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Teaching Essential Competencies for Social and Sustainable Engineering Design – Case Study of a Research-Oriented Master's Seminar*

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The master's seminar "Competencies for Social and Sustainable Engineering Design" at RWTH Aachen University is part of the study programs Environmental Engineering, Civil Engineering and Industrial Engineering. Focusing on Education for Sustainable Development (ESD), this course covers, teaches and reflects relevant competencies for socially responsible and sustainable engineering design. Following a research-orientated focus, the following research question was addressed: "Which competencies are considered relevant by future engineers in the context of sustainable and socially responsible engineering design?". The purpose of this paper is to present this approach and, on the basis of the seminar, to explain how relevant competencies for socially responsible and sustainable engineering design can be acquired by engineers. Moreover, the seminar concept is explained and a methodology for teaching the aforementioned topics is described that can also be transferred to other courses. The evaluation of course-specific feedback allows to present both conclusions and corresponding solution approaches, as well as challenges associated with the concept. Results show that engineering students call for competencies which go beyond pure technical knowledge, and, at the same time, determine that these competencies, like social competencies, are missing in their studies. Accordingly, this leads to implications for future curricula development.

Keywords: engineering education; engineering skills; competencies; sustainability; responsibility

1. Introduction

Regarding their impact on society and environment, engineers are jointly responsible for transformations and innovations and thus, need to reflect upon this responsibility [1–4]. Accordingly, relevant competencies to reflect on their responsibility as engineers are required and must be embraced and enabled by education [1]. In the last years discussions about competencies of engineers needed to meet challenges of the 21st century have arisen [1, 3–5]. As stated in the SEFI position paper [1] "engineering is a collaborative, complex activity that demands socio-technical, societal and systems perspective." Thus, engineering graduates must cope with challenges and complex problems affecting society. Understanding environmental context and planning for sustainable development are relevant aspects here, therefore future engineers should be enabled to create sustainable and socially responsible solutions [2, 3].

The fourth goal for sustainable development of the United Nations states, by 2030, "ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development." [6] Accordingly, education for sustainable development (ESD) also has a significant role in engineering education. The increasing debate on competency-based teaching in engineering is therefore accompanied by a stronger integration of competencies for sustainable development as well as ethics, social responsibility and intercultural cooperation [3, 7–13].

For this reason, the Faculty of Civil Engineering at RWTH Aachen University offers the master's seminar "Competencies for Social and Sustainable Engineering Design" as part of the degree programs Environmental Engineering, Civil Engineering and Industrial Engineering. In this seminar, relevant competencies for socially responsible and sustainable engineering design are presented, taught and reflected upon. Together with the students, the research question "Which competencies are considered relevant by future engineers in the context of sustainable and socially responsible engineering design?" is answered in the course of the seminar.

The aim of this paper is to present this research-oriented teaching approach in terms of a case report. It elaborates how engineering students can acquire competencies for a socially responsible and sustainable engineering design by letting them do research relating thereto themselves. For doing so,

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a case report based on Malmi et al. [14] was chosen in order to propose a novel educational setting and teaching concept and to improve practice [14]. Thus, the focus of this paper is in describing this concept and in reporting student's results and feedback. In the following, first, the theoretical background is described, based on discourses on ESD and the relevance of competencies for socially responsible and sustainable engineering design. Afterwards, section 3 presents the seminar concept and a methodology for teaching the aforementioned topics that can also be transferred to other courses. The methodology is based on the analysis of 24 students-led interviews, which results are presented in section 4. For this purpose, a deductive category system is used, which is based on a pre-given interview guide. The evaluation of course-specific feedback allows to present both conclusions and corresponding solution approaches, as well as challenges associated with the concept.

2. Theoretical Background

2.1 Competencies for Sustainable Development

The concept of Education for Sustainable Development (ESD) is internationally framed by UNESCO [15–17]. ESD "empowers everyone to make informed decisions for environmental integrity, economic viability and a just society for present and future generations, while respecting cultural diversity." [17] and thus, requires competencies like critical thinking, system thinking, future-oriented thinking or taking action for sustainable development [15, 16]. As Higher Education Institutions (HEIs) have an expanding influence on ESD by value and impact of their teaching and research both on local and global level, they are particularly relevant in promoting competencies for ESD [15].

In an educational context, competencies describe desired educational outcomes [18, 19]. They can be defined as a combination of knowledge, skills and attitudes appropriate to the context [19] or more precisely they describe "a potential for the presumed ability of a person to act intentionally, purposefully and successfully" [18, p. 10].

In the last decade, the scientific discourse around competencies for Sustainable Development (SD) has become increasingly important. There are several lists of competencies and definitions regarding education for sustainable development, proposed by different authors [20]. Wiek et al. [21] summarized and categorized SD competencies in a broad literature review. This resulted in five key competencies: systems-thinking, anticipatory, normative, strategic and interpersonal competence. Barth et al. [22] analyzed the implications for different learning settings regarding the development of key competencies in higher education. Lozano et al. [20, 23] connected competencies and pedagogical approaches for SD in higher education.

In Germany, "Gestaltungskompetenz" (shaping competence, [24]) has been discussed as a central educational objective of ESD [22]. This means "having the skills, competencies and knowledge to enact changes in economic, ecological and social behaviour without such changes always being merely a reaction to pre-existing problems." [24, p. 22]. "Gestaltungskompetenz" in this context comprises eight sub-competencies that are central to the design of educational standards: competencies in foresighted thinking, interdisciplinary work, cosmopolitan perception, transcultural understanding and co-operation, participatory skills, planning and implementation, capacity for empathy, compassion and solidarity, self-motivation and motivating others, and distanced reflection on individual and cultural models.

This also goes along with the understanding of "Change Agents" [25]. Change agents have, for example, the skills to engage in self-assessment, self-reflection and analysis, engage in civil discourse and debate or to recognize the global implications of their actions. These skills should enable students to create a sustainable future.

Those understandings of "Gestaltungskompetenz" and "Change Agents" and the underlying key-competencies were used as the basis for the seminar described in this study.

2.2 Competencies for SD and Responsibility in Engineering Education

With regard to the relevance and impact of their work, the previously described competencies are correspondingly relevant for future engineers who need to be sensitized to topics such as sustainability, ethics and responsibility as part of their education [8, 9, 11, 13].

In their multi-year project, the American Society for Engineering Education (ASEE) studied attributes needed by engineers to live and work effectively in a global context [26]. The *Attributes of a Global Engineer* project identified several relevant competencies. Attributes of a global engineer are for example communicating effectively in a team, thinking critically and creatively, possessing a global perspective or embracing an interdisciplinary perspective. Downey et al. [27] also stated that one important aspect regarding global competence is to understand that working effectively with different cultures means to work with people who define problems differently. In 2004, the National Academy of Engineering [4] published attributes engineers should have in 2020. In their literature

review, Guerra et al. [28] compared NAE attributes to the *Attributes of Global Engineer* project and found few differences.

Referring to Europe, the engineering education initiative CDIO (Conceive, Design, Implement and Operate) has developed a syllabus of knowledge, skills and attitudes engineers should acquire during their study programs [2, 3]. In the updated version, the syllabus includes a category referring to roles and responsibilities of engineers, impact of engineering on society and the environment, development of a global perspectives and sustainability and the need for sustainable development.

The Association of Engineers in Germany (VDI), which is the largest technical-scientific association in Germany, regularly publishes standards for technical regulations. In 2002, the VDI published the ''Fundamentals of Engineering Ethics'' [29] in order to contribute to raising awareness about engineering ethics and engineering responsibilities. These fundamentals state that for example, engineers are responsible for their professional actions, are committed to developing sensible and sustainable technological systems, are aware of the embeddedness of technical systems into their societal, economic and ecological context, and their impact on the lives of future.

However, research with students showed substantial knowledge gaps regarding sustainability, responsibility and ethics in engineering programs [8, 11, 13, 30, 31]. Even though there is agreement on the necessity and relevance of these topics in engineering education, their concrete implementation in curricula remains a major challenge.

3. Course Framework

3.1 Course Description and Learning Outcomes

The seminar ''Competencies for Social and Sustainable Engineering Design'' takes place annually in the winter semester and addresses master students of the study programs Environmental Engineering, Civil Engineering as well as Business Administration and Engineering specializing in Civil Engineering at RWTH Aachen University, one of the leading technical universities in Germany.

In the winter semester 2020, the seminar was restructured in a research-oriented way. Together with the students, the following research question had to be answered: *''Which competencies are considered relevant by future engineers in the context of sustainable and socially responsible engineering design?''*

Following the concept of constructive alignment [32], the intended learning outcomes were orientated on the research question. They included in particular the reflection of responsibilities of engineers and the relevance of sustainable engineering design, the relevance of interdisciplinary thinking and acting, the assessment of competencies for a social and sustainable engineering design, the development of problem solving competencies with regard to the integration in the university context as well as the evaluation of self-generated research results referring to the previously defined research question.

Active participation, independent learning, curiosity and reflection are necessary for the success of the teaching and learning concept. For this purpose, the sessions were structured according to the think-pair-share principle, which is well received in literature [33]. Accordingly, students first had to read a paper independently and assess it with regard to a question and then discuss the results together with others. At the end, the group results were presented to the plenary. The group work was organized in breakout sessions via the online video-conference tool Zoom and the creative mind mapping tool Miro was used for collaborative work. Moreover, students were able to voluntarily submit a critical reflection related to each session.

To meet the intended learning outcomes, the seminar was divided into five topics that addressed the following competencies and guiding questions:

Shaping competence: Why are topics such as sustainability, engineering ethics and responsibility relevant for engineers? Which key competencies are relevant for shaping a sustainable future in the context of shaping competence?

As described in the theory section, ''Gestaltungskompetenz'' is a key competence regarding sustainable development. Students had to prepare the session by reading and answering questions to the paper of Wiek et al. [21]. In addition, this session required students to act as ''change agents'' [25] in group work by reflecting on what competencies and characteristics change agents must have in order to promote sustainable development.

Engineering competencies: What factors define technology science/engineering? Which competencies are addressed in the scientific discourse and to what extent are ethics and responsibility mentioned as such?

Based on the study of Rulifson and Bielefeldt [13] students had to reflect on social responsibility of engineers and what does that mean to themselves.

Global competence: Which global challenges are relevant for engineers and why? Which competencies are necessary for these?

Students had to prepare this session by reading Downey et al. [27] in order to reflect on competencies that are relevant for effectively global working of engineers. Again, students had to act as change agents reflecting on relevant aspects regarding

intercultural teamwork and communication in a fictive case of construction and implementation of a water supply system.

Academic competencies: What does competence-oriented teaching mean? Which competencies should engineers acquire during their studies?

In this session, students gained knowledge about competence-orientated teaching and learning and the underlying models in Germany for this in order to reflect upon their own acquired competencies in their study programs.

Finally, a *transfer into practice took place*: With the involvement of the student initiative ''Technology without Borders'', a workshop on the topic of ''Intercultural Competence'' was held, in which the students were to independently work on an application-related practical example from a water project in Ecuador. They learned about challenges of intercultural working and communication and reflected upon their specific role as engineers.

3.2 Method: Guideline-Based Interviews

Qualitative interviews and their evaluations were set as both examination and an appropriate means to answer the above-mentioned research question. On the one hand, the students thereby become acquainted with a social science-oriented research process, and on the other hand, they enter into an exchange with other students and learn new perspectives that are intended to promote self-reflection.

The students had to independently conduct interviews with master students of engineering programs, which were then evaluated and presented using a qualitative content analysis, based on Mayring [34, 35]. The guideline for the interviews was based on the topics of the seminar and was provided by the lecturer. Interview questions were categorized in four groups, namely covering the topics studies and engineering identity (1), engineering competencies in general (2), sustainability and responsibility of engineers (3) and competencies regarding sustainability and responsibility of engineers (4). Table 1 provides an overview of these questions.

Questions 3e and 3f are adapted from the study of Rulifson and Bielefeldt [13] who performed longitudinal interviews with engineering students regarding social responsibility.

The students had to conduct qualitative interviews individually and then evaluate them in groups of four or five. In total, 24 students participated in the seminar in winter semester, which, accordingly, results in 24 interviews. For each group, the subjects of the conducted interviews were to be as heterogeneous as possible with regard to course of study, age and gender.

4. Results and Discussion

First, it is important to mention that none of the 24 students in the course had any pre-experience regarding interviewing or qualitative content analysis. Students in technical fields in Germany seldomly have subjects or courses in social sciences. Therefore, the basics of interviewing and analyzation, based on Mayring [34, 35] were presented and explained beforehand in the seminar in order to introduce the students in methods of social sciences.

Since the students only evaluated and presented a maximum of five interviews in their groups, the

Table 1. Summary of the interview questions

Studies and Engineering Identity (1)	
Are you satisfied with your studies so far?	1a
Are you missing something in your studies?	1b
What does it mean to you to be an engineer?	1c
Regardless of your own previous education, how should engineers be trained in the future?	1d
Should certain emphases be set in the course of study? What would these look like?	
Engineering competencies (2)	
Which competencies do you see as particularly relevant for future engineers?	2a
Would you say that you are acquiring the competencies you mentioned as part of your studies? Which competencies are you missing?	2b
Do you think that the demand for competencies has changed in the last 20 years for future engineers?	2c
Sustainability and Responsibility (3)	
Are you familiar with terms like sustainability and engineering ethics?	3a
Did your studies cover topics such as sustainability or engineering ethics?	3b
Do you think these topics are fundamentally relevant for engineers?	3c
Do you know the Ethical Principles of the Engineering Profession from the Association of German Engineers (VDI)?	3d
What are the responsibilities of an engineer?	3e
For whom? In which area or context and why?	
What do you think is the role of an engineer in society?	3f
To what extent do engineers influence society, or to what extent should they do so?	
Competencies for a Sustainable and Responsible Engineering Design (4)	
What competencies are necessary for engineers to assume responsibility in the sense of the Ethical Principles?	4a
Would you say that you have acquired these skills as part of your studies?	4b

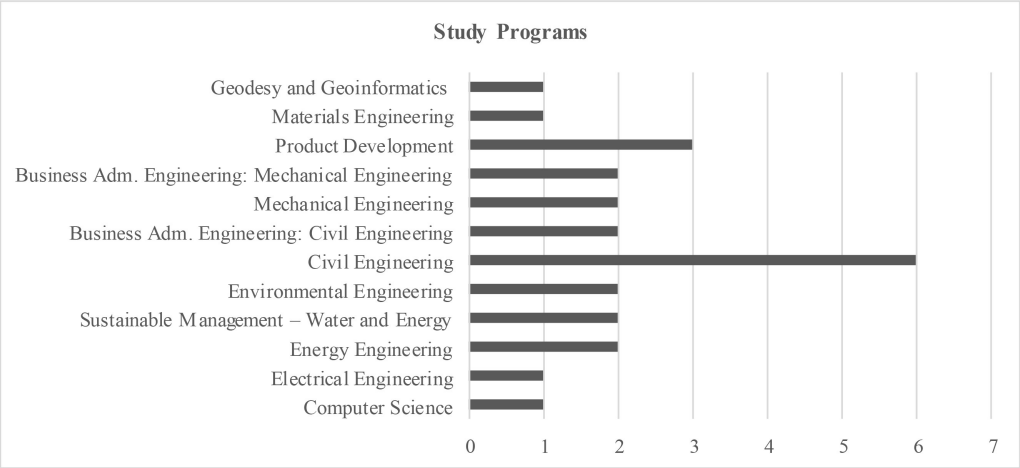

Fig. 1. Overview and number of master's degree programs of engineering students surveyed.

results of the total of 24 interviews were analyzed afterwards by the lecturers as presented below. The transcripts written by the students were once again compared with the audio recordings. Subsequently, based on the interview guide described above, a deductive category system was developed, which is based on the four groups of the interview guide.

In total, 19 persons were male and five were female. 23 of the interviewees were between 22 and 28 years old, one person was 32 years old. Twelve different engineering study programs were identified, two of which represent specializations of a study program (see Fig. 1).

In the following, the results of the four categories are briefly presented and discussed.

4.1 Category 1: Studies and Engineering Identity

In general, most of the students (20) showed satisfaction with their study programs (1a). The reasons given for this were, for example, fulfilled expectations, sound basic knowledge and general enjoyment of the study program. Only two people made negative comments on this, the reason given being a lack of practical relevance. Although the majority expressed basic satisfaction, some aspects were mentioned that were lacking in their study programs (1b). The lack of practical relevance was mentioned by 13 students, and the strongly theoretical content was also often criticized. These results go along e.g., with the study of Miranda et al. [36] who highlighted the need for problem-based and active learning methods for engineering students in order to address the lack of practical experiences. Moreover, five students commented on the lack of social and ethical topics.

Regarding engineering identity (1c) results showed that 18 students mentioned "problem solving" as a key attribute of engineers, which in literature is also described as a key competence for engineers [1, 2, 37, 38]. Some students described this also as "creative" or "complex" problem solving. Two students explicitly addressed "Identify and solve problems in the society" as relevant qualities of engineers. The second most frequently cited factor was technical knowledge. This includes practical experience and qualifications, technical and logical understanding as well as technical aptitude. Other aspects mentioned were frustration tolerance, perseverance, analytical and structured thinking, sense of responsibility, impact assessment, construction, dealing with complexity, creativity, communication, learning ability, and helping society. These were each named only once.

The answers to question 1d went along with the previous ones. According to the students, future engineering education should not only have a stronger practical orientation, but also social and personal competencies, such as taking responsibility and impact on society should become more prevalent. Furthermore, interdisciplinarity and data literacy were mentioned as relevant topics for future engineering education. The results coincide exactly with the demanded competencies in theory, as described in section 2.

4.2 Category 2: Engineering Competencies

As particularly relevant competencies for engineers, three were mentioned most frequently: professional competence, problem solving and social competence. At the same time, social competence stood out as a missing competence in studies. Table 2 shows an overview of the number of competencies mentioned as both relevant and as missing in studies (2a–2b):

Regarding the development of acquired competencies for engineering students, students thought that especially digitalization, globalization and intercultural cooperation, teamwork and social

Table 2. Competencies mentioned by students as relevant for engineers and competencies missing in studies

Relevant competencies for engineers (2a)	Number of mentions	Competence missing in studies (2b)	Number of mentions
Professional Competence	13		
Problem Solving	12	Problem Solving	2
Social Competence	9	Social Competence	11
Communication	7	Communication	3
Teamwork	6	Teamwork	3
Analytical Thinking	5		
(Self-)Learning	4	(Self-)Learning	1
Methodological Competence	4		
Ethical Behavior and Understanding	3	Ethical Behavior and Understanding	1
Impact and Risk Assessment	3	Impact and Risk Assessment	1
Personal Competence	2		
Willingness to Perform	2		
Creativity	2		
Sympathy and Empathy	1		
Responsibility	1	Responsibility	1
Interdisciplinarity	1	Interdisciplinarity	2
Openness	1		
Holistic Thinking	1	Holistic Thinking	1
		Presentation Skills	3
		Leadership	1
		Intercultural Competence	1

competencies in general have become much more relevant in recent years (2c). This question was included in the guide primarily to help students reflect on the changing demands and developments of the engineering profession.

It is important to note that the competencies listed above were named by the students themselves. For example, teamwork and communication could also be listed as "social competence". Of course, there are several options to define and formulate competencies [10, 39, 40], but the purpose here was to investigate and reflect the students' points of view and not to categorize the freely given answers.

4.3 Category 3: Sustainability and Responsibility

23 students stated that they know the term sustainability and could explain it (3a). Only 12 people were able to confirm this for the term engineering ethics, 11 had not heard this expression before. However, when students were asked to explain the term sustainability in their own words, only a few were able to clearly delineate it. After the respective question, sustainability and engineering ethics were explained to each participant, in order to create a common understanding of the terms for the subsequent interview. The focus here was on the presence of these topics in engineering studies (3b). 16 students stated that sustainability had already been addressed in some form in their studies, while eight denied this. Engineering ethics was assessed by eight students as being represented in their studies, 15 could not confirm this. A lack in the understanding about the relevance on ethics for engineers was similarly found by Valentine et al. [8] in their study on ethics in engineering.

With regard to the relevance of sustainability and engineering ethics (3c), 19 students thought that these topics were definitely relevant. One person each only considered sustainability and engineering ethics to be relevant. Two people did not make a statement and one person was unsure.

As formulated in the theory section, the *Fundamentals of Engineering Ethics* formulated by VDI state duties and responsibilities of engineers [29]. Although engineering students in Germany are often confronted with VDI standards, for example regarding boundary conditions or building components, 22 students have never heard of the standards, two persons were not sure (3d). This result was also mirrored within the course, where none of the participants declared to had heard of the VDI *Fundamentals of Engineering Ethics* before.

All students named areas of responsibility of engineers (3e) in the course of the interviews. Safety-related aspects were frequently listed, such as in construction and building planning. According to the students, engineers are also seen to have the responsibility to provide technologies that are accessible and user-friendly to as many people as possible. Moreover, they are responsible for assessing consequences, which results in a responsibility

for society. As one student noted: "Engineers are people who develop tools, products and solutions, not only for today, for our generation, but also for the generation after 100 years. And accordingly, they have an enormous responsibility to think not only about themselves and their current generation, but also about the future." (translated by the authors)

This goes along with question 3g referring to the role of an engineer in society. Answers of students could be categorized in two topics: relation to society and areas of responsibility. In terms of relation to society, engineers were often described as "driving forces" who improve and shape people's lives. They were seen as both the foundation and the center of society. Furthermore, engineers in Germany are seen to enjoy a high standing in society. Only two people did not see any relevant role of engineers in society. With regard to the areas of responsibility, the development of technologies and products was mentioned above all, on the basis of which added value could be created. Engineers are also seen as responsible for preventing hazards, developing solutions for everyday life and meeting the needs of society, as one student noted: "I think engineers have the task of simplifying the world or life, precisely through possible developments, and somehow also making life more worth living." (translated by the authors)

4.4 Category 4: Competencies for a Sustainable and Socially Responsible Engineering Design

After having talked and thought about basic competencies of engineers as well as about sustainability, engineering ethics and responsibility of engineers, the focus at the end of the interviews was specifically on competencies that are relevant for social and sustainable engineering design (4a). The interviewed students had to connect the aforementioned topics in order to derive implications for relevant competencies. The competencies mentioned in this context are listed in the following table, which also compares the results with the competencies mentioned in chapter 4.2.

Analogous to 2b, most respondents reported that these competencies – with the exception of technical or professional competencies – are not taught in their course of study (4b). Two persons pointed out that this was not the function of the university.

Contextualizing Table 3, it clearly shows an ambivalence regarding relevant competencies from students' point of view and missing competencies in their study programs. Especially regarding "social competence" it becomes clear that students define this as a relevant competence in general for engineers, but named this competence as not represented in education. However, some students noted that the reflection process regarding relevant competencies has developed during the interview. The majority had never dealt with the treated topic before and only after the competencies of engineers or the responsibility of engineers had been discussed in the course of the interview, they were able to see the connections more clearly in the last block (4). Accordingly, biases cannot be excluded. However, the aim of the study was to see students' thoughts and just in time answers in order to get a precise impression of their mindset towards topics of sustainability and ethics.

Comparing the competencies mentioned from 4a to Wiek et al. [21], all competencies can be found in their study. Of course, it cannot be ruled out that the understanding of the competencies mentioned by the students does not coincide with those of the authors, as it is possible that the same competence is meant, but formulated differently [10]. Referring to "Gestaltungskompetenz" [24], students addressed its sub-competencies foresighted thinking, interdisciplinary and intercultural work as well as social and personal competence (like empathy, compassion and solidarity).

4.5 Evaluation and Acquired Competencies

In order to evaluate the seminar concept, a total of three different types of feedback were offered. On the one hand, students were able to give anonymous feedback after each session by naming particularly positive or negative aspects as well as making suggestions for improvement. The weekly feedback made it possible to implement the negative feedback or suggestions for improvement directly in the next session. However, these were mostly aspects regarding the technical implementation of the seminar. In addition, a central evaluation was conducted at the end of the semester. As a third feedback option, the students had the opportunity to exchange ideas among themselves in small groups during the last session and to reflect on the competencies they had acquired.

The seminar concept was rated "very good" overall. The main negative aspect was the lack of personal exchange, as the seminar had to be held online due to the COVID-19- pandemic. Furthermore, the time for group work in the sessions was considered too short. With regard to conducting the interviews, the students would have liked more introduction to qualitative content analysis, since, as previously described, they had no experience in it.

The following aspects were overall positively highlighted: interactivity and group work, ability to work in a team, discussions, communication with other students, exchange with different courses and characters, active participation, creativity, regular feedback opportunities and the use of Miro as an

Table 3. Competencies mentioned by students as relevant for engineers, competencies missing in studies in comparison to relevant competencies for sustainable and socially responsible engineering design

Relevant competencies for engineers (2a)	Number of mentions	Competence missing in studies (2b)	Number of mentions	Relevant competence for sustainable and socially responsible engineering design (4a)	Number of mentions
Professional Competence	13			Professional Competence	5
Problem Solving	12	Problem Solving	2	(Ethical) Problem Solving	2
Social Competence	9	Social Competence	11	Social Competence	5
Communication	7	Communication	3	Communication	2
Teamwork	6	Teamwork	3	Teamwork	2
Analytical Thinking	5			Analytical Thinking	2
(Self-)Learning	4	(Self-)Learning	1	Learning Ability	2
Methodological Competence	4			Methodological Competence	1
Ethical Behavior and Understanding	3	Ethical Behavior and Understanding	1	Ethical Behavior and Understanding	3
Impact and Risk Assessment	3	Impact and Risk Assessment	1	Impact and Risk Assessment	4
Personal Competence	2			Personal Competence	1
Willingness to Perform	2			Willingness to Perform	1
Creativity	2				
Sympathy and Empathy	1			Sympathy and Empathy	4
Responsibility	1	Responsibility	1	Responsibility	4
Interdisciplinarity	1	Interdisciplinarity	2	Interdisciplinarity	1
Openness	1			Openness	2
Holistic Thinking	1	Holistic Thinking	1	Holistic Thinking	5
		Presentation Skills	3		
		Leadership	1		
		Intercultural Competence	1	Intercultural Competence	1
				Diversity	1
				Usability	1
				Adaptability	1
				Honesty	1

interactive collaboration tool. On the content level, the following aspects were highlighted: learning something new (''very interesting topics through which you can broaden your horizons and could definitely learn more skills''), learning social science methods, relevance of ethics and social competencies for engineers (''The subject matter around the seminar are more important than you think at the beginning. So I liked how they were able to get me excited about it.'') and self-reflection even beyond the seminar. Furthermore, the critical reflections were singled out: ''In fact, the most interesting part was writing a critical reflection. [...] By writing a text, I was able to broaden my point of view.'' (translated by the authors)

In addition, a survey on the acquisition of competencies was conducted once at the beginning of the semester and again at the end. In this survey, the students were able to provide information on professional, methodological, social and personal competencies. By the end of the seminar, the majority reported progress, for example with regard to the statement ''I know different competence models and can explain them independently.'' or ''I know my way around qualitative research.'' (translated by the authors) Furthermore, the students were able to describe in their own words which competencies they thought they had acquired through the seminar. Here, teamwork, communication, conflict management, adaptive thinking, methodological competencies, flexibility, critical reflection and social competencies were mentioned.

The feedback from the students is thus overall in line with the intended learning outcomes defined in advance. Suggestions for improvement, such as detailed explanations of the qualitative content analysis, will be incorporated and implemented in next semester.

5. Implications

Results showed that competencies which are mentioned by the students as relevant for social and sustainable engineering design are also included in

the literature review by Wiek et al. [21] and some of those are sub-competencies of "Gestaltungskompetenz" [24]. Students named some competencies that they consider relevant for a social and sustainable engineering design, but which are missing in their studies. Moreover, they frequently criticized the lack of practical orientation in their education which goes along with the theoretical-based focus of engineering education [36]. Accordingly, this results in implications for the curricula in order to also meet the required demands on future engineers [1–3]. There are several teaching and pedagogical approaches which go along with teaching competencies for sustainable development [20, 23]. These approaches are relevant for engineering curricula, in order to promote sensitization and reflection on those topics and their importance for future engineers. For example, an effective step could be the application of the Sustainability Literacy Test (Sulitest, [41]), the idea of which emerged within the framework of the United Nation's Rio+20 world sustainability summit and goes along with the Sustainable Development Goals. The test aims to enable higher education teachers to assess their students' knowledge, skills and awareness on sustainability. Karvinen et al. [7] tested the tool for integrating sustainability into engineering curricula in Nordic universities which could be also adapted to German technical universities.

Regarding the methodology used, it is again important to mention that this paper is by nature a case report and aims to propose and present a new educational setting and teaching concept within engineering education. Thus, the focus of the paper was in describing the aforementioned concept and to present student's results, feedback and learning outcomes. This is also reflected in the presentation of a course of 24 participants, or 24 interviews as a result, as the sample. As previously described, the students had no prior experience in conducting interviews or analyzing them. The results presented here are based on the audio recordings of the student-conducted interviews. At one point or another, the students interviewed were primed, for example, by leading questions. Furthermore, the interviews portray a snapshot in time. Some of the students interviewed also stated that they had not previously dealt with the topic. Accordingly, naming as well as definitions of the respective competencies are difficult and it remains unclear what exactly students e.g., understand by "social competencies", which poses further challenges [10, 39, 40, 42]. The results were also evaluated in the overall context. In the future, it would be interesting to analyze the extent to which there are differences in the respective study programs. To further validate the interview results presented here, a next step would be to conduct these statements as a quantitative survey to represent a larger group. Moreover, critical reflection papers by the students could be analyzed regarding to their self-reflection process in order to evaluate how they understand and reflect the topics.

6. Conclusions

The goal of the seminar was to find out, together with the engineering students, in a research-oriented way, which competencies are relevant for a social and sustainable engineering design. The special feature of the seminar concept was, on the one hand, to regularly talk to the students about and discuss various competencies of engineers and, on the other hand, to let them talk about them independently with other students by means of interviews. By putting the students themselves in the situation of explaining competencies, sustainability or engineering ethics in the seminar, the understanding as well as the reflection for these topics could be strengthened. This is also reflected in the evaluation results. The research and application-oriented approach enabled the students to learn new scientific methodological skills, which are often less represented in engineering study programs in particular.

The seminar concept, consisting of think-pair-share, critical reflection and acquisition of competencies, can be transferred very well to topics other than sustainability and ethics. It is important to build up the seminar concept in the sense of constructive alignment, so that the specific content, intended learning outcomes and examination performance are coordinated. By independently carrying out a research process and active learning, students acquire new knowledge and skills, which in this case particularly promote competencies for sustainable development, such as shaping competence.

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