Land & Water Management) are working on BC-learning outcomes, activities, assessment and alignment thereof in learning trajectories. BC is becoming a cornerstone at WUR. In an inspiration session in April 2021, a BC portfolio for MSc students (MSc Biobased Science), BC in online education (Agricultural Water Management MOOC) and a BC in a new MSc programme (Data Science for Food & Health)

were presented as some of the examples. This session brought together many WUR colleagues from various departments, levels and functions. Now in the last phases of the project, the core team is working on disseminating BC WUR-wide and compiling a toolbox of BC-learning activities and materials. The team is also evaluating the innovations in the pilot programmes' courses, a BC Teachers' Training, and will come up with a plan to further embed BC in the genes of WUR, ensuring its continuity after the project ends.

ARNOLD BREGT

"I was impressed by the participants' creativity and positive energy. I saw many nice examples of boundary crossing implementation. We seem to advance from a project to a movement! Apparently, lecturers gain energy from working with boundary crossing. I also noticed that relatively simple learning activities can have a big impact. Boundary Crossing is at the core philosophy of Wageningen University education and we need to further elaborate on it."

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 done 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 current project, interdisciplinarity is studied within challenge-based courses in the TU/e Innovation Space. Results suggest that students learn 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, despite challenges being open-ended and ill defined, students are in need of clear-signposting and structure for their learning process. Teachers are in need of support in scaffolding and assessing interdisciplinary student efforts.

Assessment Practices in Inter-Programme Challenge-Based Learning education

Ana Valencia and TU/e colleagues have conducted research 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 is 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 also has defined a set of intended learning outcomes for ISBEP, to be used as starting point or inspiration in the design/implementation of assessment practices and learning activities in these and similar contexts. Currently, the project is focused on the design and evaluation of assessment tools (e.g., rubric) and procedures for ISBEP, emphasising assessment as learning, a tool to foster the development of students.

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."

The Joint Interdisciplinary Project

In 2019 and 2020, the Joint Interdisciplinary Project (JIP) at TU Delft became a proven concept and scaled up to 200 students and 58 companies and (semi)-governmental institutes, such as hospitals and TNO. The student body is currently extended to Leiden and Erasmus, allowing for a wider interdisciplinary challenge definition and team and growing impact in technology and innovation. Despite the COVID-19 pandemic, last year's group has had a good learning experience, with group support for community and cohesion via podcast and at a distance physical meetups. Some of the groups have received funding for the continued development of their proof of concept, such as the Embraer Team. Their project is selected for the Ambitious Idea grant by FAST University Fund TU Delft.

For the Joint Interdisciplinary Project, the team was assigned by Embraer to design a system to combat the waste problem in the Municipality of Ulundi. Within ten weeks, the team designed a facility that employed locals to collect and recycle plastic waste into structurally sound bricks. Their solution is cost-efficient, financially independent and ventured out in order to make this reality!

Like previous years, the project results have a relatively significant impact on in-company /organisational R&D. JIP has also been nominated by the TU Delft Board for the SEFI Maffioli prize 2021 for Pedagogical Innovation in Engineering Education. The pedagogical concept of JIP will be embedded in a handbook for designing interdisciplinary learning. It is based on the experience with JIP, interviews with 20 experienced TU Delft lecturers and several papers published on this topic in Delft and in collaboration with the other 4TU partners.

"I would like to say that JIP was an experience I was fortunate enough to have. We learned various things such as camaraderie, communication, professionalism, and time management, among others. It was a great opportunity and a perfect incubation centre to hone my skills. Things I learned here, like collaboration, innovation, and team building, I couldn't have learned in the classroom, and I am glad about my choices. This exposure has broadened my mindset and thinking, and I am grateful for it. Despite the current situation of a pandemic that we find ourselves in, it was a delight. Thank you, Staff!"

Interdisciplinarity / Challenge-Based Learning

Interdisciplinarity is at the heart of education at the UT. All bachelor programmes consist of project-based modules in which several disciplinary subjects are taught that are applied, integrated and studied in depth in the projects. In the master programmes interdisciplinary projects and case studies are also common. Development of soft skills is integrated, such as cooperation and interdisciplinary skills and critical thinking, as well as ethical thinking and entrepreneurial skills. Apart from the STRIPES project, 4TU.CEE has supported several initiatives and projects.

Over the last few years, challenge-based learning (CBL) as a specific form of interdisciplinary and project-based education has been growing fast. At the UT, it started with the pilot in 2018 done by Raymond Loohuis. Together with 4TU.CEE, a seminar was organised to disseminate the experiences, and since then the role of CBL has expanded rapidly, actively supported by 4TU.CEE. At the UT, CBL has been included in the new UT Strategic plan, and many teachers experiment with CBL. The first cohort in the 4TU.CEE pilot of Teaching & Learning Fellows focuses on the implementation of CBL. UT is the leading university of an EU consortium working on the establishment of a CBL-based European university. 4TU.CEE has chosen CBL as one of the four strategic focal points for the next strategic period 2022-2024.

INTERMEZZO
CBE Webinar Series

In spring 2021, 4TU.CEE started a webinar series on challenge-based education at the 4TUs. Challenge-Based Education (CBE) is one of the main strategic topics at 4TU.CEE. Each of the 4TU researches different questions related to CBE realised at their institution, and the centre is closely involved in the CBE best practices. To share our mutual knowledge within the 4TUs and beyond, we have started a CBE webinar series. The series initially shared best practices on:

- Formulating the Challenge with stakeholders (TUD)
- Interdisciplinarity in CBE (UT)
- Innovation spaces and the CBE curriculum format (TU/e)
- Professional skills for CBE learning (WUR)

Currently, the series evolves from a national to an international level, from best practice to policy and research. Anette Kolmos from Aalborg University, who has extensive experience with problem-based learning and institutional change in higher education, was our first international guest.

We will continue the series with a mix of national and international guests on embedding CBE from a policy perspective and a research perspective in the months to come. A spinoff of the initiative is the close collaboration and knowledge exchange between the institutions.

In July, the 4TUs have given a joint seminar at the Educational Research Days, a scientific, educational research platform in the Netherlands. Hopefully there are many more to come in order to increase collaboration on the research issue of CBE/CBL.

3 Engineering Educational Ecosystems

Introduction

Modern engineering education contexts allow for multiple stakeholders, links to society, learning at multiple locations and using ICT in a smart way to support for this. 4TU.CEE 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. 4TU.CEE also initiated a white paper that reflects on what the COVID-19 pandemic has brought to our education system. View the intermezzo: COVID-19 Teaching and Learning in this report for more information.

Digitalisation of Education

In the field of engineering educational ecosystems, various projects have taken place at UT on the digitalisation of education. There has been a wide range of topics and smaller projects:

- Experiments with virtual reality to improve presentation skills for students. This has led to various master theses (see appendix 3)
- A project to gain insight into the learning paths that students follow at the ITC faculty within the Living Textbook
- Setting up a cooperative e-learning platform for cooperation between academia and enterprise in the field of industrial innovation in the ERASMUS+ project CEPHEI
- Digital assessment in mathematics has been sparked by research to find out to what extent digital testing could assess first year calculus for engineering studies
- The implementation of an inquiry-based lab education software tool improved students preparation and overview of the whole experiment in biomedical engineering

Characteristics of Educational Innovations at Wageningen University

Between 2018 and 2020, WUR, via 4TU.CEE, started a study to more scientifically underpin its innovation process for innovating courses. The project investigated almost 100 course innovation plans that were funded via the WUR innovation fund. It also looked at outcomes of projects, student evaluations and other information for a selected set of innovations. A framework was constructed based on literature and available data, consisting of relevant criteria that institutes and innovators might want to consider before starting an innovation. These criteria include goals, elements of course design, evaluation strategies, the nature of innovations, innovation products and dissemination. The framework was discussed with different stakeholders and presented at several conferences. At WUR, several changes were implemented based on recommendations from the study. Currently, several universities are using the framework, and a scientific publication is under way.

Education Design for New Educational Challenges of Universities

The 4TUs are transforming programme and course designs into flexible educational ecosystems for educating new generations of engineers. WUR is doing research on the required changes.

The results so far were published in four publications and presented in SEFI and CDIO conferences, a meeting of the Euro league universities for Life Sciences as well as in internal meetings and online communication with staff and teachers. In 2020 research using the 4TU.CEE innovation map gave a clear picture of our educational innovation and changes needed for the next years. For example, the need for more visible education innovation

on the programme level. Also an analysis was made of present cross-cultural education, focusing on support and the 4TU.CEE training programme for it. All results are shared online using the WUR intranet group and the 4TU.CEE website. They were also presented in the CDIO 2020 international conference and are available in two publications (1, 2).

2021 started with a report on teaching staff's opinion for future education innovation. This report is one of the inputs for articles on lessons learned during the pandemic and recommendations for new education design after the pandemic.

"The study highlights that we do not focus enough on the evaluation of our innovations. I recognise that and would like to improve it for my future innovations. It also shows we often worked on educational innovations in a reactive way (e.g., because of growing student numbers). It would be great to move towards more future-proof innovation themes."

Comprehensive Ethics Teaching (COMET); Ethics and Responsible Engineering in Engineering Education
Over the past years the ethics department at the faculty of Technology Policy and Management (TPM) of TU Delft has built a theoretical model that offers practical recommendations for teaching engineering ethics. Specifically, the department established the theoretical foundations for ethics education, developed a framework for best practices in ethics engineering education focusing on reflections on moral sensitivity, the engineering practice and the ethical impact in the COMET (Comprehensive Ethics Teaching) project. With the growing awareness that ethics should play a key role in engineering education comes also the challenge of determining exactly how engineering ethics education should be designed and taught. COMET is a two-year research project that is focused on the future of engineering ethics education at TU Delft.

After looking back at the successes and challenges from the last 20 years of integrating ethics into the curriculum at TU Delft, the project develops best practices for ethics education going forward. One of our primary goals is to develop an account of moral sensitivity and how it can be fostered in engineering ethics education. Though moral sensitivity is widely acknowledged as a key ethical competency it is less than clear how it should be understood concerning concept and operationalised pedagogically.

The efforts culminated in the SEFI 2020 best short paper award.

JANNA VAN GRUNSVEN

"Nobody has found the golden recipe yet for how to effectively teach ethics as one small component of an otherwise technical or design-oriented curriculum. Supposedly this doesn't really translate into any practical advice when it comes to researching engineering ethics education, but it does underscore the urgency of such research."

PRESTO Open Asynchronous Learning in Virtual Peer Groups

In his educational fellowship, Pieter Bots of the TU Delft faculty Technology, Policy and Management (TPM) aims to gain a better understanding of how students experience peer feedback and peer appraisal as part of their academic education. Five years ago, Bots developed the 'project relay' method to help students develop computational skills by individually and repeatedly iterating through a six step modelling cycle. According to Bots, students find it difficult and stressful to mark the work of their fellow students. With 4TU.CEE, a research was done on operationalising 'Evaluative Judgement' realised within the project relay (PRESTO): Evaluative judgement is the capacity to be able to judge the work of oneself and that of others, which implies developing knowledge about one's own assessment capability. In this study, we found a close link between domain knowledge and the capacity of peers to provide appropriate feedback. This study will be elaborated upon in the Uncage project, where chatbots are embedded in the curriculum.

PIETER BOTS

"In this project, we found a close link between domain knowledge and the capacity of peers to provide appropriate feedback."

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 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.

ALEX SCHULER-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."

Challenge-based Learning

An important game-changer has been the flight 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 will continue to do so in the coming years. Together with our colleagues from TU/e Innovation Space and different departments at TU/e we are exploring what CBL has to offer to students, teachers and other stakeholders in our society. These projects vary from a framework for measuring learning gains by CBL to a research on CBL in hard-core engineering studies like mathematics and physics.

Other examples are defining challenge-based tasks for fundamental knowledge acquisition as well as the development of associating professional skills, changing courses at several departments into (interdisciplinary) challenge-based learning courses, and research on learning experiences of students.

Learning Spaces Tour

On 24 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 was 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 organisations 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 realised in a non-hierarchical, constantly developing collaborative environment in which students, teachers, researchers and business practitioners across hierarchical, professional and disciplinary boundaries work together.

In these tours, we've learned about the various approaches that can be taken to design education involving external stakeholders, real-world challenges and the competences students are likely to learn:

- Design and execute inter/transdisciplinary oriented projects on a real-life challenge
- Communicate viewpoints and findings
- Reflect and give feedback
- Demonstrate attitude and skills for working within real-life complex collaborative contexts

The questions and concerns addressed in the 2018 SEFI paper 'space-driven educational innovation' on learning spaces have partly been addressed.

These questions were as follows: 1) What could be the strategic vision of our institution and/or how to effectively implement this in our context? 2) What do we need to do in terms of staffing, staff development and student tutorials for teams to run on their own and stimulate entrepreneurial mindsets (needed to make this a success)?

3) How do we ensure that all our lab/maker space facilities are built on the same knowledge framework and how can we co-create learning in the institution? and 4) What is the effect or learning outcome (added value for learning), and what are effective ways to realise assessment?

TU/e has developed the innovation spaces and a challenge-based education vision. Different frameworks of learning space learning have evolved, some learning outcomes are identified and staff training is still deliberated. A PhD on the AMS Living labs and transdisciplinary learning has even started in Delft as an immediate result of this tour. The Learning Spaces Tour has inspired teachers, support staff and policy makers on how to realise their best possible learning space ecosystems. In total, the Learning Spaces Tour has been attended by around 200 participants.

Photo: Marte Hofsteenge

4 Teaching Excellence in University Engineering Education

Introduction
Teaching quality is key for achieving the ambitious goals of student-driven (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 beyond. 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 recognised and rewarded.

Senior University Teaching Qualification & more
The UT addresses Recognising and Rewarding Teaching and teaching excellence with the Senior University Teaching Qualification (SUTQ), for example. The SUTQ is focused on skilled and collegial teachers who are ready to move to the next level of scholarly teacher as mentioned in the career framework for university teaching. The participating teachers determine their personal learning path and execute their own sub-project (160 hours) to innovate and improve their practice. They are supported by a coach, educational research and design seminars and peer feedback from colleagues.

The SUTQ approach was evaluated after it ran for three years. Although participants feel inspired and appreciate the clarity, usefulness and feedback during SUTQ sessions, some challenges remain in terms of facilitation (e.g., time) and approach (e.g., the steps from clear problem statement to innovation design). Additionally, community-building needs more attention in order to promote further continuous development in the university as a whole. This paper (on p. 1042) sets out an agenda for doing so.

Besides the SUTQ initiative, UT also started a pilot with the Teaching & Learning Fellowship in April 2021. Over the next four years, two cohorts of seven fellows will have the opportunity to improve education with the help of practice-oriented research. Moreover, three clusters with representatives from different faculties of the UT are involved in setting up criteria, an HR framework for recognising and rewarding teaching and setting up a UT Teaching Community.

Pilot Learning Assistants at UT
It is common at the 4TU to appoint students as student assistants, and as such they can fulfil many different tasks related to education, research and organisation. These students usually get a task-specific training.

4TU.CEE at UT has piloted a new trajectory for students who are supporting other students in their learning process (Learning Assistants / LAs), to further improve the quality of education. In the training, LAs receive general didactical expertise and didactical reasoning on top of expertise they need to perform their specific task. This prepares them for other LA tasks they might get in the future and makes them look at education differently, from the perspective of the teacher.

LAs are trained once and do not need new training when they decide to work as LA again in other courses. The pilot was successful, and the trajectory is now taken over by the Centre of Expertise in Learning and Teaching of the UT and offered as one of their standard courses. The next step is to work towards a nationally recognised Student Education Qualification, together with other HE institutes, and to align with the UTQ for starting teachers.

LEARNING ASSISTANT

"Before these sessions, I always assumed that if I passed the courses I would end up with enough skills to get to work. I thought the goal of the classes was to gain more knowledge. Now I think more actively what the goal is of a certain class. (...) It made me realise that a good process is important to get a good result and that a good process is a goal in itself."

Pedagogical Development Programmes in Higher Education

Most university teachers are not trained to teach. In the last few years, higher education institutes have developed pedagogical courses and require teachers to follow these, such as the University Teaching Qualification trajectory in the Netherlands. These courses vary in goals, activities and duration. However, deep insight into what works for whom and under which circumstances is lacking. In her PhD project, Marloes Vreekamp (WUR) aims to find an answer to the question: *How are characteristics of Pedagogical Development Programmes (PDP) in higher education related to changes in teacher development for the personal domain (knowledge, skills and attitude), the domain of practice (professional experimentation) and the domain of consequences (student behaviour and outcomes)?*

The project team has started a systematic literature review, which will is finalised in 2021. The first results have been presented at a national conference in 2021. A survey study will also be set up to gain insight into what characteristics of PDPs teachers from the 4TUs perceive as related to their development as a teachers, and what hinders or stimulates their learning.

Teacher Professional Learning and Development in Higher Education

The research project on 'Teacher professional learning and development in higher education' aims to answer the question whether, how and why different approaches to teacher professional learning and development work for different innovations, contexts and populations. This is done by conducting a literature study, a broad as well as in-depth study of existing cases and an intervention study, in which data is collected on the innovation (context),
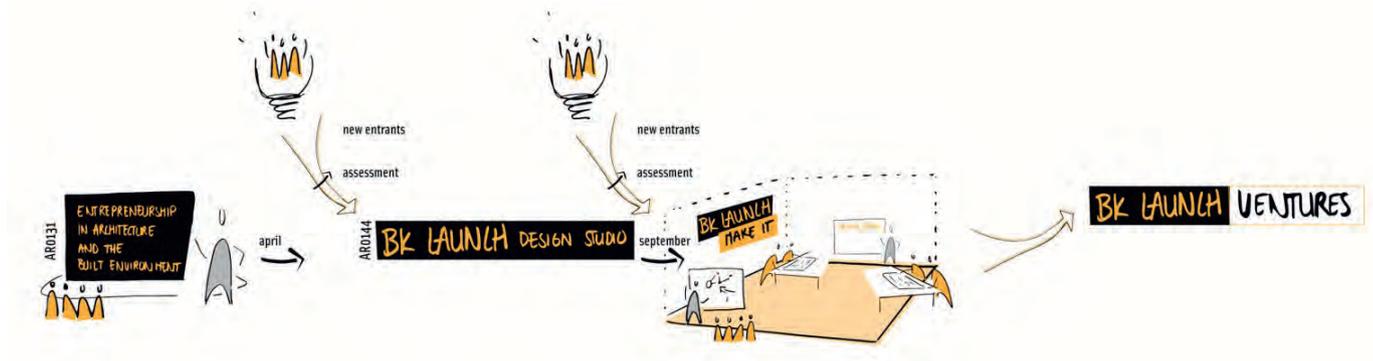
teacher activities, support for teachers, teachers' learning and the effect on students.

The project was granted in July 2020 by NWO and runs from 2020 - 2024. It involves 25 higher education universities and universities of applied science. Main applicant of the project is Jan Vermunt (TU/e) and the project is managed by both Jan Vermunt and Perry den Brok. 4TU.CEE is involved in several aspects of the study, and 4TU innovations are studied as part of the project. Currently, a literature review is in progress, as well as a collection of innovation cases, and frameworks to map these are being constructed.

Architecture and the Built Environment Educational Research Portfolio

In 2018, the faculty of Architecture and the Built Environment (ABE) at TU Delft established an educational research programme into architectural education. To give the programme a boost, 4TU.CEE supported writing a 2020 Special Journal Issue on Interdisciplinary Design Learning and Design Pedagogies. In the 2018-2019 period, thirty lecturers were involved in eight different writing teams. Each team had innovated and evaluated their teaching practices and shared this knowledge in an article. Noteworthy is the professional learning that took place due to the reflections in the writing process.

The faculty ABE continues with this approach to inspire and support staff with writing journal articles and books on pedagogical insights, and to help staff writing education innovation and research project proposals when calls are out. By doing so, ABE actively contributes to setting an example for many others to explore a different way of professionalising the workforce.

Topics currently addressed in the ABE educational research and innovation agenda which are supported by 4TU.CEE are as follows: 'study stress in design education' (research project), 'academic skills for architects' (book project),

"In writing the article, we were stimulated to formally assess the success of our new methodology through questionnaires. The collaborative writing has led to a refining of our teaching practice in distinguishing the various steps to be taken during analysis and also highlighted where students required additional support."

'research interventionist methods' (book project), 'design studio pedagogies' (research project), 'BK Launch' (see image on p. 27), on entrepreneurship education within the ABE field (innovation project) and 'Education Pathways for the Buildings and Cities We Need' (book project + seminar).

COVID-19 Teaching and Learning

In 2021, 4TU.CEE published a white paper on the impact of COVID-19 on higher education, and several studies were combined from the 4TUs and presented and discussed at the 4TU board. The aim was to profit from four excellent studies realised at each institution and bring together the different results to generate new research questions and generate some policy advice.

The white paper has been followed up with a seminar in which a lively discussion emerged on the future of university education implying that simply mixing online/offline education and seeking the optimal mix is not the answer to improved or post-Covid education. Another important finding is that well-being and emotions (personal development) should be essential parts of the curriculum in future education.

A selection of Research Questions have emerged from this initiative:

- How do we design and measure the value of in-presence, on-campus class, laboratories and projects?
- How do we seamlessly integrate the virtual and physical mobility of students?
- How will exams and student assessment change?
- How should we design new offices and shared spaces for both faculty and staff?
- What is the role of the campus in creating a new university culture that fits the new normal?

The four studies that are combined in the white paper are described separately hereafter. 4TU.CEE would like to thank all parties at the 4TU that contributed to the white paper.

TU/E PROJECT TEAM

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

WUR: Online Education During the COVID-19 Crisis Situation
At WUR, 4TU.CEE, the Education & Student Affairs (ESA) of WUR, and the Education and Learning Sciences (ELS) chair group have joined forces to investigate and evaluate the process and outcomes of the transition to online education at WUR. The aim is to identify how the transition influences course design, teaching and the learning of students.

Research consisted of surveys, interviews, co-creation sessions and other data collection methods, while each education period reports were created describing trends in learning and teaching. Four teacher profiles were found in how teachers dealt with the transition to online education and how they used university support.

Also, three student profiles were found, showing differences in stress, ability and beliefs of students. Currently, apart from workshops and practical reports, two journal articles are being written and other projects emerged from the COVID-19 situation.

TU/e: COVID-19 Pandemic Research into Student Learning and Well-being

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 also delivered three sets of hands-on recommendations for teachers to use in their courses to improve student learning and well-being. The project results also provide useful input for the post-pandemic period when teachers will aim for an optimal mix of blended learning.

UT: Impact of COVID-19 in Education at UT – Opportunities and Challenges

UT wanted to get insight into how students and teachers have experienced online education during the academic year 2019-2020 and how support was provided during this period. Teachers and students could also state their expectations of future education at UT by means of a survey. This survey was conceived and executed as a joint effort of Technology Enhanced Learning and Teaching (TELT), Centre of Expertise in Learning and Teaching (CELT) and the faculties. The survey results demonstrate a strong interest from teachers and students to explore and experiment with online and blended education in the future.

This report can serve as a useful source of information for the supporting organisation, the faculties and UT management teams to continue fulfilling their missions to deliver high-quality education.

TUD: Designing a Campus-Wide Well-being Assessment & Implementation Ideas

At TUD a well-being monitoring tool was developed that was scientifically tested: 'MyWellness-Check'. The researchers wanted to provide a low-burden survey that also had a human-touch. Both the survey software and the content was designed using a human-centred participatory design process.

This meant involving students and staff in the generation and revision of survey items as well as extensive, iterative user testing. 50+ TUD community participants were recruited to review 4000+ responses to identify needs & ideas. Many of these ideas have been embedded in the organisation.

This study was done by the human-centred design department and Educational Support. 4TU.CEE highly appreciated their input for the white paper.

4TU.CEE

Appendix 1: Impact
January 2019 – December 2021

4TU.CEE events	
CBL webinar Series	Participants
5 events in 2021: 1 per TU 1 international hosted by Aalborg University	65 on average per event
CBL webinar Series: Research into Challenge-Based Education Participants	Participants
Kick-off in Nov 2021, with follow-up meetings in 2022	50
Learning Spaces Tour	Participants
5 events in 2019-2020: At AMS, UT, TU/e, WUR and Aalto Design Factory (hosted by TUD)	35 on average per event
SEFI2020	Participants
5-day event in September 2020	365
Practese PhD symposium series (together with with KU Leuven and the University of Western Australia	Participants
2 events hosted in 2021	35 on average per event
Webinar rewarding teaching excellence with VSNU, Comenius & Ruth Graham	Participants
2x in November 2020	192 and 124
Workshops on interdisciplinarity/cultural diversity for 4TU staff	Participants
7x Culturally appropriate and effective feedback 4x Essentials of conflict management in interdisciplinary group work 3x Intercultural group dynamics 1x Teaching in the international class room (WUR) 1x Inclusiveness for better study results (TU/e) 1x Fear of failure (WUR) 1x How to beat procrastination (WUR)	14 on average per event 14 on average per event 11 on average per event 6 11 9 8
Education/ Teachers days (yearly event at TUD, TU/e and WUR)	
3x TUD 3x WUR	+/- 150 per event +/- 200 per event

Other events	Participants
- Innovative Classroom pilot; 2019 (UT)	20
- Seminar: the ins and outs of project-led and student driven education; 2019 (UT)	30
- Workshop interdisciplinary team work skills by Reider Lyng/ Bjornt Sortland (NTNU)/ Hanne Loje (DTU); 2019 at UT and TUD	28 (UT) 59 (TUD)
- Adaptive expertise in leadership and professional learning; 2019 (UT)	15
- CEPHEI consortium team meeting video and studio training; 2019 (UT)	12
- Supporting student project teams at EPFL; 2019 (UT)	41
- Workshop creating educational innovations that work; 2019 (TUD)	7
- Challenges of CBL in university context: lunch and workshop; 2020 (UT)	52
- Lunch lecture Team-based professional development by Inken Gast; 2020 (TUD)	11
- 2x workshop TU/e innovation fund: 2020	26
- Technical Knowledge or Professional Skills Inspiration webinar Kristina Edström: 2020 (UT)	29
- Teaching Academy and Rewarding Teaching Inspiration webinar Warwick University; 2020 (UT)	19
- Inspiration session Improving student learning through teamwork experiences: from practice to research to practice, Roland Tormey; 2020 (TUD)	24
- Panel discussion Consequences of corona: lasting positive change (UT) 8 June 2021	20
- Webinar| Diversity & Inclusion on campus: a general framework and the D.I.V.E.R.S.I.T.Y. model, 2021 (UT)	36
- Webinar on 4TU.CEE white paper about the transition to online learning during the pandemic (4TU)	35
- Webinar: An Exercise in Inclusive Experiential Engineering Ethics with Janna van Grunsven (TUD)	28

Review activities 4TU.CEE

PUBLICATIONS	
SEFI2020 117 research papers/30 short papers	26 reviewers (UT) 10 reviewers (TUD) 9 reviewers (TU/e) 7 reviewers (WUR)
CDIO	5 reviewers (WUR)

Keynotes, Lectures & Workshops by 4TU researchers

Bohm, N. (2020) several presentations at City Deal kennis maken platform

Brok, P. den (2020). Online engineering education in Corona times: results from a large scale evaluation at WUR and lessons learned. Keynote at the 2020 national Innovation Centres in Academic Beta education conference, Eindhoven, November 5.

Brok, P. den (2019). Course innovations at the university: innovative education or educated innovations? Keynote at the symposium Studievoorschotsmiddelen 'Enhancing Education, discover what is possible', 11 June 2019, Rijks Universiteit Groningen, Groningen.

Brok, P. den (2019). Characteristics of educational innovations at Wageningen University: now and in the future. Keynote during the WUR annual Teachers' Day, 11 December 2019, Wageningen.

Ceulemans, D. (2019). Designing Educational Innovation in Higher Education, Education day 2019, TU Delft

Fortuin, K.P.J., Gulikers, J.T.M., Oonk, C., Post Uiterweer, N.C., Tho, C.W.S. (2019). Designing a learning trajectory for boundary crossing competence development. Workshop/presentation at the Association for Interdisciplinary Studies Conference 2019, 24-26 October 2019, Amsterdam.

Gavioli, M. several presentations at: ASCM Group meeting, TUD Eng. Edu. Network; AE PhD academic event. Presentation on literature review on Conceptual Understanding at PRIME, - Presentation Italian embassy on Engineering Education and lab demonstration, - PhD scientific event AE. PRACTESE symposium presentation (PhD network 4TU.CEE)

Kamp, A. (2020). Rethinking higher engineering education. Keynote at ASEE annual conference, 22 June 2020

Kamp, A. (2020). Presentation: The World Itself is the Most Effective Teacher, and panellist in the panel session 'Leveraging Experiential Education to Become an International Engineering Education Leader'. at ASEE Virtual Conference 2020.

Kamp, A. (2019). Presentation on Diversity. at IVA in Stockholm on 28 august 2019.

Kamp, A. (2019) keynote Adapting Engineering Education to Changing Demands: how much, how fast, in what way? At IVA in Stockholm 29 august 2019

Kamp, A. (2019) Leading the discussions and workshops within the task force and at the CESAER Annual Meeting 2018 (Bucharest) to gather input from multiple and diverse sources (2018-2019), as input to the development of a Discussion Paper about 21st century engineering education in Europe.

Kamp, A. (2019) 4TU.CEE Member of international assessment panel to evaluate the Centre of Engineering Education (CEE) at the Faculty of Engineering at Lund University (26-27 February 2019).

Kamp, A. (2019) Task Force "S&T Education for the 21st Century" of CESAER, with report Science & Technology Education for 21st Century Europe Discussion paper in collaboration with the task force S&T Education for the 21st Century. 18 December 2019.

Klaassen, R.G. (2020). Engineering Roles in Higher Education. Guest speaker honours programme TU Delft.

Klaassen, R.G. (2020). Engineering Roles and Reflection in Higher Education. Guest Speaker Kick of Robotics programme TU Delft

Klaassen, R.G. (2020), Disentangling the different layers of interdisciplinarity, interactive session LDE- CEL, Annual conference 2020

Macleod, M. (2020). Best Practices in Interdisciplinary Education. Workshop at Aalto University.

Oonk, C., Gulikers, J.T.M., Brok, P. den (2019). Building a boundary crossing Master course through an intervention-based approach. Presentation at the EARLI 2019 Conference, Aachen.

Oonk, C., Fortuin, K.P.J., Tho, C.W.S. (2019). Presented the BC project in a workshop at the Comenius Network Festival, 6 June 2019, Utrecht.

Tho, C.W.S., Oonk, C., Fortuin, K.P.J., Gulikers, J.T.M. (2019). Students' boundary crossing awareness and experiences in an inter- and transdisciplinary MSc course. Presentation at the National Interdisciplinary Education Conference, 22 January 2019, Utrecht.

Van der Veen, J.T. (2020). Interdisciplinary project work: Solving real world problems. Online address for the academic network of the Zentraleinrichtung Wissenschaftliche Weiterbildung und Kooperation, Technische Universität Berlin.

Van Dijk, M. (2019). Vision of the Future University in Engineering Education. Education Day 2019 TU Delft.

4TU.CEE Media Appearances

TU Delft Delta Aldert Kamp	'JIP prepares students for agile future'	13 November 2019
NRO Kennisinfrastructuur rapport	'Slimme verbindingen'	2019
4TU.nl, Perry den Brok	'Recipe for tomorrow's engineer'	October 2020
Techniekpact, Perry den Brok	'Recept voor de ingenieur van de toekomst'	February 2021
Erasmus University Rotterdam, Perry den Brok	'Future education and investing in soft skills'	20 May 2021

Blogs, Newsletters and 4TU.CEE website

Activity (Jan 2019-Nov 2021)	Views	Receivers/ users
4TU.CEE Blogs: 22	Varies per blog from 250-5,000 views	Not specified
4TU.CEE Newsletters: 16	Not specified	TUD: approx. 2800 TU/e: approx. 1500 UT: approx. 200 and dispersion through employee portal WUR: approx. 800, dispersion through employee portal
Hits visitors of the 4TU.CEE website (main and sub sites)	2019: 25,153 2020: 38,774 2021 (till Nov): 38.842	6,731 (in 2019) users 11,603 (in 2020) users 11,533 (in 2021) users 10,023 (in 2019) sessions 16,409 (in 2020) sessions 17,076 (in 2021) session +/- 12% returning visitors

4TU.CEE Innovation Map

Activity	Projects	People involved
Innovation Map	264 projects per Nov 2021	384 per Nov 2021

Appendix 2: Output
January 2019 – December 2021

Publications

INTERNAL (RESEARCH) REPORTS

Bayram-Jacobs, D., Mesutoglu, C., Vennix, A., & Birgit, P. (April, 2021). Mid-report: Deepening multidisciplinarity within Systems & Control. Eindhoven: TU Eindhoven, School of Education.

Conijn, M. A. R., Matzat, U., Kleingeld, P. A. M. A., & Snijders, C. C. P. (2021). The Corona transition and student learning. Student evaluations of exams, student well-being & engagement and their relationships with the learning environment. Third Report.

Drolsbach, S.; Laarhoven, M.; Bala A.; Van Saltbommel, V. (2021). Entrepreneurial engineering education at 4TU.

Klaassen, R.; van Dijk. M.; Hoope, R.; Kamp, A. (2019). Engineer of the Future: envisioning higher engineering education in 2035.

Kamp, A. (2019). Navigating the landscape of higher engineering education, TU Delft, 4TU.CEE.

Kleingeld, P. A. M. A., Matzat, U., Snijders, C. C. P., & Conijn, M. A. R. (2020). The Corona transition and student learning: Second Report-December 2020: Student well-being and influencing factors.

Matzat, U., Kleingeld, P. A. M. A., Snijders, C. C. P., & Conijn, M. A. R. (2020). The Corona transition and student learning: What works, what doesn't work, and what needs improvement?

Ping, C., Kleingeld, P.A.M., & Rispens, S., & Taconis, R. (2020). Multicultural student group work in an international classroom: An explorative study of students' experiences at TU/e (study 1b).

Ping, C., Kleingeld, P.A.M., & Rispens, S., & Taconis, R. (2021). Does nationality composition affect student groups' collaboration and performance? A cross-case analysis (study 2a).

Sewnarain Sukul, I., Taconis, R., Kleingeld, P.A.M., & Rispens, S. (2019). Effective learning and student collaboration in the international classroom at TU/e (study 1a).

Specht, M.; Rooij. R.; Klaassen. R. (2020). 4TU.CEE projects at TU Delft.

Tassone, V. C., den Brok, P. J., Biemans, H. J. A., & Runhaar, P. R. (2020). Characteristics of Intended, Implemented and Attained Educational Innovations at Wageningen University: A Research Study Executive Summary.

Tauecchio, N.; den Brok, P.; van Puffelen, E. (2020). 2020 Year Report 4TU.CEE WUR.

Tho, C., den Brok, P. J. (2019). Teaching Large Groups. Wageningen University & Research.

Van Puffelen, E., & Tauecchio, N. (2021). Future education Innovation at WUR: Report on requested topics for future education innovation at Wageningen University & Research. Wageningen University & Research.

SCIENTIFIC ARTICLES OR BOOK CONTRIBUTIONS

Gast, I., van der Veen, J. T., McKenney, S. & Schildkamp, K. (2019). Team-based curriculum design in higher education: A qualitative study of design conversations.

Gueudet, G., Pepin, B. & Lebaud, MP. (2021). Designing meta-resources for mathematics teachers in the context of curriculum reforms: the case of digital technology use and student autonomy in France. ZDM Mathematics Education 53, 1359–1372.

Gueudet, G., Pepin, B., Courtney, S., Kock, Z.-J., Misfeldt, M., & Lindenskov Tamborg, A. (2021). Digital platforms for mathematics teacher curriculum design: Affordances and constraints. In A. Clark-Wilson, A. Donevska-Todorova, E. Faggiano, J. Trgalova, & H. Weigand (Eds.), Mathematics Education in the Digital Age : Learning, Practice and Theory. Routledge.

Hartmann, A. & Gommer, L. (2019): To play or not to play: on the motivational effects of games in engineering education, European Journal of Engineering Education, DOI: 10.1080/03043797.2019.1690430

Klaassen, R.G., Kothuis, B, Slinger, J.K. Vol. 7 (2021): Building with Nature perspectives: Cross-disciplinary BwN approaches in coastal regions, Research in Urbanism Series, in van Bergen, J., Nijhuis, S., Brand, N. Hertogh, M. (2020), Building with Nature Perspectives. Cross-disciplinary BwN approaches in coastal regions, RiUS - Research in Urbanism Series published by Delft University of Technology (http://rius.tudelft.nl/).

Klaassen, R. (2020), Disentangling the Different Layers of Interdisciplinarity, Journal of Science Communication, Vol. 19 (4).

MacLeod M. & J. T. van der Veen (2019): Scaffolding interdisciplinary project-based learning: a case study, European Journal of Engineering Education, DOI: 10.1080/03043797.2019.1646210

Möller M., Schalkers M. (2020). A Cross-Platform Programming Framework for Quantum-Accelerated Scientific Computing. In: Krzhizhanovskaya V. et al. (eds) Computational Science – ICCS 2020. ICCS 2020. Lecture Notes in Computer Science, vol 12142. Springer.

Olde Scholtenhuis, L. L. , Vahdatikhaki, F. , & Rouwenhorst, C. (2020). Flipped microlecture classes: satisfied learners and higher performance? European journal of engineering education, 1-22. https://doi.org/10.1080/03043797.2020.1819961

Pepin, B., Biehler, R., Gueudet, G. (2021). Special Issue on 'Mathematics in/for Engineering Education'. Volume 7, issue 2. IJRUME (International Journal of Research in Undergraduate Mathematics Education)

Pepin, B. (2021). Connectivity in support of student co-design of innovative mathematics curriculum trajectories. ZDM Mathematics Education 53, 1221–1232.

Pepin, B., Biehler, R. & Gueudet, G. (2021.) Mathematics in Engineering Education: a Review of the Recent Literature with a View towards Innovative Practices. Int. J. Res. Undergrad. Math. Ed. 7, 163–188 (2021).

Pepin, B., Kock, Zj. (2021). Students' Use of Resources in a Challenge-Based Learning Context Involving Mathematics. Int. J. Res. Undergrad. Math. Ed. 7, 306–327.

Rezat, S., Fan, L., Pepin, B. (2021). Mathematics textbooks and curriculum resources as instruments for change. Special Issue in ZDM-Mathematics Education: Volume 53, issue 6.

Rezat, S., Fan, L. & Pepin, B. (2021). Mathematics textbooks and curriculum resources as instruments for change. In ZDM Mathematics Education 53, 1189–1206.

Rezat, S., Fan, L., Pepin, B. (2021). Mathematics textbooks and curriculum resources as instruments for change. Special Issue in ZDM-Mathematics Education: Volume 53, issue 6.

Rooij, R., Klaassen, R., Cavallo, R., & Arts, J. A. (2020). Architecture and built environment design education: disciplinary and pedagogical developments. International Journal of Technology and Design Education, 30(5), 837-848.

Stevens, T., Brok, P. den., Biemans, H., Noroozi, O. (in submission). A typology of Teacher Profiles in higher education: the move to online education during the Covid-19 crisis. European Journal of Teacher Education.

Trouche, L., Gueudet, G., & Pepin, B. (Eds.) (2020). The resources approach to mathematics education. Dordrecht: Springer.

Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., van Baalen, S., Klaassen, R. & Boon, M., Jul 2020. Interdisciplinary engineering education: A review of vision, teaching, and support. In Journal of engineering education. 109, 3, p. 508-555 48 p.

Van Grunsven, J. B., Marin, L., Stone, T. W., Roeser, S. & Doorn, N. (2021) How to Teach Engineering Ethics? A Retrospective and Prospective Sketch of TU Delft's Approach to Engineering Ethics Education. In: Advances in Engineering Education.

CONFERENCE CONTRIBUTIONS

Alink, C. O., Schretlen, J., Thomas, T., & Stobbelaar, T. (2019) Making Engineering students think about their study approaches. SEFI 2019 Budapest.

Cabo, A. & Klaassen, R., (2019). The influence of Teacher cues on self-directed Learning in Math Education 11 p.

Ceulemans, D. S. & Klaassen, R. G. (2019). Impact of engineering roles in a design process for solving complex problems. Proceedings of the 46th SEFI Annual Conference 2018: Creativity, Innovation and Entrepreneurship for Engineering Education Excellence. Clark, R., Hussmann, P. M., Jarvinen, H-M., Murphy, M. & Vigild, M. E. (eds.). European Society for Engineering Education (SEFI), p. 674-681 8 p.

Cristea, T.S., Snijders, C.C.P., Conijn, M.A.R., Matzat, U. & Kleingeld, A. (2021). The relation between autonomy and well-being in higher educational students during the COVID-19 pandemic. SEFI 2021 Annual Conference, Berlin, September, 2021.

De Fouw, N., Van der Tang, Y., Klaassen, R. (2020), Pre-Requisites for Interdisciplinary Course Development – Organisation and Staff, CDIO 2020 accepted research paper

De Vink, E. Presentation "Baby-steps into Automata Theory with Jupyter Notebooks: GAMBA project". ICAB 2020, Eindhoven, November 5, 2020

Goethem, A. Presentation: "An automated checker for schematic structures: project GraphChecker". ICAB 2020, Eindhoven, November 5, 2020

Kiliç, A., & Pepin, B. E. U. (2020). Modular approach perspective in engineering education. Abstract from 2020 ICAB Conference, Eindhoven, Netherlands. https://www.icab2020.nl/home/wiki/575140/parallel-session-b

Kiliç, A., Kock, Z.-J. & Pepin, B. (2021). Connectivity related issues in a modularised course involving mathematics. The 15th International Conference on Technology in Mathematics Teaching –(ICTMT 15), Copenhagen, September 13-16.

Klaassen, R., de Fouw, N., Rooij, R., & van der Tang, Y. (2019). Perceptions of Interdisciplinary Learning: A qualitative approach. In B. Kloot (Ed.), Proceedings of the 8th Research in Engineering Education Symposium, REES 2019 - Making Connections (pp. 398-407). Research in Engineering Education Network.

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Vreman-De Olde, G. C. , Rouwenhorst, C. , Alers, J. C. , & van der Veen, J. T. (2020). E-learning on the lab with lab education software: Deeper learning & more efficiency? In B. V. Nagy, M. Murphy, H-M. Jarvinen, & A. Kalman (Eds.), Varietas delectat... Complexity is the new normality: SEFI 47th Annual Conference Proceedings (pp. 1261-1270). SEFI 47th Annual Conference.

SEFI2020 4TU.CEE papers 40 in total

SKO contributions UT

Appendix 3: Overview 4TU.CEE Postdocs, PhD researchers & master students

Postdoc	Subject	Supervisor	End date
Dr. Marieke van Geel (UT)	Learning assistants: Training and coaching of students with teaching assistant roles	Drs. I. ten Dam	2019
Dr. Lavinia Marin (TUD)	Comprehensive Ethics Teaching for Engineers/ Designers (COMET)	Prof. N. Doorn, Prof. S. Roeser	2020
Dr. Martina van Uum (TU/e)	Developing a learning gains framework for innovative engineering education	Prof. B. Pepin	2020
Dr. Carla Oonk (WUR)	Boundary crossing at WUR	Prof. A. Bregt, Prof. A. Wals, Prof. P. den Brok	2020
Dr. Tracy Craig (UT)	Mathematics in project team work	Dr. C. Poortman	2021
Dr. Tim Stevens (WUR)	Education in Covid-19 times at WUR	Prof. P. den Brok, Dr. H. Biemans, Dr. O. Noroozi	2021
Dr. Claire Goriot (WUR)	Skills learning lines in WUR bachelor programmes	Dr. H. Biemans, Dr. J. Gulikers, Dr. C. Oonk	2021
Dr. Kiki Buijs / MSc. Cassandra Tho (WUR)	Learning in extracurricular challenges at WUR	Dr. C. Oonk, dr. Y. Baggen	2021
Dr. Taylor Stone (TUD)	Comprehensive Ethics Teaching for Engineers/ Designers (COMET)	Prof. N. Doorn, Prof. S. Roeser	2021
Dr. Janna van Grunsven (TUD)	Comprehensive Ethics Teaching for Engineers/ Designers (COMET)	Prof. N. Doorn, Prof. S. Roeser	2021
Dr. Mara Saeli (TU/e)	Challenge Based Education in/for mathematics and physics education	Prof. B. Pepin	2021
Dr. Miles MacLeod (UT)	Interdisciplinarity, scaffolding strategies and international toolbox collection	Prof. J. van der Veen	2022
Dr. Cornelise Vreman-de Olde (UT)	Interdisciplinarity in TechMed context	Prof. J. van der Veen	2022
Dr. Mark Young (TUD)	Research on critical thinking skills for engineers resulting in a handbook and training for students	Dr. S. Swart	2022
Dr. Tahir Abbas (TUD)	Uncage Project	Mr. Gadiraju	2022

Dr. Nauman Ahmed (TUD)	Libket project	Dr. M. Moller	2022
Dr. Nathalie van der Wal (TUD)	PRIME Project and Math Education: self-directed learning in blended education and transferable skills in engineering curricula	Dr. A. Cabo, Prof. G. Jongbloed	2022
Dr. Jacqueline Wong (TUD)	PRIME Project and Math Education: self-directed learning in blended education and transferable skills in engineering curricula	Dr. A. Cabo, Prof. G. Jongbloed	2022
Dr. Karolina Doulougeri (TU/e)	Challenge-Based Learning		2022
Dr. Ana Valencia (TU/e)	Assessment practices in inter-programme CBL education: Innovation Space Bachelor End Project	Prof. I. Reymen & Prof. B. Pepin	
Dr. Ayse Kilic (TU/e)	Modularization project	Prof. B. Pepin	2022
Dr. Zeger Jan Kock (TU/e)	Challenge Based Education in Maths and Physics – Mobile Learning	Prof. B. Pepin	2022
Dr. Cui Ping (TU/e)	International classroom	Dr. R.Taconis	2022
Dr. Canan Mesotoglu (TU/e)	Deepening multidisciplinary within signals & control	Dr. D. Bayram-Jacobs	2022
Dr. Tim Stevens (TU/e)	Teacher professional learning and development in higher education	Prof. J. Vermunt	2023

PhD researcher	Subject	Supervisor	End date
Rike Bron (UT)	Teacher teams and team learning processes	Promotor: Prof. B. Veldkamp; Daily supervisor: Dr. M. Endedijk	2019
Bram Vaessen (TU/e)	Students' perceptions of assessment and student learning in higher education courses	Promotores: P. J. den Brok, L. Lemmens, Co-Promotor: A. van den Beemt	2021
Ljubov van Beek (TUD)	Self-directed learning in Higher Education	Prof. M.J. de Vries; Co-Promotor & Daily supervisor Dr. M. van den Boogaard	2021
Marta Gavioli (TUD)	Instructional design for laboratory settings in∞structural analysis education	Prof. C. Bisagni, Prof. P. den Brok, Daily supervisor Dr. R.G. Klaassen	2022
Priyanka Pereira (UT)	Student driven learning: self and peer regulation	Promotores: Dr. K. Schildkamp, Prof. B. Veldkamp	2022
Kostis Karanasios (TU/e)	Designing authentic learning environments to educate the future engineer	Promotor: Prof. J. Vermunt Daily supervisor: Dr. G. Bombaerts	2022
Nina Bohm (TUD)	Living labs in engineering education	Promotores: Prof. E. van Bueren & Prof. P. den Brok, Daily supervisor: Dr. R. Klaassen.	2023
Laura Menschaart (TUD)	Emotion regulation in online Math (service) Education	Promotores: Prof. G. Jongbloed, Dr. A. Cabo	2023
Xin Ming (UT)	Interdisciplinary engineering education	Promotor: Prof. K. Schildkamp; Daily supervisors: Dr. M. MacLeod, Prof. J. van der Veen	2024
Marloes Vreekamp (WUR)	Pedagogical development programmes in higher education: what works for whom under what circumstances?	Supervisors: Prof. P. den Brok, Dr. P. Runhaar, Dr. J. Gulikers	2024

Gitte van Helden (TUD)	The development of collaborative designlabs for Educational Purposes	Promotores: Prof. E. Gill, Prof. M.Specht, B. Zandbergen	2025
Kishore Sivakumar (UT)	Promoting higher order thinking skills in engineering education for interdisciplinary research	Supervisors: Prof. M. Boon and Dr. M. Orozco	2025
LinLin Pei (UT)	An effective professional development model for higher education institutions - Support for instructors on blended learning development	Supervisors: Prof. K. Schildkamp, Prof. N. Benes, Dr. C. Poortman	2026

Master student	Subject	Supervision	End date
Nikos Basbas (UT)	Advanced professional development for university teachers	Dr. K. Schildkamp/ Dr. J. van der Veen	January 2019
Alisa Lochner (UT)	Digital testing in mathematics.	Dr. J. van der Veen	January 2019
Kirsten Olde Heuvel (UT)	Influence of personality traits and emotional content on the sense of presence in a VR application	Dr. B. Kollöffel	August 2019
Viktoriia Bolotina (UT)	Student acceptance of the VR environment for practicing public speaking skills	Dr. B. Kollöffel	September 2019
Coralie Johnson (UT)	Product Design: interdisciplinary case study	Dr. J. van der Veen/ Dr. C.L. Poortman	April 2020
Nikola Petrova (UT)	Efficient algorithms: interdisciplinary case study	Dr. J. van der Veen/ Dr. C.L. Poortman	September 2020
Jeroen Rou (UT)	The effect of an online training on students' public speaking skill of 'using your voice'	Dr. B. Kollöffel	November 2020
Niveditha Uthrapathi Shakila (UT)	Science2Society: interdisciplinary case study	Dr. J. van der Veen/ Dr. C.L. Poortman	February 2021
Anny Rey-Naizaque (UT)	Flexible pathways in mathematics	Dr. J. van der Veen/ Prof. B. Veldkamp	Summer 2021

Appendix 4: SEFI2020

■ 20 September 2020: Doctoral symposium SEFI@2020 conference – online symposium
21 PhD students and 15 senior-researchers/supervisors participated

KEYNOTES

■ Greet Langie: Focus on the exit to keep them in. Career development at the start of engineering education
■ Pierre Dillenbourg: Escaping Reality: The Value of A in Augmented Reality
■ Gerard van der Steenhoven: Climate change teaching and the COVID-19 crisis
■ Ruth Graham: Celebrating and rewarding teaching: global collaborations for change

CONTRIBUTIONS FROM 4TU

11 Workshops

■ Maaike Endedijk: How to stimulate collaboration and performance of highly diverse student teams in engineering education?
■ Hannah Bijlsma: Smartphone-assisted student feedback to lecturers for better engineering education
■ Jan Jaap Wietsma, Talitha Visser, Tim van Dulmen, Aernout van Rossum, Ed van den Berg: Supporting Secondary STEM education and attracting students to science and technology
■ Frank Van Den Berg, Andrea Brose: Design of Challenge Based Education: Experiences with introducing CBE in the ECIU University (max. 40 participants)
■ Ellen-Wien Augustijn-Beckers, Ivan Oliveira, Marie-Jose Verkroost: Gardening with the Living Textbook - Navigation via Learning Pathways and a Concept Map
■ Frank Van Den Berg, Pascal Wilhelm: Focus on self-directed learning: the learning and assessment philosophy of the University College Twente

■ UT+TUE+LUW
Chantal Scholten, Marie-Jose Verkroost, Hubertie Kroon, Vincent Merk: Toolbox for Internationalisation: a digital box full of relevant insights, hands-on solutions and useful tips

TUD
■ Wiebe Pieter Dijkstra, Katie Goeman: The next step in blended education: a hands-on experience

TUD
■ Calvin Rans: SEFI SIG - So I hear you are an expert on online teaching now?

TUD
■ Kristina Edström, Lisa Benson, John Mitchell, Sally Male, Jonte Bernhard, Maartje van den Bogaard, Jennifer Case, Shannon Chance, Cynthia Finelli, Manish Malik: Best Practices for Reviewing Manuscripts in Engineering Education Research Journals

TUe
■ Gunter Bombaerts: SEFI SIG - Coaching Engineering Ethics Education Research

3 SYMPOSIUMS

■ Engineering curriculum design, challenge based education, maker projects, use of professional tools
Organised by Robin De Graaf
■ E-learning, open and online learning, blended learning, virtual reality
Organised by Eugenio Bravo
■ Engineering in Schools, improving visibility of engineering disciplines
Organised by Pieter Boerman

SEFI2020 4TU.CEE PAPERS: 40 in total

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