TRAINING FUTURE SKILLS - SUSTAINABILITY, INTERCULTURALITY & INNOVATION IN A DIGITAL DESIGN THINKING FORMAT

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ABSTRACT

The complex questions of today for a world of tomorrow are characterized by their global impact. Solutions must therefore not only be sustainable in the sense of the three pillars of sustainability (economic, environmental, and social) but must also function globally. This goes hand in hand with the need for intercultural acceptance of developed services and products. To achieve this, engineers, as the problem solvers of the future, must be able to work in intercultural teams on appropriate solutions, and be sensitive to intercultural perspectives. To equip the engineers of the future with the so-called future skills, teaching concepts are needed in which students can acquire these methods and competencies in application-oriented formats. The presented course "Applying Design Thinking - Sustainability, Innovation and Interculturality" was developed to teach future skills from the competency areas Digital Key Competencies, Classical Competencies and Transformative Competencies. The CDIO Standard 3.0, in particular the standards 5, 6, 7 and 8, was used as a guideline. The course aims to prepare engineering students from different disciplines and cultures for their future work in an international environment by combining a digital teaching format with an interdisciplinary, transdisciplinary and intercultural setting for solving sustainability challenges. The innovative moment lies in the digital application of design thinking and the inclusion of intercultural as well as trans- and interdisciplinary perspectives in innovation development processes. In this paper, the concept of the course will be presented in detail and the particularities of a digital implementation of design thinking will be addressed. Subsequently, the potentials and challenges will be reflected and practical advice for integrating design thinking in engineering education will be given.

KEYWORDS

Design Thinking, Sustainability, Future Skills, Interculturality, Interdisciplinarity, Transdisciplinarity, Standards: 5, 6, 7, 8

INTRODUCTION AND BACKGROUND

United Nations Brundtland Commission defined in 1987 one of the most cited definitions of sustainability: “[…] meeting the needs of the present without compromising the ability of future generations to meet their own needs.” (United Nations, 1987, p.15). Considering today's consumer habits (e.g., Umweltbundesamt, 2022), it becomes clear that to achieve this goal, social transformations are needed so that today's generation can assume its responsibility towards future generations. Engineers will play a central role in these social transformation processes as they are significantly involved in the development of solutions for more sustainable production processes or products, for example (UNESCO, 2021; Magnell et al. 2022). Consequently, engineering students will be confronted with diverse requirements. These requirements can be divided into two levels, one related to engineering working content and the other to the working environment. From a content perspective there is an increasing need for a continuous reflection of the sustainable development goals (SDGs) (United Nations, n.d.; Lupi et al., 2022) in one's own activities, the question of sustainability in engineering processes and solutions (e.g., Brent & Labuschagne, 2004; Burke & Gaughran, 2007), but also the global applicability of solutions and products in a networked world (Konar et al., 2016). In practical implementation, this means, for example, the reflection of social diversity in innovation development, the reflection of different (cultural) perspectives on innovations and the consideration of the sustainability issue on the ecological, economic, and social level (Morandín-Ahuerma et al., 2019) already in development processes (Steuer-Dankert & Leicht-Scholten, 2016; Thürer et al., 2018; Fenner & Morgan, 2021). In addition to a stronger substantive focus on sustainability issues in engineering (Thürer et al., 2018; Sánchez-Carracedo et al., 2019; Lupi et al. 2022), engineers of the future will face an ever-changing work environment. Consequently, from a working environment perspective, changes due to an increasing digitalization, the world of work 4.0 and the disruptive transformation of industries and business models (Regnet, 2020; Albrecht, 2020; Mertens et al., 2022) can be mentioned as developments having an impact on the way engineers will work in the future. The digital transformation in companies (Teichmann & Hüning, 2018; Petry, 2019), new concepts of leadership styles such as digital leadership (Eggers & Hollmann, 2018), but also globalization and the associated need for (digital) collaboration in intercultural teams (Fajen, 2017), are examples of this.

Within the framework of their studies, engineers of the future must be prepared for these challenges in the best possible way to be able to meet them and fulfill the generational responsibility formulated by the United Nations (1987) and the UNESCO (2021). Consequently, the changed demands, both in terms of content and work organization, require an adaptation of curricular content in the context of engineering training. The CDIO Standards 3.0 as well as the CDIO Syllabus 3.0 represent initiatives, promoting the necessity of establishing sustainable development as central topic and giving with the CDIO Standard an optional advice for objectives and guidance (Malmqvist et al., 2020 a & b; Rosén et al., 2021; Malmqvist et al., 2022). In addition to the development to new standards and educational reforms (CDIO, n.d.), the discussion of the so-called *future skills* shows, that there is a need for competency-based teaching aiming to prepare students for the demands of tomorrow's world. In addition to the so-called technical engineering content, the teaching of these future skills is therefore becoming increasingly important.

As a central joint initiative of companies and foundations in Germany that provides holistic advice in the areas of education, science and innovation, the Stifterverband is a trend-setter in terms of studies that investigate future competencies. In collaboration with McKinsey, the German Stifterverband has identified which competencies will be of great importance in the future and has compiled 21 competencies for a changing world (Stifterverband & McKinsey, 2021). The 21 competencies have been broken down into four key competency areas:

1. Technological competencies (e.g., data analytics & AI, user-centered design),
2. Digital key competencies (e.g., digital ethics, agile working, digital collaboration),
3. Classical competencies (e.g., problem-solving skills, intercultural communication),
4. Transformative competencies (e.g., innovation skills, change skills, dialogue, conflict skills) (see figure 1).

The Stifterverband and McKinsey (2021) emphasize that transformative competencies are playing an increasingly important role as they are fundamental to courageously shaping social change by creating awareness of societal challenges and supporting both the development of visionary solutions and uniting people. This is confirmed by their survey conducted among 500 German enterprises and public authorities, stating the importance of transformative competencies. In this context especially the skills of dialogue and conflict ability as well as the ability to make judgments are emphasized as particularly important. In addition to transformative skills, digital key competencies (e.g., digital literacy) and classical skills (e.g., ability to solve problems) are also highlighted and it is predicted that these will continue to gain in importance over the next five years. (Stifterverband & McKinsey, 2021)

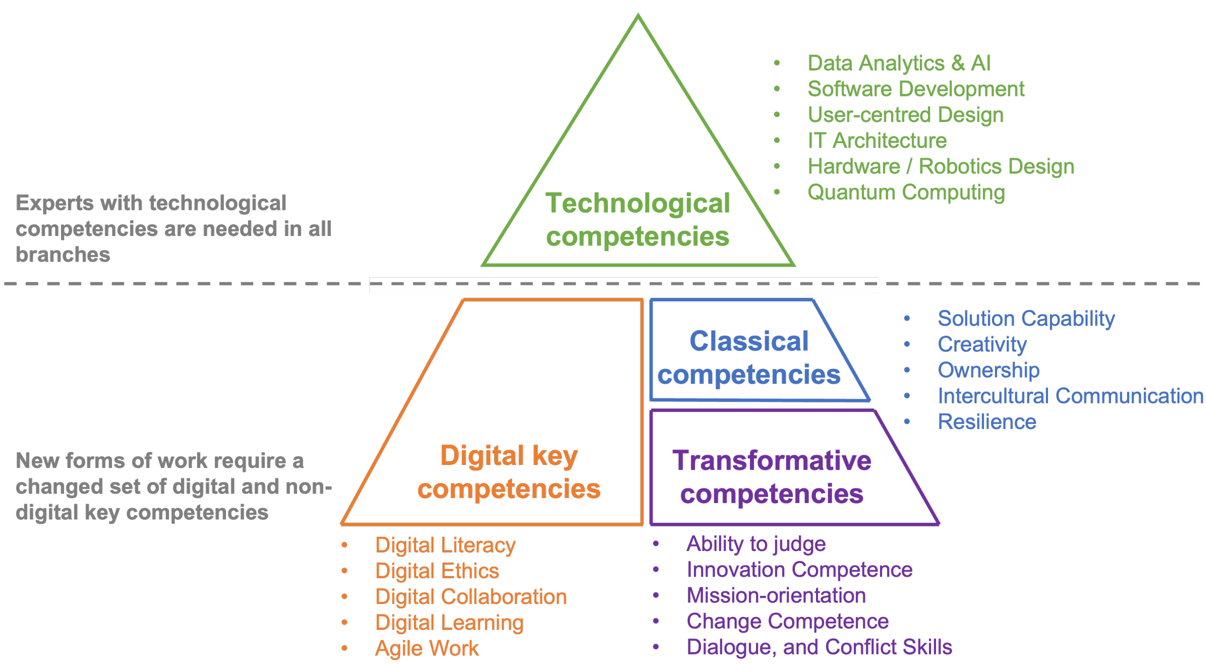

Figure 1. Future Skills (Own illustration following Stifterverband & McKinsey, 2021)

Because higher education has also become aware of the need to teach such skills, there are already various approaches. Alswad and Junai (2022), for example, see potential in integrating debate as an educational tool as it helps students to improve "[…] their critical thinking, increase the retention of the information gained, enhance communication and teamwork skills, promote their confidence and help them to better construct their ideas and thoughts in a logical and sound structure." (p. 1003). Summarizing Alswad and Junais (2022) experiences, the deliberate use of debate as a method can address both classical and transformative competencies. Soleimani et al. (2022) conducted a study exploring the sustainability of knowledge acquisition in the context of the SDGs. Their results show that personal reflection ensure a holistic acquisition of knowledge and conclude that reflection processes should be an integral part of teaching in higher education (Soleimani et al., 2022), which would also support the development of transformative competencies. Foley, Foley and Kays (2022) discuss the necessity of actively dealing with a culture of failure in engineering as it represents a "[…] necessary part of transformative learning in line with the intentions of CDIO." (Foley, Foley & Kays, 2022, p. 1009). In summary, there are different initiatives to rethink the engineering curriculum to be able to teach the future skills. Since previous approaches focus individual areas of competence to be able to teach them in the appropriate depth, the course presented attempts in a first step to tackle all four areas of competence and to make them a topic of discussion. However, since a more in-depth teaching of future skills is also to be achieved, a focus is laid on the competencies emphasized by the Stifterverband and McKinsey study (2021): the classical, the transformative and the digital key competencies. At this point, it is reflected that a more profound training of the respective competencies is more difficult if three competencies are to be addressed at the same time. The course therefore serves as a first step to deal with the new competencies and therefore needs to be integrated into a course of studies that ensures a more profound examination of the single competencies.

In the following, a block seminar is presented lasting a total of five days. The course is divided into two phases. The kick-off in the form of face-to-face teaching during the semester is combined with digital teaching outside the lecture period. Holding the block course outside the lecture period allows international students to participate from their home country. This enables the intercultural student teams to collect user perspectives and experiences directly at the respective location and thus to incorporate an intercultural perspective into the digital group work. This ensures an ongoing intercultural reflection of the group's innovation ideas. The innovative moment lies in the digital application of the design thinking approach and the inclusion of intercultural as well as trans- and interdisciplinary perspectives in innovation development.

COURSE CONCEPT

The course "Applying Design Thinking - Sustainability Perspectives, Innovation and Interculturality" aims to prepare students for their future work in an international environment. The 5-day course concept (Figure 2) consists of two elements. Day one in presence at the Jülich campus and days 2-5 as a digital block format outside the lecture period. The kick-off day at campus aims that students get to know each other personally during the semester and gain a scientific knowledge base on the topics of interculturality, sustainability and innovation. The course starts with the cultural dimensions according to Hofstede (2001), House et al. (2004) as well as Trompenhaars and Hampden-Turner (2012). The three concepts of cultural dimensions are discussed and reflected upon from the perspective of the different cultural backgrounds of the students. Based on the cultural dimensions and the resulting diverse perspectives, students are introduced to the scientific discourse on sustainability concepts (e.g., Morandín-Ahuerma et al., 2019; Pelenc, 2015; Dedeurwardere, 2013; Corsten & Roth, 2012). With the help of the sustainable development goals (SDGs) (United Nations, n.d.) the connection between diversity concepts (Gardenswartz & Rowe, 2003; Pelled, 1996; Loden & Rosener, 1991) and sustainability is clarified. To raise awareness through reflection on a personal level, the social responsibility of engineers and the individual role in societal transformation as well as the impact of diversity sensitive innovations (Gillwald, 2000; Mulgan, 2006) are discussed afterwards.

Building on the kick-off day (day 1), the digital design thinking challenge (days 2-5) takes place outside of lecture time. Days 2-5 focus on the teaching and practical application of the design thinking approach. Based on the scientific state of the art as well as the discourses about social innovations and the own role as an engineer in the development process, day two starts with an introduction to human-centered design and in this context design thinking. The experience of many years of teaching and applying design thinking has shown that especially engineering students are looking for a structure that provides orientation in a process. The open questions and the challenge of first understanding the problem from the perspective of the potential user and not arriving too quickly at a solution of one's own, turned out to be the main challenges for engineers in the design thinking process. The reason for this can be seen in the engineering culture which is influenced by the clearly structured processes, norms, and standards of the engineering working environment. While design thinking courses usually get to the part of the practical application quite quickly, design thinking formats with an engineering focus require an introduction to the design thinking process and a transparent explanation of the iterative process steps. This approach allows students to find their way through the process and gives them orientation and confidence. (see also Leicht-Scholten & Steuer-Dankert, 2020; Steuer-Dankert et al., 2019)

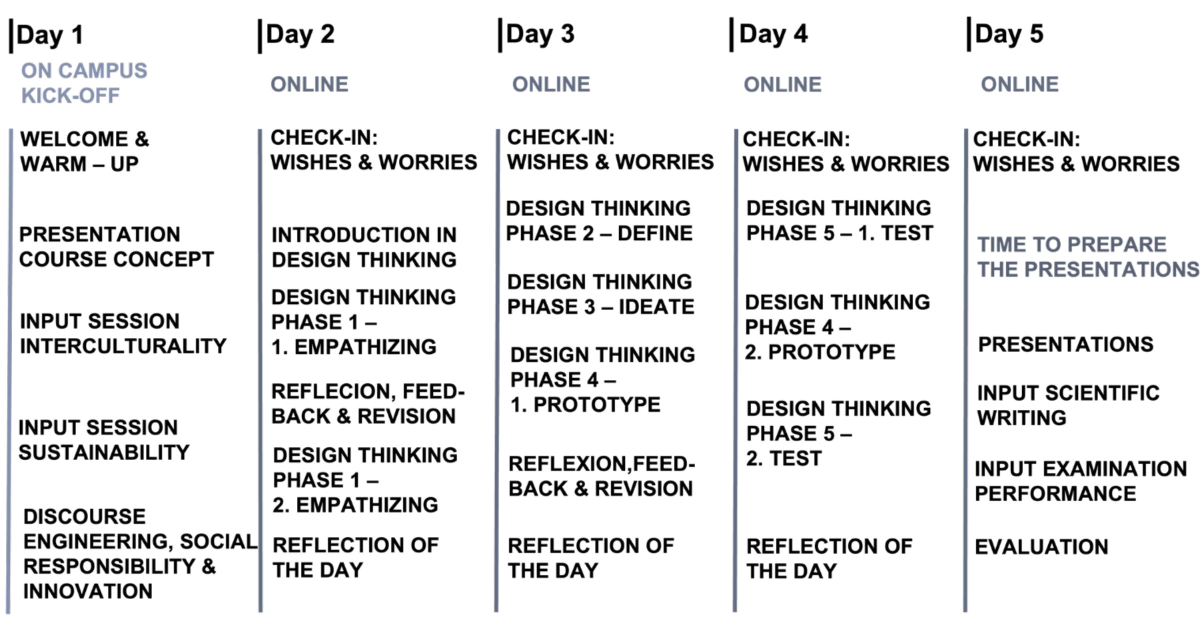

Figure 2. Course Concept (Own illustration)

To make the process more transparent and to convey the design thinking spirit to students, the 5-step design thinking process (Plattner et al, 2011) is applied (Fig. 3). A special focus is laid on the empathizing phase, giving students time to investigate user needs and perspectives in the respective country. Despite the defining and ideating phase (phase 2 + 3), students have two cycles to reflect their ideas with the potential target group and to improve their identified problem (phase 1) and solution (phase 4 + 5).

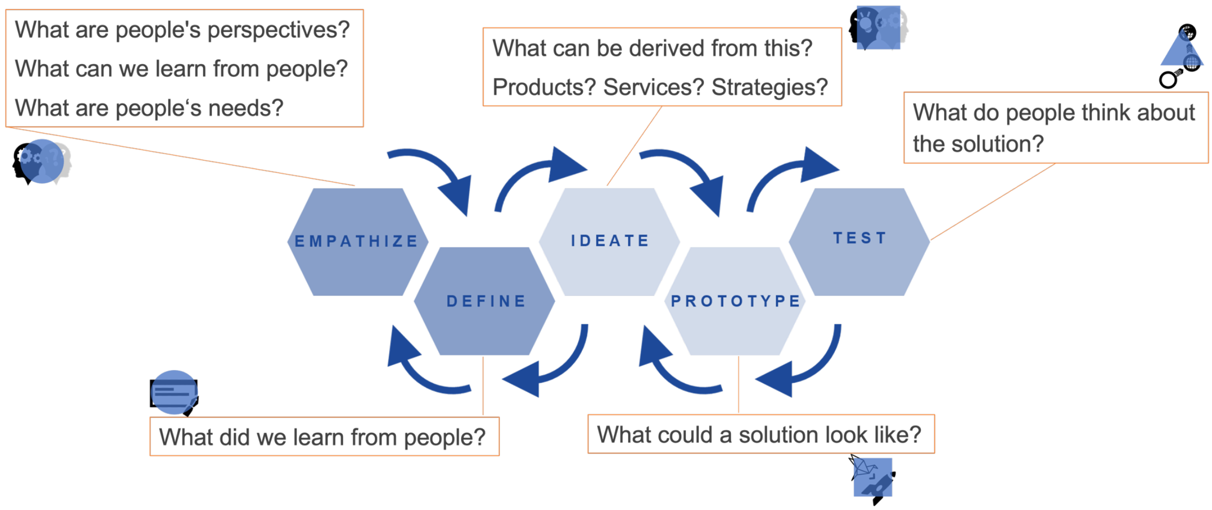

Figure 3. Key questions in the 5-step process (Own illustration)

The individual phases are discussed in more detail below:

Empathize & Define - Days 2 + 3

Students work in small groups whose group members belong to different nationalities. This entails different perspectives on innovation and collaboration in digital networked teams, as well as active contacts in different nations. To deal with the potential user needs, students contact people on site. Using quantitative and qualitative survey methods, they conduct surveys to identify the needs and perspectives of potential target groups in the sustainability context. In the next step, they bring together their findings and the different perspectives on the sustainability context in the digital learning space. The focus during the definition phase is to analyze the user perspectives and to identify the underlying problem or challenge. Especially engineering students need to be guided to focus purely on problem identification during the first two phases.

Ideate & Prototype & Test - Days 4 + 5.

In the further course of the process, the students develop innovation ideas based on their findings from the surveys and the derived user problems. Students then convert the ideas into digital prototypes (e.g., digital services, product ideas, concepts) which are then tested again on the target group. The digital implementation enables testing at the respective location and thus the continuous integration of intercultural perspectives on innovations. They are supported in this process by digitalized creative techniques (e.g., Disney Method, Six Thinking Hats, Crazy 8) and rapid prototyping methods. The development of the prototype and testing takes place in two runs to obtain user feedback and then incorporate it.

Reflection - Day 5

The examination performance consists of a final presentation as well as a reflection report. On the one hand, this trains the ability to create appropriate materials in a team environment, and on the other hand, it deepens the methods learned and trains presentation skills. In preparation, the students also learn how to write scientific texts. The final presentation (pitch) is held digitally on the last day of the course. The report focuses on the reflection of the individual steps and the respective insights that the group was able to gather in the steps. Based on this, it is deduced how the product idea was developed and which insights underlie the idea.

Another element of the last day is the teaching evaluation consisting of two elements. Element one is a quantitative evaluation questionnaire standardized by the university. The collected, mostly organizational, categories of the evaluation will be supplemented by element two, a focus group interview (qualitative approach), which should give an insight into the learning process of the students. A special focus in these interviews will be placed on the reflection of the acquired competences and their applicability in the future field of activity. Furthermore, the interviews will serve the continuous reflection of the teaching elements and the improvement of the course concept.

Course-Companying Elements

Especially with digital formats, there is a need for a joint reflection on concerns and factors that can impede digital collaboration. For this reason, days 2-5 are framed by reflection exercises that ensure transparent communication and the methodical monitoring of challenges. Every day begins with collecting and discussing students' concerns and wishes. Experience has shown that initially the main concern is not being able to be creative enough and that it is perceived as a challenge to approach potential users and ask the right questions (Steuer-Dankert et al., 2019). Teaching basics of social science research methods and implementing creativity exercises enables access to methods that help to cope with these challenges. On a social level, making these challenges transparent helps to recognize that this is not a subjective individual phenomenon, and emphasizes that different competencies within the team can also complement each other. To maintain the process character and allow an open and trustful reflection in the course, a code of conduct is used as an agreement within the course. The code of conduct includes aspects such as unprejudiced cooperation, respectful communication, and the courage to be creative, and is intended to contribute to an open and respectful course culture (Leicht-Scholten & Steuer-Dankert, 2020). Complementary to the reflection of wishes and worries in the morning, there is a daily reflection in the evening. As part of this daily reflection, the wishes and concerns mentioned are again addressed and reflected together with the students. In a group session, students reflect to what extent the challenges could be successfully mastered or which follow-up questions have developed over the day.

The creation of a safe working environment, where students can be creative and are open for a culture of failure (see Foley, Foley & Kays, 2022) is a key aspect of successful design thinking. Consequently, especially a digital design thinking course requires a constant moderation of the process. The challenge of a digital design thinking process consists in the precise alternation between open discussions in the course and the discussion of questions in the teams. Both formats require support and continuous responsiveness from the course leader. The teaching principle focuses on a moderation through the right questions and less the direct communication of the solution. In addition, interactive elements such as voting (e.g., via Mentimeter), and brainstorming sessions (e.g., via Miro) provide digital supportive moderation. Transnational teamwork is complemented by in-course reflection rounds where teams share their findings and experiences. The moderation of virtual discussion rounds within the course as well as teamwork phases enable peer feedback, which is complemented by group coaching by the course instructor.

In terms of credit points, the course is assessed at 6 ECTS to the scope of student work. Regarding the integrated study programs, higher semesters from the bachelor's programs Electrical Engineering, Mechanical Engineering, and Physical Engineering located at the

Faculty of Energy Technology are addressed in a first round. In a second round it is planned that the departments Biotechnology, Techno Mathematics and Medical Technology will implement the course in their study programs, too. The course will be part of the elective catalogue and is offered in both winter and summer semester. Regarding the organization of the two course elements, the aim is to have the kick-off course and the digital course take place fairly close to each other. However, the exam phases and the time until the international students have travelled to their home countries must be considered. Regarding these framework conditions, there is a time gap of one month between the kick-off course in presence (day 1) and the online course (days 2-5). As the time interval might have an influence on the students' willingness to perform and their ability to connect with the course contents discussed at day 1, a joint reflection with the students at the end of the course is planned, to discuss the impact of the time gap on the students' learning outcome.

REFLECTION AND CONCLUSION

The purpose of engineering education is to enable students to "[…] get technical expertise, social awareness and the bias towards innovation. This combined set of knowledge, skills and attitudes is essential to strengthening productivity, entrepreneurship and excellence in an environment that is increasingly based on technologically complex and sustainable products, processes and systems. It is imperative that we improve the quality and nature of […] engineering education." (Crawley et al. 2014, p.4). The CDIO standard 3.0 as a set of principles provides an overview of elements that enable future-oriented engineering studies.

In this paper, a digital design thinking teaching concept was presented which intends to convey future skills to future engineers. The course allows students to learn important future skills, with a focus on the classic, transformative, and digital skills - the areas of competence that, according to the study by the Stifterverband and McKinsey (2021), will gain in importance in the future (see figure 1). The concept was based on the CDIO standards 3.0 and addresses Standard 5, 6, 7 and 8 in particular.

Participants learn the practical application of the design thinking approach in interdisciplinary and international teams. Consequently, students gain experiences in the design of products, services, or systems by developing an idea basing on the user perspective. In this way, they gain transdisciplinary experience as they must combine scientific content with the experiences of people from the non-scientific community (Standard 5 - Design-Implement Experiences). As part of the course, students are involved in different working contexts. On the kick-off day students learn on campus in activating group work, then work in digital teams during the challenge and get in personal contact with potential users as part of the first design thinking phase (Standard 6 - Engineering Learning Workspaces). Students learn to work in an interdisciplinary and transdisciplinary manner and to link their findings with the specialist focal points. The active engagement with potential users of the sustainability challenge to be developed allows a new perspective on different cultures and the diversity of target groups. Thus, a contribution can be made to ensure that engineers reflect more strongly on social diversity and the effects of engineering developments by getting in contact with end users and key stakeholders (Standard 7 - Integrated Learning Experiences). Furthermore, students acquire competencies for their future professional activities, such as coordinating in intercultural as well as interdisciplinary teams, organizing collaboration in a digital setting and taking other perspectives into account. In addition, through the structure of the design thinking process, students learn to make decisions in a team setting within a short time frame and to transform them into a solution approach. The course format enables, direct feedback and complements the learning process with daily reflections and group discussions (Standard 8 - Active Learning). From a content perspective, students learn the basic principles as well as selected concepts of sustainability management (e.g., UN Sustainable Development Goals - SDGs), innovation management and diversity management. From a scientific perspective, students learn how to prepare presentations and reports according to scientific standards. In addition, students learn how to research scientific sources and how to apply them in the context of the reflection report.

In addition to the numerous potentials, there are also challenges. Working together in diverse teams not only offers potential but also challenges in group work (see Bartz et al., 1990; Nooteboom et al., 2007; Lorenzo et al., 2017). Therefore, close supervision of the groups and extensive sensitization for diversity and the resulting diverse perspectives are mandatory. There is also a challenge in the different time zones of the participants. This challenge should be made transparent to the students at an early stage and solutions for cross-time zone cooperation should be worked out together with the students. Another limitation is the number of course participants. The course is currently being conceptualized for 15-20 people, as close, digital support is difficult to implement for one teaching person.

If engineering education wants to contribute to overcoming global problems, then it must rethink its engineering curricula and create space for interdisciplinary, transdisciplinary and intercultural teaching formats. The course concept presented is intended to serve as an inspiration for how engineers of the future can be trained in order to be able to master the challenges of the future.

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