D 6.1 Report on indicators for co-creation teaching

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Author: Corinna N. Voll, DTU

Contributors:

Maja Horst, Monamie Bhadra Haines (DTU); Jitka Anderssonová, Ludmila Dohnalová (CTU); Shobhit Shakya (TalTech); Lukas Fuchs (TU/e); Carlos Cuevas Garcia and Michael Clark (TUM)

31 students, 8 teachers, 9 professionals at teaching and learning units

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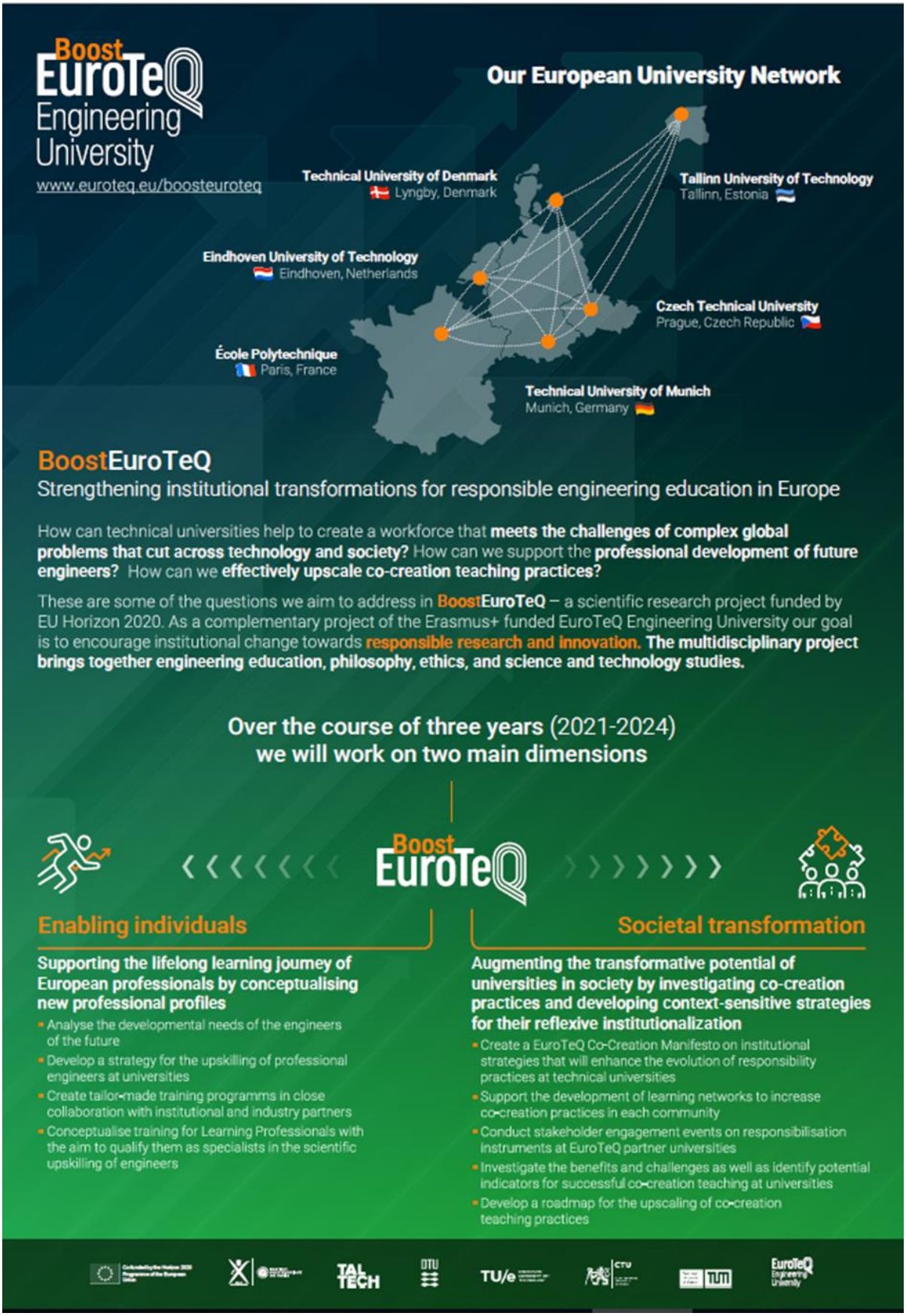
Contact:

Lisa Hasenbein (TUM), Project Manager: lisa.hasenbein@tum.de

Corinna N. Voll (DTU), Work Package Lead WP6: cnavo@dtu.dk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Strengthening institutional transformations for responsible engineering education in Europe
How can technical universities help to create a workforce that meets the challenges of complex global problems that cut across technology and society? How can we support the professional development of future engineers? How can we effectively upscale co-creation teaching practices?
These are some of the questions we aim to address in BoostEuroTeQ – a scientific research project funded by EU Horizon 2020. As a complementary project of the Erasmus+ funded EuroTeQ Engineering University our goal is to encourage institutional change towards responsible research and innovation. The multidisciplinary project brings together engineering education, philosophy, ethics, and science and technology studies.
Over the course of three years (2021-2024)
we will work on two main dimensions
Boost EuroTeQ
Enabling individuals
Supporting the lifelong learning journey of European professionals by conceptualising new professional profiles
Analyse the developmental needs of the engineers of the future
Develop a strategy for the upskilling of professional engineers at universities
Create tailor-made training programms in close collaboration with institutional and industry partners
Conceptualise training for Learning Professionals with the aim to qualify them as specialists in the scientific upskilling of engineers
Societal transformation
Augmenting the transformative potential of universities in society by investigating co-creation practices and developing context-sensitive strategies for their reflexive institutionalization
Create a EuroTeQ Co-Creation Manifesto on institutional strategies that will enhance the evolution of responsibility practices at technical universities
Support the development of learning networks to increase co-creation practices in each community
Conduct stakeholder engagement events on responsibilisation instruments at EuroTeQ partner universities
Investigate the benefits and challenges as well as identify potential indicators for successful co-creation teaching at universities
Develop a roadmap for the upscaling of co-creation teaching practices
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CONTENT

EXECUTIVE SUMMARY

This report provides **indicators for co-creation teaching based on fieldwork throughout the EuroTeQ alliance**. The indicators offer a tool to guide future steps towards concerted action for co-creation teaching. Within this report, we explain our procedure to find indicators of existing co-creation teaching to help identify, characterize, and measure co-creation initiatives in engineering education. Based on these insights, we reflect on potential impacts on course management and teaching and learning units. As co-creation teaching is dynamic and our understanding continuously improving, we see this report as a work-in-progress, being refined with our increasing knowledge of the field.

This deliverable is embedded in WP4-6 with the goal to strengthen **reflexive institutionalization of responsible and co-creative teaching and research practice at the EuroTeQ universities.** Milestone 5 clarified how the classroom is an overlooked site for understanding questions of democratization in learning and state-public relations. Reflexivity in co-creation practice requires problematizing the "deficit model" in the classroom, where students are constructed as vessels to be filled with various forms of knowledge, ranging from the technical to ethical to 'soft skills'. Further, we describe a methodology to select relevant empirical case studies through which to understand how responsibility is lived and understood in the classroom. This deliverable now builds on and explains in depth how co-creation is constituted with a focus on indicators. Such a new perspective provides another angle to understand the practices, synergies, and differences between the EuroTeQ universities. This deliverable thereby complements previous work in EuroTeQ and BoostEuroTeQ, where the focus lay on future engineering skills in dialogue with industry partners;[1] to add to these viewpoints, this deliverable takes a close look at **student-teacher-stakeholder interaction in the classroom**.

[1] For instance, BoostEuroTeQ D.3.2 "Analysis of the developmental needs of the engineer of the future" or EuroTeQ WP4's "21 Future Competencies for the EuroTeQ Professional".

1. CO-CREATION IN EDUCATION: WHY, WHERE AND HOW?

1.1. Rising interest and changing values

The rising interest in co-creation in education goes hand in hand with our universities' shifting role in society: Once greatly concerned with knowledge-production, universities are now increasingly required to participate in reaching new, mutually beneficial, and often unconventional solutions with stakeholders outside of academia (Pulkkinen & Hautamäki, 2019). This turn can also be recognized on a policy level, with EU schemes evolving from "Science and Society" to "Science in Society" towards "Science with and for Society" themes (Pulkkinen & Hautamäki, 2019). For several years now, funding from side of the EU has allowed a variety of participatory forms of public engagement with science to grow (Stilgoe et al., 2014). Since 2015, the concept of co-creation became more widely used within the EU and has over the years become an important criterion for good innovation within the Horizon Europe framework (Broekema et al., 2021).

With its focus on participation, partnership, and the inclusion of different voices in the decision-making processes, co-creation encourages liberal values of democracy and equality. Often, however, co-creation is portrayed as a way to make innovation merely more marketable through user-friendliness. In fact, much-cited early work on co-creation foregrounded the harnessing of people's expertise for generating company profit (Prahalad & Ramaswamy, 2000). Yet, this approach to co-creation does not address growing concern about making innovation more socially robust and responsible. We are inspired to foreground a more diverse perspective on co-creation, in line with many European innovation policy documents. The Horizon 2020 funded interdisciplinary research project SCALINGS provided a unique perspective on the growing role of co-creation in different societal contexts, paying attention to different legal, social, and cultural frameworks.[2] Here, co-creation is defined as "an opportunity for making innovation processes more socially inclusive and responsible because it allows innovators to integrate diverse actors into the innovation process" (SCALINGS @ Munich Center for Technology in Society, 2021, p. 2). A responsible way of collaboration foregrounds claims of equity and benefit sharing, and in this way distinguishes itself from earlier work on mainly market-based ideas of co-creation (Papageorgiou, 2021). When discussing how different aspects of responsibility come together, are enhanced, or overlooked in current co-creation education at the EuroTeQ universities, we are inspired by this perspective on co-creation, as it widely aligns with the values of the EuroTeQ universities.

[2] More information at https://scalings.eu/

1.2. Application of co-creation

With increasing popularization of co-creation initiatives, activities now cover a wide variety of projects, sometimes under the name of community involvement, participation or civic engagement (Voorberg et al., 2015). While co-creation has been continuously discussed and integrated in public sector governance, the conversation has recently become more multidisciplinary, with economists, political scientists and marketing experts engaging in the discussion (Trui Steen & Verschuere, 2018). Even though marginal, co-creation has also been discussed in higher education literature. For instance, Dollinger et al. (2018) frame a model for co-creation in higher education based on business and marketing views, which demarcates the student as co-producer of good education. Through feedback and evaluations, the student provides advice for the redesign of course activities. Here, the student equals the user in early consumer studies, who, through feedback, co-creates a satisfying "product", decent education. Yet, with our framing of co-creation, we see the student not only as contributor to universities' internal performance, but also as a potential agent in broader societal transformation.

While agency and dialogue between educational designers and students are indeed a relevant part of co-creation, another aspect of co-creation is therefore crucial for how we understand co-creation in education in this report. This added layer focuses on co-creation with actors outside of academia with a focus on dialogue. Specifically, we see co-creation activities mainly concerned with the third, or fourth, mission of universities. While not uniformly defined, third mission efforts commonly contribute to local, regional, and (inter)national communities (Compagnucci & Spigarelli, 2020). One of such examples is the case of community-based health services (Greenhalgh et al., 2016). Here, co-creation programs show a high potential for societal impact as they increase dialogue and understanding between researchers and research users; however, their success depends on central principles such as (1) a systems perspective; (2) the framing of research as creative enterprise with human experience at its core; and (3) an emphasis on process, rather than product. Those factors show that co-creation can only flourish in a well-curated setting, and it thus becomes evident that some research contexts are more suitable for successful co-creation than others are.

Going beyond the third mission, Trencher et al. foster the idea of co-creation for sustainability as universities' fourth mission (Trencher et al., 2014)[3]. The focus here lies on "*creating* societal transformations in pursuit of realizing sustainable development" (p. 157, italics in text). For instance, students reconfigure a subsystem such as car sharing, sustainable food networks or carry out plans for the restoration of a local ecosystem. Similar to the previous example, the respective geographical context plays an important role in determining which local knowledge and expertise is considered influential, and which actors from government, industry and civil society partake in the transformation of societal, environmental and technological structures.

[3] The reason why Trencher et al. move away from the idea of university's third mission – originally, that of *societal contribution* – is because of its widespread misunderstanding as purely *economic contribution*.

1.3. Moving forward: Important characteristics of co-creation in this report

As co-creation emerges as a malleable concept adapted and redefined in various contexts, we want to stress a few relevant characteristics before moving on.

We see co-creation as a **mutually beneficial process**, where participants are not only contributing to increased economic revenues, but where ideas around **responsible innovation** are regarded as important. We share the conviction that an approach is needed that actively involves society in partnership-building, including relevant stakeholders such as developers, producers, utilisers, civil society, and policymakers.

The participatory character of co-creation practices aligns with liberal **values of democracy and equality**, where new forms of decision-making processes between **several areas of expertise** are practiced. University projects are carried out in collaboration with external stakeholders, where **increased societal wellbeing**, as part of the third mission of universities, plays an important role. Characteristic here is a focus on inclusion and access. Another important aspect is **the contribution to sustainable development**, where co-creation activities focus on a thriving environment and the reduction of detrimental emissions.

We recognize the **importance of the local context** and a **systemic view** on social, natural, technical, and political systems. All EuroTeQ universities are located in different cultural contexts, which need to be respected when we talk about co-creation more generally. Instead of a one-size-fits-all approach, we acknowledge the different implementation of co-creation activities due to **place-specific histories and relations**. Based on these insights, the next chapter describes how we methodologically approached the field study cross-culturally.

2. METHODOLOGY

2.1. Co-creation as analogy: Selecting cases

Several months of qualitative investigation throughout the EuroTeQ alliance between January and December 2022 lay the background for this report. The collected data should include a variety of perspectives. In total, 31 students participated in an interview (22 one-to-one interviews, four group interviews), including five students who worked as teaching assistants. Eight interviews with teachers and course organizers were conducted. Additional evaluations were collected from three courses. Participant observation was conducted in 11 courses and ranged from one to eight site visits. In addition, interviews with teaching & learning units were conducted at all six universities. The reason for varying data at each university is related to questions of access and different availability of data; for instance, some courses did not provide evaluations due to missing student or teacher feedback. Most data were collected at DTU due to the work package lead's workplace location. Quotes used in this report have been smoothened to ease readability, and doublings and fillers have been removed.

Our initial entry point was to look for courses at university course databases, which included the term “co-creation”. However, across the EuroTeQ universities, only one course carried the term in its title. This fact sheds light to co-creation not being an emic concept, a term from within the field, but instead an etic concept, a concept that we apply to our case from the outside. Therefore, it appeared fruitful to see co-creation as an analogy, that is, we had to look for courses that featured *co-creation-like characteristics*. When we approach concepts such as co-creation cross-culturally, the idea of an analogy shows how we connect knowledge between already known features, and things we are continuously in the process of understanding better (Walford, 2021). In our case, co-creation presents a concept that we already, to some degree, know from literature and initial empirical observations, and are therefore able to look for in the field. At the same time, it represents a concept that we constantly come to know better through each investigative act.

Our next step therefore was to look for courses that contained an element of co-creation. While many of such initiatives exist in extra-curricular programs, we focus on ECTS-based courses, since the goal is to compare curricular education between the universities. Fusing inspiration from the SCALINGS project with our initial knowledge from literature and observations, a primary criteria catalogue was created to determine relevant courses. Courses should have at least an element of working on a real-life problem, ideally with an external stakeholder, or should address the topic of responsibility practically or theoretically. The list of criteria was sent to relevant university staff across the alliance, which helped us find courses that would fall under those criteria. The final data set comprised 15 courses from our universities, with at least two courses from each location.[4] In this sense, our approach mixed deductive and inductive approaches; overarching themes guided our entrance into the field, while deeper analysis of cases and indicators were abstracted from the material itself.

2.2. Ethnographic case study approach

Course-based fieldwork was inspired by an ethnographic case study approach. This approach entails a focus on the specific cultural traits and characteristics of an event or system (Creswell, 2006). Interviews with teachers addressed course history and vision, the set-up of the specific learning experience including methods, as well as the relationship between teachers and students. Student interviews focused on their general experience during the course, the discussions they had within their group and teaching staff, and how the course relates to their engineering education. All interviewees were informed about their rights as study participants, and consent was given orally or in written form.

When selecting students, a mix between genders and between local and foreign students was guiding. Often, foreign or exchange students could point out specificities of their host-university quite uniquely due to their experience of different contexts. Participant observation (on-site and

[4] Research focusing on L’X is limited since there are no staff members represented in WP4-6, who could gather the required information for this deliverable locally. However, an interview with three pedagogical designers at L’X shed light on current developments in this area. Progress regarding co-creation seemed limited at the time of data collection due to a variety of reasons, mainly the university’s strong focus on traditional teaching styles.

online) was conducted during lectures and presentations; it added an extra layer of data to understand the atmosphere, material aspects and smaller, otherwise unnoticed aspects of interaction (such as dress code, interaction in breaks, dynamics and tone between actors). Data was, where necessary, transcribed in NVivo and coded in the same software.

3. INDICATORS OF CO-CREATION TEACHING

In the field, we realized that some courses set better examples of co-creation than others did. The collection of a wide variety of material contributed to understanding what co-creation *is not* and pointed to obstacles hampering the implementation of such. For instance, we learned that more open-ended forms of student engagement pose a difficulty to some teachers in respect to student evaluation. As student projects with unpredictable outcomes – an inevitable characteristic of co-creation – can end up in multiple directions, such conditions make it hard for some teachers to evaluate the feasibility and validity of proposed solutions. We therefore find it suitable to see co-creation as *a spectrum*, with some courses integrating more indicators, and others less, for varying reasons and rationales.

With increasing knowledge of the field, indicators of co-creation became visible and detectable. Several layers of the co-creation experience in the classroom emerged as relevant parts for a full experience. Checking the box of one indicator is not enough to characterize as "co-creation", but the more indicators are combined, the "fuller" the experience. The following describes which indicators emerged as central in the material, followed by a tabular overview.

3.1. Indicator A: Collaboration in a real-life context

The first subset of indicators relates to case-based collaboration. In this indicator, the following aspects are foregrounded:

- **"Real-life" case**
- **Complex problem framing**
- **Engagement with different forms of expertise**
- **Dedicated time & space for proximity-seeking activities**

Discussions in co-creation exercises are not centred around abstract, theoretical examples, but "real-life" cases. When working with companies, those cases often represent problems the industry partners themselves are currently tackling. In our sample, cases with a focus on the environment for instance dealt with more intelligent heat systems, lowering carbon emissions on energy islands or the introduction of new sustainable materials as well as the reuse of existing material. Transportation and mobility systems were another prominent area, in relation to the introduction of autonomous vehicles or the connection between rural and urban areas. A minority of cases focused on predominantly social topics, such as supporting social business or the wellbeing of people with disabilities.

Co-creation is different for many engineering students in that cases do not come with a predetermined solution. How this approach is new for students can be seen in the following characteristic example, where a CTU student reflects on his learnings in such a course:

> *I learned that the real-world problems do not have specific solutions. Because problems and homework at university usually have some specific solutions. And you either do it right or do it wrong. But when you have a real-world problem, you need to assume some stuff and try something and try if it could work. And it's, it's a little bit different.*
>
> *— CTU student*

Students with a highly technical study line, such as mechanical engineering, describe how they usually "*have a path to check*" (DTU student), where problem and solution are quite narrowly defined. With more open-ended problems, many students find themselves challenged to begin with; "*you have no boundaries, and maybe that's why it is hard*" (DTU student).

A real case scenario comes with a different form of authenticity, and as such often means more engaged student involvement. Many students appreciate working on a problem that matters for a stakeholder, while describing an additional motivation to do good work:

> *The people in the companies are really trying to solve something. If you came up with something that really doesn't make any sense, I would be kind of embarrassed to present it to them. So yeah, I feel like it's more responsibility of explaining your idea.*
>
> *— CTU student*

It is visible that working on a real-life case can motivate students to perform at their best. The idea of responsibility portrayed here is one of professional appearance with the goal to take the company's concern seriously. Not only students can find working on a real case stimulating; a teacher from CTU also stressed how he "really want(s) to deal with the real things, not just theoretical calculations".

Indicative of such an approach is the necessity to understand different viewpoints, expertise, and ways to measure achievement. For many students "thinking outside the box" was a common connotation when describing their approach in this regard. As a student from TalTech puts it:

> *You have to think outside the box, and in order to solve this problem, you have to search about how your idea could be implemented for society, the change for business, for research, or how others perceive this idea*.
>
> *— TalTech student*

The solution in co-creation inspired formats is seen to be located and addressed across different sectors, and the presentation towards an outside stakeholder impacts the performance of the student's work. Throughout the collected material, problem framings were

open to different degrees across the courses; some were mainly oriented towards product optimization, while others left room for intervention on different levels. We observe that in those cases where problem formulations are sufficiently complex, discussions were lively and encouraged students to try out new creative pathways, considering a diversity of possible answers.

The way forward in such open-ended scenarios is often through communication and consultation of stakeholders, users, or citizens. In those situations, it is likely one enters the situation with a different mindset than leaving it. With ongoing exchange between the involved parties, knowledge accumulates and changes initial expectations. A student describes the experience of a profound change of problem formulation after having visited and talked to the people in the field:

> *If you ask me before going there and ask me again, after going there, it was completely changed. And so that had to do with all the inputs that I got there and the interaction that I had with the people and the students.*
>
> *— TUM student*

This type of perspective change is present in many courses where students closely interact with people. Here, the aspect of collaboration is important; such an approach means to be open to emphasize with other people and to be willing to let the course of action be influenced by different, previously unseen concerns. New forms of expertise beyond textbook knowledge are integrated and students open up to different types of knowledge. This, however, is not always easy for students. As a course organizer at DTU mentions, engineering students often see the need to perform the domain-specific, knowledgeable expert, which can run counter to being curious and open for different lived experiences. As he describes, Biochemistry students are generally used to reading up on scientific papers before answering questions and performing domain-specific lab tasks. Leaving this mindset behind to immerse oneself in open-ended, explorative innovation processes, where the “love to fail” for the sake of process improvement is on the agenda, requires time, encouragement, and explanation.

Cooperation partners in the courses we observed were mainly local to the university’s national context; for specific collaborations, students could even draw on their personal network and experience. A few collaborations with African regions also existed (at TUM and DTU). Here, contact was facilitated either through an interlocutor or through shorter fieldtrips. TU/e’s location in Eindhoven is special in the sense that the university’s history is inextricably linked to the development of the brainport region[5] and close collaboration with municipalities. Those established pathways between university, industry and public governance pose a benefit for creating courses within a local setting. According to a teacher, Challenge-Based Learning (CBL) in collaboration with an often-local challenge-owner, which is increasingly mainstreamed at TU/e, shares many similarities with co-creation. Commonalities might be summarized in the

[5] The brainport region brands itself as the “home of pioneers” and the most innovative technology region in Europe. Philips has historically been one of the largest industrial players in the area, scaling their investment in the company ASML in the 1980s, which now is one of the global leaders in the semiconductor industry.

aspect of contextual learning experience; students are as well following real-life open-ended challenges, involve stakeholders, are encouraged to think creatively and experience self-directed learning. However, there are also some differences between the concepts.[6]

Since the engagement with external actors is vital for co-creation, courses need to provide a dedicated timeframe for engaging with third-party actors locally and/or internationally. Students often recognized the relevance not only of desk-research, but also of interviewing people or visiting the site first-hand. When courses did not provide enough time for those activities, students were concerned about not finding the relevant issue to work with. In those cases where students could not experience a context first-hand, some students struggled with the feeling of remoteness. Co-creation activities that allow for direct, unmediated experience, for instance through seeing or feeling the problem in context, add an additional layer of understanding and can support the feeling of relevance.

Real-life collaboration also helps students to move away from an idealised or imagined user, towards grounding technology development in people's actual concerns. A teacher from DTU describes this shift in mindset as follows:

> *Typically, you have companies and researchers trying to create solutions for someone that's ideal. That's typically white males in their 20s, that is typically the kind of target group that everyone designs for or develops for. And in that sense, you would rather want to develop solutions for people like the real users and not the idea that someone created a persona like this (imagined user), we are always developing stuff for (…). And of course, in order to be able to do that, you need to involve users, involve real people in those processes.*
>
> *— DTU teacher*

The practice of collaboration and case-based engagement supports the transformation towards engineers who critically think about including different voices and expertise in their work processes. Not all teachers across the EuroTeQ alliance are familiar with the ethical aspect of user-inclusion, but the discussion seems to have started at most locations to some degree. Here we see potential to exchange best practice and challenges regarding the collaboration with "real users" across our alliance.

Case-based collaboration lies at the core of co-creation. Next, the focus will shift to how students are uniquely engaged in such endeavours.

[6] As an educational concept, CBL comes with an initial emphasis on *learning*. In contrast, co-creation has not started as an educational concept, but derives from more general claims for participation, partnership, and inclusion in (technological) decision-making processes. Amongst others, the CBL compass (van den Beemt et al., 2022) mentions the "T-shaped professional", global themes and learning analytics as relevant for CBL, which we do not see as necessary requirements for co-creation. How co-creation and CBL can cross-fertilize each other, will be point of discussion in upcoming workshops within BoostEuroTeQ.

3.2. Indicator B: Holistic student experience

The experience of students mirrors a form of engagement and personal investment often beyond mere disciplinary knowledge. The characteristic student experience in co-creation courses is indicated by the following:

- **Student ownership and emotional experience**
- **Dialogical engagement with co-creators**
- **Working through different value-systems**

Co-creation courses differ from the traditional engineering classroom setup in that students do not exclusively learn things by heart to be reproduced in an exam but engage in a project with their own ideas through dialogical engagement with other students.[7] This means that students show a different degree of ownership, given there is space for participatory discussion. Such a high level of ownership entails that students go through different emotional phases during the project. Through exposure to different perspectives, students engage with conflict-resolution and open their mind to new ideas out of their personal and disciplinary comfort zone. Students therefore have a unique opportunity to practice their communication skills.

In our case samples, it has often been one of the students' first experiences during their university education to engage with students beyond their study line, pointing to the novelty of such formats. Emotional development was not explicitly mentioned as a course objective; instead, almost all course objectives included interdisciplinary learning, which in itself addresses the aspect of personal development out of one's disciplinary home. One of the courses explicitly mentions "working through personal differences", another one the goal to reflect on one's role as engineer (both DTU courses). A course at TU/e explicitly addresses the self-directed and self-responsible learning journey (as part of CBL).

Student ownership and investment seem to depend on students' perceived relevance of their case in relation to their professional development. Showing his emotional investment in the case, a TalTech student describes how he would be "really disappointed" of not continuing the project further. In this case, the project was closely connected to another important student project, and his eagerness to move further with the course was especially high since he chose the course voluntarily. On the other hand, in mandatory courses, some students exposed lower personal investment, when they did not see a relevance to their study program. This depended highly on the selection of cases and the student's overall personal motivation.

Almost all interviewed students stressed the enjoyment of working with students across different study lines. Being exposed to people who think differently increases the students' skills to become more self-conscious about their own point of view and how to connect with different knowledge. As a student mentioned:

[7] Only one course was conducted primarily digital, due to the Corona crisis. While the comparison therefore is limited, it seems as if the students who could meet in real life and engage with stakeholders personally, greatly benefitted from this experience.

> *I was very surprised because it's the first time I'm working with people from different studies. (…) I think it was very, very interesting. It's (about) how you see it, the different problems and how we solve them, and taking into consideration their skills, their capabilities. I think it's very, very interesting because we have so much knowledge at the end.*
>
> *— DTU student*

For such a fruitful exchange to happen, the right setting seems decisive. Here, the experience of the teacher to create a comfortable environment is crucial. At TU/e for instance, several of the observed events were carefully arranged not only in regard to food and drinks, but also in making the students mingle and walk from presentation to presentation during final events. In addition, invited stakeholders and former students supported the community feeling, the interdisciplinary aspect, as well as cross-sectoral and "intergenerational" exchange.

Learning across sectors, disciplines and generations strengthens the students' ability to listen and reflect. In some courses, there was a special focus on having an individual in the group responsible for guiding the interpersonal exchange between students, while in other universities the students themselves were asked to define roles within their teams. In an example of students co-creating together with a facilitator, the new experience during co-creation was described as follows:

> *Most of the time it could be like, 'OK, I know a lot about electronics over here and you know a lot about chemistry.' But we cannot...we have nothing in common. And I feel like co-creation (...) is also forcing to make some sort of glue between those two, and the facilitating role can be glue in that too. (…) And in order to co-create, you need to listen to the other ones in the room as much as you need to be enforced to say something yourself and bring something to the table. So, it goes both ways.*
>
> *— DTU student*

Co-creation can be the bridge to "glue" people together. For such a close contact to happen, there needs to be space for mutual vulnerability and encouragement to "think about yourself more than just your study program" (DTU teacher). Listening to each other is crucial in this process, while at the same time students can experience first-hand what individual responsibility within a group means, which also depends on cultural norms. Here, students need to be understanding of each other's skills and capabilities; in such a case "delegating the work properly, so nobody sits there and does nothing" (CTU student) is an additional skill students learn during collaboration.

Another aspect particularly relevant in international groups, is the student's increased sensitivity to different norms and values when it comes to developing more sustainable technologies:

> *It was since we are a multiracial, multinational, multi everything team, we have someone from Estonia, one from Azerbaijan, from Egypt and one from Mexico. So yeah, it's spread out all over the globe. So, I think if we didn't have the right ethics and we didn't have some kind of sense of humor about this, we would never be able to collaborate with each other. So yeah, it's 100% needed within any team to understand different cultures, different people, and we should accept each other. (…) So, in my culture it's not ethical to do that, but in his culture it's ethical (…). We have to find a middle ground between both of us and no one should reject each other.*
>
> *— TalTech student*

Beyond being a "dry" course experience, co-creation comes across as a very engaged, even humoristic experience while being exposed to new value systems. Such a growth of perspective requires emotional maturity of students to step out of their comfort zone and realise that the "right" approach can look different across cultures. In some courses, however, an overly focus on methods and predetermined criteria coupled with a tight timeframe seemed to hinder a deeper engagement with each other's ethical standpoints and value systems.

The ability to gather people to engage with each other's perspective also depends on the student's experience with leading larger group projects. At DTU for instance, the role of facilitator in groups is given special attention through targeted training. A student who experienced both French and German engineering study culture, describes TUM students as more ready to lead technical projects, while French engineering students are prepared specifically for more individualized disciplinary expertise in the natural sciences.[8] Such perspectives show that co-creation experiences and the necessary personal skillset to do so seem to differ considerably across universities. If co-creation were to be mainstreamed more broadly across the alliance, personal and study-line specific differences need to be understood and addressed in more detailed.

3.3. Indicator C: Pedagogical setup supporting multi-layered learning experience

The pedagogical setup of classroom activities is another relevant aspect for the co-creation experience. This indicator relates more broadly to the different roles in the classroom, focusing on teachers and the infrastructure of course activities. The following aspects are decisive:

- **Teacher as "scaffolder" of learning journey**
- **Mixture of theoretical and hands-on sessions**
- **Application of methods for exploration and reflection**
- **Complex learning goals and multi-layered evaluation**

[8] At TUM and most other universities, one is eligible to study with a qualified secondary school diploma or sufficient professional qualification. In France, engineers are required to visit preparatory education for 2 years before starting higher engineering education. This process is highly competitive and selective around the best grades in classical science disciplines, such as math, physics, chemistry, and technology.

In co-creation activities, the focus lies on student learning and exploration, which is why the teacher functions as scaffolder, coach, or mentor of the learning journey. Such roles are applied already at various courses at TU/e as part of Challenge-Based Learning, where a coach can accompany students through the process of a course and, sometimes even weekly, reflects with students on deeper challenges and ethical questions. Such a focus on reflection pedagogy goes hand in hand with the rather “backstage” presence of the teacher and can impact future engineers by bringing often overlooked issues to the table such as unintended consequences, or the role of data ethics in technology development. Close contact to students is in many co-creation-inspired courses “outsourced” to student assistants, coaches, or other staff, owing to the more complex nature of decentralised group work in comparison to classic lecture formats.

As course designer, the teacher provides methods and methodological advice for students to explore the case and to reflect about the decisions taken. Here, a big emphasis is put on the process dimension, of how to work towards a common goal. While a large part of co-creation courses is based on hands-on elements, there is space for theoretical input in a lecture-style format as well. Teaching is, however, linked closely to improving the case-based process, for instance by addressing lectures on facilitation, teamwork, innovation, or stakeholder engagement. For instance, students at DTU were introduced to Belbin Team Roles, the role of diversity in teams, and different workshop formats during such lectures. Some teachers were inspired by “studio teaching”, where the focus is on experimentation in a hands-on practical project. Yet, the students’ ability to apply theoretical input in practice seemed to vary, showing the pedagogical challenges of formats that aim to combine theoretical and practical training. Here, the necessity for facilities that support the reorganized classroom also emerged as important. Besides the central “lecture theatre”, students benefit from smaller rooms with screens, whiteboards, and other material to support the integration of knowledge in group discussions.

Co-creation seems to draw on a variety of methods to support the learning experience. We could mainly observe a mixture between design- and business-inspired methods as part of course design. For instance, at a TalTech course, methods inspired by “The Medici Effect” were chosen to guide students to define a problem statement and by digging into “the problem”, “technology”, ”human needs” and “existing services”. At a TU/e course, much attention was given to the C-P-S model, a business model focusing on customer, problem, and solution as relevant areas. Throughout DTU’s co-creation-inspired courses, the Double Diamond, a famous design method, was used to guide students through the process. Such methods are needed to give students a point of reference in their development throughout the decentralized project development. The methods have a strong impact on the framing and outcome of co-creation activities, and it is therefore relevant to discuss their advantages and drawbacks further within EuroTeQ.

As co-creation processes are indeterminate by nature, learning goals and evaluations mirror this complexity. Instead of multiple-choice questions or reproduction of a specific mathematical formula, learning goals include aspects related to learning goals higher up in Bloom’s

Taxonomy, for instance design, create, or evaluate. Final examinations often include various elements beyond a written exam, such as a combination between oral and written presentation, individual reflections and/or a specific object the students created. This complexity is not always easy for teachers; “it would be so much easier in a math’s class, where there is a right and wrong” (DTU teacher). Such new formats require extra effort, and demanding written reports on a standardised topic is still sometimes preferred. The new pedagogical setup supporting a multi-layered learning experience is especially new for universities with a long tradition of strong hierarchies between teacher authority and students. In such cases, co-creation can sometimes be pushed forward by often younger individuals.

The previous indicators point to the characteristic nature of co-creation courses at the EuroTeQ universities, summarized in the following table.

3.4. Indicator overview

Collaboration in a real-life context

Subindicator	Characteristics	Opposed to
"Real-life" case	• Problem relevant for people and/or environment • Solution & suggestions can have a practical, tangible impact; someone is affected • "Real user"	• Problem is imagined, has no major relevance for anyone • "Imagined" or non-existent user
Complex problem framing	• Problem is open-ended and contingent on different factors • Contextual and societally embedded nature; ambiguity • Open-ended, unpredictable journey for both students and partners	• Problem can be solved by a specific formula • Ambiguity plays no role
Engagement with different forms of expertise	• Industry or civil society partner • Partnership throughout the process • Encounter of different forms of expertise	• Teacher provides example • Strongly hierarchical relationship
Dedicated time & space for proximity-seeking activities	• Allocated time to engage with one or more third-party actors • Interaction through different means, e.g. interviews, participant observation, desk research • Benefit of first-hand bodily/physical encounters	• No consultation of affected stakeholders • Immediate technical approach to solution • Physical and mental remoteness

Holistic student experience

Subindicator	Characteristics	Opposed to
Student ownership and emotional experience	• High degree of personal and emotional involvement • Various sides of personality and expression are addressed • Learning of "mood management"	• Project and solution feel irrelevant (to continue) • Anonymous and only intellectual involvement
Dialogical engagement with co-creators	• Practice of listening and communicative skills • Learning to interact with different perspectives; working through discomfort • Broadening of disciplinary thinking; often interdisciplinary solution finding	• Individual problem-solving; non-communicative • No exchange of perspectives; low conflict potential
Working through different value-systems	• Facing each other's cultural background to explore biases, norms and beliefs • Encouragement and support to work through difference	• No or little discussion about different value-systems

Pedagogical setup supporting multi-layered learning experience

Subindicator	Characteristics	Opposed to
Teacher as "scaffolder" of learning journey	• Teacher as mentor or consultant; process orientation • Gives space for students' creativity and self-determinacy	• Teacher as main source of knowledge • Encourages replication rather than self-determinacy
Mixture of theoretical and hands-on sessions	• Introduction to theoretical concepts to be applied and experienced first-hand • Alternation between "front stage" and "backstage" activities	• Only or mainly theoretical input
Application of methods for exploration and reflection	• Methods and tasks supporting different phases of learning experience to embrace complexity (e.g. design methods) • Includes self-reflection, group reflections and feedback • Facilities supporting collaborative learning and groupwork; movement between different sites	• Single-solution methods, no tools for perspective change • Dominant focus on "optimization" rather than exploration • One-sided lecture hall
Complex learning goals and multi-layered evaluation	• Learning goals higher up in Bloom's Taxonomy • Often combination of assessment types	• Often only one right answer (e.g. multiple-choice) • Singular assessment

4. IMPLICATIONS FOR COURSE MANAGEMENT AND TEACHING & LEARNING UNITS

4.1. Reflections on the relationship with third-party actors

For collaboration with external partners to succeed, an appropriate collaborator first needs to be found. At some universities, such as TU/e, close contact between individual teacher and industry already seems widespread and teachers could resort to existing contacts. At a course at DTU, a specific university-unit was in charge of finding and managing industry-contact, thereby taking considerable workload off the teacher. Here, expectation management between university and external stakeholder is crucial to ease the process.

The role of and relationship to the third-party actor seems relevant to discuss in the classroom. A discussion could for instance be encouraged about the partner's role in society and towards the environment. Aspects such as CSR or the SDG's should be reflected where relevant. Through critical reflection on the positioning of the third-party actor, "responsibility washing" on the company's side can be counteracted. Here, a reflection can also take place about how the external actor presents the problem, for instance, through which data they make their point clear, and which values and missions are foregrounded or missing. While for many universities the "third mission" often equals that of economic contribution (Trencher et al., 2014), there should be space for students to reflect on which priority economic, societal, or sustainability-related aspects should be given during co-creation. As part of this, it might seem relevant to discuss if – or to which degree – students carry responsibility to change structural problems, and if and how the problem can be tackled through the course-based activity.

As students and companies are differently powerful actors particularly in financial terms, the issue of power should also be addressed during co-creation activities. Here, it seems as a good practice to encourage the third-party actor to see students not merely as unpaid labour, but to promote the idea of being receptive to creative ideas "outside the box". Not every issue is suitable for such a collaboration; a too narrowly defined problem hampers the potential for new and surprising solutions. Likewise, not every issue can be "solved" through co-creation but some require a different format. Quality of the cases should therefore be examined critically beforehand. If the goal is to encourage reflective engineering education, the limitations and benefits of co-creation are important to discuss with students to support an elaborate discussion of such an approach.

4.2. Reflections on successful student interaction

Student interaction seems to work more smoothly if students implicitly agree on the terms of dialogue. Especially for those universities in the EuroTeQ alliance, where many different nationalities form part of university life, it seems important to train intercultural communication skills to discuss assumptions of "good group work". Often, assumptions about the right performance in a group setting can vary across cultural contexts but remain implicit. Different personality types, such as introvert or extrovert tendencies, and neurodiversity in a broader

sense, should be respected in course design. This could for instance mean to allocate more time for individual work, instead of the often-fulltime group setting which we found in many co-creation-inspired courses. Letting students choose different responsibilities, such as note taker or facilitator, is an additional idea of how to adapt courses to individual preferences. Such considerations help make co-creation not only comfortable for talkative extroverts, but also to people with different personalities, needs, and communication styles.

Another aspect is the encouragement of mutual vulnerability. As co-creation comes with a much broader personal investment than disciplinary knowledge alone, it is important for students to be supported to show up with their full self. That means, there should be encouragement to incorporate different parts of one's personality. Such preferences could be thematic preferences and experiences, but also humour, playfulness, or hobbies such as drawing. In order to encourage a "safe space", where students feel brave enough to share vulnerabilities, icebreakers at the beginning of a course can be a good idea to set the scene. Safety and a relaxed atmosphere are also important for fruitful peer-to-peer feedback, which not only takes workload from the teacher, but also helps students learn how to considerately articulate and receive feedback.

4.3. Reflections on the role of the teacher

The role of the teacher is crucial for facilitating a positive co-creation experience in the classroom. Essentially, the teacher takes a much more decentralized role than in a classical lecture-based setup. Instead of providing replicable solutions, the teacher provides coaching and supports student ownership and conflict resolution. Only few teachers however perform this role, where continuous reflection and accompaniment of students during the process are key, fully. In few university teacher trainings across the alliance, these skills are part of teacher training and would require more targeted training. What seems decisive is learning how to stay with students in the process of co-creation when challenges arise. Here, skills such as conflict management could be beneficial.

Learning from individual teachers' examples could be a fruitful way forward, but also requires a broader discussion on human resources. To support teachers, sufficient resources are vital. As co-creation as such is a more decentralised process with new responsibilities and roles for, during, and at the end of a course, sufficient teaching support is an important pillar for success. During the course, teaching assistants or other support staff can be available for additional questions as well as for administrative tasks. Even though more in the background, the teacher is still acting as a science advisor. That also means that the final evaluation should not be outsourced to the company or other external actors, but should still be done by the teacher.

It is likewise important to recognize that co-creation is not for every teacher. Teachers should be made aware of different expectations towards the learning process in the co-creation journey, as it can otherwise be a frustrating experience. Based on our fieldwork, we see that engineering students as well find formats that diverge from the classical learn & repeat format challenging; thus, there needs to be an additional focus on understanding students'

engineering mindset and how it links with other experiences during their study programs, for teachers to communicate more efficiently. While learning how to facilitate co-creation in engineering education is a skill for teachers that will likely become more relevant in the future, it means additional time investment. Teaching and learning staff at TalTech and TU/e have made clear that such teaching formats therefore need incentivizing.

As new methods of teaching and supervisions are in place with co-creation teaching, those methods require critical reflection. Not only do students according to our data request background knowledge as to why certain group work methods are suggested over others, but there also exists the risk of oversimplifying co-creation to a specific methodological procedure. Here, there is a risk that a "checking the box" mentality dominates, where students merely execute methods without further thought, thereby reducing creativity and appropriate care for all involved. For instance, when working with people with disabilities, prompts such as "disability cards" could support students to become more aware of the experience of people with handicaps. However, it needs to be made clear that such cards cannot replace longer engagement and dialogue with people with disabilities. While there often is limited time for students to have an in-depth encounter with users and/or the local site, students should be taught that prompts or methods used within the course are only exemplary and should always be accompanied by empathetic dialogue.

5. CONCLUSION

Co-creation is not a new concept but has been used in various business and public governance contexts. With increasing attention towards universities' responsibility towards society and sustainable development, engineering universities are as well facing a transition towards more dialogical, participatory educational formats. Co-creation and the unpredictability it entails are new and therefore challenging to many teachers, students and teaching and learning units. We find different variations of co-creation-like education across the Alliance since all universities build on their respective histories and local contexts; some of these could be addressed in this deliverable, while the general focus lay on abstracting three indicators that emerged as central across all courses. Taken together, the collaboration in a real-life context, a holistic student experience and a pedagogical setup supporting multi-layered learning experience are the central indicators of co-creation education in engineering education at the EuroTeQ alliance. Encounters with co-creation are coined by the experience of "thinking outside the box", with all the joyful and difficult aspects this entails. Working with students from different study lines on a real-life case was for many a refreshing experience; at other times, the open-endedness can feel challenging for all.

With those perspectives in mind, we want to stress that co-creation is not only about the students' experience. While the goal of higher education is the students' educational development, we realize that teachers, stakeholders, and teacher trainers alike need to be open to engage with a "co-creation mindset". Such a perspective points towards a systemic transformation of engineering education towards more participatory and democratic forms of

teaching. At the same time, we acknowledge that the ground for co-creation is paved more smoothly at some universities than others. Cultural and historical contexts, as well as sufficient resources play important roles here. This report showed some of the crucial milestones to consider when continuing the co-creation journey and thereby supports future work in BoostEuroTeQ towards putting these ideas into practice.

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