SEFI Journal of Engineering Education Advancement
Vol. 2, No. 2, 2025, pp. 32-53, ISSN 3006-6301
DOI : 10.62492/sefijeea.v2i2.40

Building Interdisciplinary Bridges in Higher Education: Social Innovation in STEM Education for Grand Challenges

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ABSTRACT

Addressing grand challenges such as climate change and inequality requires more than technical solutions - it demands socially innovative approaches that transcend disciplinary boundaries. This paper examines the role of interdisciplinary collaboration in higher education STEM fields in fostering the development of social innovations. Drawing on thematic analysis of 83 reflection papers written by STEM students enrolled in a cross-university, problem-based learning (PBL) course on sustainability, transformation and social innovation, the study explores students' experiences with interdisciplinary teamwork. Findings reveal that students initially faced significant challenges - especially in communication and coordination - but ultimately perceived these as valuable learning opportunities. The interdisciplinary setting, which includes three universities and students from various disciplines, enhances creativity, broadens perspectives, and results in more holistic social innovations. The course also fostered essential competencies such as communication, collaboration, and systems thinking, with some students reporting increased interest in entrepreneurial endeavors. These results highlight the potential of interdisciplinary and socially oriented education in STEM fields, underscoring the need for curricular reform to better prepare students for addressing complex grand challenges.

KEYWORDS

Social Innovation, STEM Education, Technical Universities, Interdisciplinarity, Cross-university Collaboration

PUBLICATION

Submitted:
10th June 2025

Accepted after revision:
28th August 2025

State of the Art

Given the urgent need to address grand challenges, social innovation is increasingly being recognized as a key component alongside technical innovations (Bayuo, Chaminade, and Göransson 2020). Studies highlight the potential of social innovations to address grand challenges such as climate change and to achieve sustainable solutions (Cunha et al. 2022; García-Flores and Palma Martos 2023).

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Consequently, the concept of social innovation has attracted growing attention in academic, societal, and political discussions (Berg-Postweiler and Leicht-Scholten 2024; Krlev 2024; Mulgan 2019). Despite its growing popularity, social innovation remains ambiguously defined, with no universally accepted definition to date (Ziegler 2017; Bayuo, Chaminade, and Göransson 2020). Various definitions have been extensively discussed in prior research; for a detailed overview, we refer readers to Phillips, Luo, and Wendland-Liu (2024), Nicholls, Simon, and Gabriel (2015) and Eichler and Schwarz (2019). In this work, we follow two definitions that are often used, both of which highlight the need for collaboration and the necessity of social innovations to meet a social need. Mulgan (2019) states that social innovations are 'innovations that are social both in their end and their means' (p.10) and highlights the mutual interdependence of the 'bees' (creative entrepreneurs) and the 'trees' (well-resourced institutions). Besides, our work relies on Benneworth and Cunha 's (2015) definition which states that 'a social innovation is a socially innovative practice that delivers socially just outcomes by developing novel solutions in border spanning learning communities thereby creating social value by promoting community development, hence forming wider collaborative networks, and challenging existing social institutions through this collaborative action' (p. 512). In short, we define social innovations as those that address social needs and require the collaboration of multiple actors.

Current academic and political debates increasingly examine the role of universities in driving social innovations and are regarded as one important actor in fostering social innovation (Bayuo, Chaminade, and Göransson 2020; Tjörnbo and McGowan 2022; Unceta, Guerra, and Barandiaran 2021). Research indicates that universities can contribute to sustainable development through research, facilitating the transfer of knowledge and expertise to and from industry and society, as well as teaching. Studies highlight the need for universities to engage in social innovation (Belcher et al. 2022; Benneworth and Cunha 2015; Tjörnbo and McGowan 2022; Bayuo, Chaminade, and Göransson 2020). Especially by integrating social innovation into teaching, universities can contribute to the education of students who can solve grand challenges as employees or founders of social enterprises (Bayuo, Chaminade, and Göransson 2020). However, complex grand challenges cannot be solved by a single actor or discipline alone, making inter- and transdisciplinary collaboration essential (Podgórska and Zdonek 2024; Morawska-Jancelewicz 2022; Kolmos et al. 2024; Cinar and Benneworth 2020). In this paper, we define interdisciplinarity as integrating knowledge, theories and methods from different disciplines (Hacklin and Wallin 2013; Kolmos et al. 2024). Furthermore, a distinction is made between narrow and broad interdisciplinarity, with narrow interdisciplinarity referring to collaboration between related disciplines. In contrast, broad interdisciplinarity connects conceptually more diverse disciplines "that cross the boundaries of broad intellectual areas" (Huutoniemi et al. 2010, 82). Besides, transdisciplinarity describes integrating various disciplines and participation of "non-academic participants in real-world settings" (p. 1176) as well as the emergence of completely new interdisciplinary disciplines (Bertel et al. 2021). In the innovation literature, there has been extensive discussion about the extent to which inter- and transdisciplinarity influence innovation capacity and entrepreneurial thinking. Brodack and Sinell (2017) argue that interdisciplinary teams demonstrate a higher commitment to entrepreneurial thinking and tend to be more innovative, motivated and effective. The collaboration among various disciplines facilitates the implementation of new ideas, cultivates a sense of responsibility and initiative, and enhances both communication and organizational skills. By integrating diverse perspectives and expertise, these teams not only achieve greater success but also improve the chances of sustained entrepreneurial achievement (Brodack and Sinell 2017). Studies also show that interdisciplinarity has a positive impact on disruptive innovations (Cheng et al. 2025), can enhance innovation performance in firms (Melnychuk and Schultz 2025), and positively influences creativity (Hacklin and Wallin 2013). Accordingly, within social innovation literature, the

need for inter- and transdisciplinarity is also discussed and calls for collaboration across disciplines (Göransson, Donati, and Wigren-Kristoferson 2021; Carayannis and Morawska-Jancelewicz 2022). For universities, this calls for structural transformation. Universities are often organized in faculties that promote disciplinary work (van den Beemt et al. 2020). These traditional disciplinary structures can hinder the emergence of social innovations, as they require collaboration between different disciplines and stakeholders.

Social innovation and interdisciplinarity in technical universities

Fostering interdisciplinary collaboration poses particular challenges for institutions with a strong disciplinary orientation, such as technical universities. Technical universities focus their activities on STEM (Science, Technology, Engineering, and Mathematics) subjects and train, for example, engineers or mathematicians (Larsen, Geschwind, and Broström 2020). Although there is growing interest in social-tech entrepreneurship (Calderini et al. 2024) and recognition of the essential role STEM graduates can play in addressing grand challenges (Bertel et al. 2021; Picard et al. 2022), the contribution of technical universities to social innovation remains underexplored. A previous work (Berg-Postweiler and Leicht-Scholten 2024) has shown that a comprehensive approach to fostering social innovation in technical universities is still lacking. In addition to a lack of research on social innovation at technical universities, existing studies on social innovation in higher education institutions often do not distinguish between different types of universities (e.g., technical universities, business schools, etc.), which makes it difficult to transfer or generalize the findings. Given the inherently interdisciplinary nature of social innovation, there is a need to create educational opportunities that enable and promote collaboration across disciplines. However, little is known about how STEM students experience such collaboration in the context of social innovation. In response to this research need, this paper investigates the following research question: How do STEM students experience interdisciplinary collaboration on social innovation?

For this purpose, 83 reflection papers written by STEM students participating in an interdisciplinary, cross-university course are analyzed using thematic analysis by Braun and Clarke (2022). The course employs a problem-based learning (PBL) approach and is collaboratively designed and offered by three German universities and various faculties. In this course, the students experience interdisciplinary collaboration on social innovation at first hand and reflect on their experiences with regard to finding solutions, group processes and skills acquisition.

Study context

The present study examines the experiences of STEM students in the context of an interdisciplinary course on sustainability and social innovations. Previous studies have thoroughly investigated the challenges and benefits of interdisciplinary collaboration. The benefits of interdisciplinarity include applying various methods and developing holistic approaches (Vantard, Galland, and Knoop 2023). Moreover, interdisciplinary collaboration enhances the integration of diverse knowledge, resulting in a complex organization of knowledge and improved problem-solving skills (Ivanitskaya et al. 2002). Such collaboration can foster creativity and adaptability, while offering an opportunity to acquire skills, such as teamwork and project management (van den Beemt et al. 2020). Even if many authors recognize the importance of interdisciplinary collaboration, research indicates that students often struggle in interdisciplinary projects (Kolmos et al. 2024; Bertel et al. 2021; Podgórska and Zdonek 2024). One major challenge is language barriers - a critical factor for interdisciplinary success or failure, which can lead to conflicts among team members (MacLeod 2018; Sonetti et al. 2020; Vantard, Galland, and Knoop 2023; Bracken and Oughton 2006). This includes differences in the interpretation

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of terms across disciplines and in identifying a problem as well as varying scientific understandings (Vantard, Galland, and Knoop 2023; Sonetti et al. 2020). Thus, establishing a common professional language is important within interdisciplinary collaborations. Furthermore, backgrounds and methodological approaches differ between disciplines, which can complicate collaboration (Vanney, Mesurado, and Aguinalde Sáenz 2024; MacLeod 2018). It is, therefore, necessary to develop an understanding of the various approaches and make compromises within interdisciplinary collaborations. Different logic and realities can also hinder collaboration, as students find it difficult to apply their skills in new situations (Kolmos et al. 2024; Kolmos, Holgaard, and Routhe 2025). In addition, studies show that interdisciplinary collaboration requires more effort for organization, coordination and clear communication (Leahey, Beckman, and Stanko 2017; Podgórska and Zdonek 2024; Walsh and Lee 2015).

To address the challenges of interdisciplinary collaboration, interdisciplinary competencies are required (Podgórska and Zdonek 2024; Lattuca et al. 2017; Nancarrow et al. 2013). Schijf, van der Werf, and Jansen (2023) highlight six elements discussed in the literature: knowledge of different disciplinary paradigms, knowledge of interdisciplinarity, reflection skills, critical reflection skills, communication skills, and collaboration skills. The need for interdisciplinarity and the development of interdisciplinary competencies for engineers is also demanded and discussed (Bertel et al. 2021; Lattuca et al. 2017; Kolmos et al. 2024). Lattuca et al. (2017) and Picard et al. (2022) state that engineers need interdisciplinary competencies, e.g. because they deal with complex problems. This results in technical universities needing to prepare students for interdisciplinary work and provide them with the necessary skills. Project and problem-based learning (PBL) is a key pedagogical approach discussed for integrating interdisciplinarity in higher education (Kolmos et al. 2024). PBL fosters students to learn actively and uses complex and ill-defined real-world problems (Edström and Kolmos 2014) emphasizing student-centred learning, where students take responsibility for their own learning process (de Graaf and Kolmos 2003). However, research indicates that PBL in engineering education often occurs within a single discipline, lacking an interdisciplinary approach (Kolmos et al. 2024).

This paper is structured as follows: First, we present the concept of the cross-university course on social innovation in detail, followed by an explanation of our method, which used thematic analysis to answer our research question. In the next chapter, the results are presented, followed by a discussion, including implications and limitations.

Methodology

The following section describes the methodology used for this study. First, we introduce the structure of the interdisciplinary course, followed by a general description of data collection and analysis. Eighty-three reflection papers from students were analyzed using thematic analysis according to Braun and Clarke (2022) regarding our research question: How do STEM students experience interdisciplinary collaboration on social innovation?

Description of the Interdisciplinary Course

The context of this study is an interdisciplinary course called "Sustainability and Transformation as Opportunity and Challenge for Society" offered since 2021 to Bachelor's and Master's students at three German universities, namely RWTH Aachen University, University of Applied Sciences Aachen (FH Aachen), and Catholic University of Applied Sciences North Rhine-Westphalia in Aachen (katho Aachen). The course is open to students from a wide range of disciplines and faculties at RWTH Aachen University. With more than 44000 students, RWTH Aachen University is one of Europe's largest technical universities, focusing on the education of STEM students. The interdisciplinary course is offered to mechanical engineering students from FH Aachen, which has more than 13000 students, mainly enrolled in STEM subjects. Besides, students at the katho Aachen, studying social work, can take part in the course. The katho has more than 5000 students, over 80% of whom are enrolled in social work degrees. Every year, around 35 students in the course take part in the examination. Upon successful completion of the course, students will receive 4 credit points, which corresponds to an average workload of 120 hours. The majority of the workload is planned for group work. This cross-university and cross-faculty collaboration can achieve a high interdisciplinarity level, as Kolmos et al. (2024) called for. Approximately 70% are studying in STEM fields, and 30% are studying social sciences. This diverse composition aims to foster an integrative learning environment essential for addressing complex societal challenges.

The course focuses on sustainability and social innovation, centered on guest lectures and interdisciplinary group work using problem-based learning (PBL). At the beginning of the semester, introductory lectures explain the most important terms and concepts, providing an opportunity to get to know the other participants. Besides, the teaching concept is explained to the students, including learning outcomes, guest lectures and examination. Each semester, up to six guest lecturers are invited to share their expertise and experiences on topics including social and sustainable innovation, sustainability and (societal) transformation. These speakers represent various sectors, including academia, business, social enterprises, and public service. The lectures give students a comprehensive understanding of sustainability challenges and innovative solutions. Considering the different disciplines and levels of study progress (Bachelor's and Master's students), learning outcomes include supporting students in inter-university teams in developing their interdisciplinary skills. Working with practical social challenges is also intended to sensitize students to social problems by enabling them to critically and actively engage with social responsibility and to create social innovations. Particular attention is given to forming networks from different disciplines and social actors to support participants in developing their own code of action and thus generating real impetus for action. The lectures mainly take place at RWTH Aachen University, as it has the necessary capacity due to its size. However, individual sessions also take place at the other two universities. To simplify the organization of tasks such as sharing information and course materials, all students have access to RWTH Aachen University's Moodle course platform.

The examination consists of a group assignment, including a pitch and a detailed video presentation, and an individual written reflection. At the beginning of the semester, students are divided into interdisciplinary teams of approximately five members, ensuring representation from all three universities and different disciplinary backgrounds. Each team is tasked with identifying a grand challenge that aligns with one or more of the United Nations' Sustainable Development Goals (SDGs). Over the semester, they develop a solution to this problem, a social innovation, which could be a product, service, or another innovative approach. Student projects in recent years have dealt with topics such as drinking water wells in Aachen and the reduction of food waste, including the development of a special food sharing machine. Through engagement with real-life scenarios and hands-on projects, students work towards authentic solutions and strengthen their ability to deal with complex issues in a broader context (Bertel et al. 2021). The course incorporates structured feedback mechanisms to support the students' progress. Students participate in feedback sessions with the instructors and are encouraged to seek additional guidance from guest lecturers. This mentoring framework allows for iterative refinement of their ideas, ensuring that the solutions developed are both feasible and impactful. Lecturers acting as a guidance rather than a "traditional lecturer" is a crucial element within the framework of PBL, too, and shows how PBL encourages students in their learning process (de Graaf and Kolmos 2003).

The course concludes with a comprehensive final phase in which students present their projects in two formats: a live pitch to the class and an extended video presentation. In these presentations, they not only propose their solutions to a grand challenge but also detail the extent to which their social innovation addresses this challenge. Additionally, students identify the key stakeholders involved in implementing their innovation and discuss practical financing options. Alongside these deliverables, participants submit individual, ungraded reflection papers in which they analyze the collaborative and interdisciplinary processes involved in generating their ideas.

Data Collection and Analysis

To address the research question "How do STEM students experience interdisciplinary collaboration on social innovation?", the reflection papers are analyzed using a reflexive thematic analysis according to Braun and Clarke (2022). We analyze 83 reflection papers from STEM students attending the seminar between 2021 and 2024. Even if students from three German universities participated in the seminar, we only analyze 83 reflection papers from students at RWTH Aachen and FH Aachen enrolled in STEM subjects. Reflection papers from social work students at the katho Aachen were not analyzed due to the focus of the research question on STEM students. Of the 83 reflection papers, 45 were written by male students and 38 by female students. Approximately 15% were written by students from FH Aachen, with the remainder written by students at RWTH Aachen University.

The students write the reflection papers individually at the end of the semester after presenting their social innovation in class. Students are given guiding questions (see Table 1) that they can use for orientation.

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Table 1: Guiding Questions for Students' Reflection Papers

Task: Use the following key questions as a guide for your report. The reflection report must cover both areas (content and personal as well as process reflection), not all key questions should be answered. Choose 2-3 questions per area.	
Content and personal reflection	- What professional insights have you gained? - To what extent can you apply what you have learned in your further studies/professional life? - What connection do you see between your subject area and the topic of sustainability? - To what extent does your own subject area contribute to solving current grand challenges (e.g. sustainability)? - How would you rate the solution of your group work? Would you want to change anything about your solution? (has no influence on the evaluation of your solution)
Process reflection	- How would you describe the collaboration in your group? - To what extent did the interdisciplinary composition of the groups contribute to the success of your project? - What challenges and opportunities do you see in interdisciplinary collaboration? - How do you like courses in which you work on current grand challenges and seek solutions to them? - What role do universities play in solving current grand challenges?

The reflection refers to three levels: The development of the social innovation and its evaluation, the interdisciplinary collaboration within the groups and the individual competence acquisition. The guiding questions can be used as a stimulus for reflection, but students can set their focus. The length of the reflection is seven pages, including a cover sheet and references. The reflections are ungraded to reduce possible social desirability bias, but submission and adherence to the scope are prerequisites for successful course completion. The aim of the reflection papers is twofold: to learn more about the process of collaboration and the necessary skills, and to encourage students to reflect on their experiences and support their learning process.

Following the research question, we used a critical realist thematic analysis approach focused on patterned meaning. Reflexive thematic analysis was chosen as the most suitable method for our analysis, as it facilitates the identification, description, and interpretation of themes and patterns within a dataset (Terry et al. 2017; Braun and Clarke 2022, 2021). Given the extensive research on interdisciplinarity in STEM education, but with few studies previously examining interdisciplinary STEM education in the context of social innovation, we employed mainly inductive, but also deductive modes and a more sematic orientation. Thematic analysis allowed us to capture the complex

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experiences of a diverse set of students. The flexibility enabled us to start the analysis using an inductive approach, meaning that the data set shapes the analysis. After developing themes, we shifted between inductive and deductive approaches (Braun and Clarke 2022). We applied a six-phase reflexive thematic analysis (see Figure 1) following Braun and Clarke (2022) by using MAXQDA, a software helping to organize and analyze qualitative data, for coding. Two researchers did the thematic analysis, which enabled a further exchange and joint reflection on the data set. One researcher was a research associate and one of the lecturers of the course, the other one was a student assistant who did not participate in the course. Students were informed in class that their anonymized reflections could be used for research purposes. All data were processed in accordance with the principles of confidentiality and informed participation. The six phases are not to be understood as a linear process. In line with the reflexive nature of the thematic analysis, the phases were alternated in some cases (Braun and Clarke 2022; Terry et al. 2017).

In the first step, we familiarized ourselves with the data by reading reflection papers several times and taking notes, followed by a first meeting to discuss the general impression. Next, the coding was carried out. The two researchers coded the data according to the research question using MAXQDA qualitative data analysis software. We used an inductive approach for this initial coding, where codes were developed from the data content. We identified more than 800 codes in this step, but a first review showed that they often captured similar meanings. Both researchers then developed candidate themes individually. By developing themes, the aim is to cluster codes which have the same idea or cover the same pattern. Even if the number of codes was quite high, codes were often similar, and clustering made it possible to reduce this number. Afterwards, a meeting was held where we presented our themes to each other, reviewed and agreed on a preliminary set of themes, and then collated the coded data to the preliminary themes in MAXQDA. In this step, we reviewed the material and codes to assess how well the themes reflected the content. In the sense of Braun and Clarke, theme development is an active and reflective process in which the themes are further developed and adapted until the report is written. The final step involves renaming the themes and recording the results. However, writing has already begun after a first set of themes has been established, as it is an important phase of thematic analysis that does not follow a strict linear process (Braun and Clarke 2022).

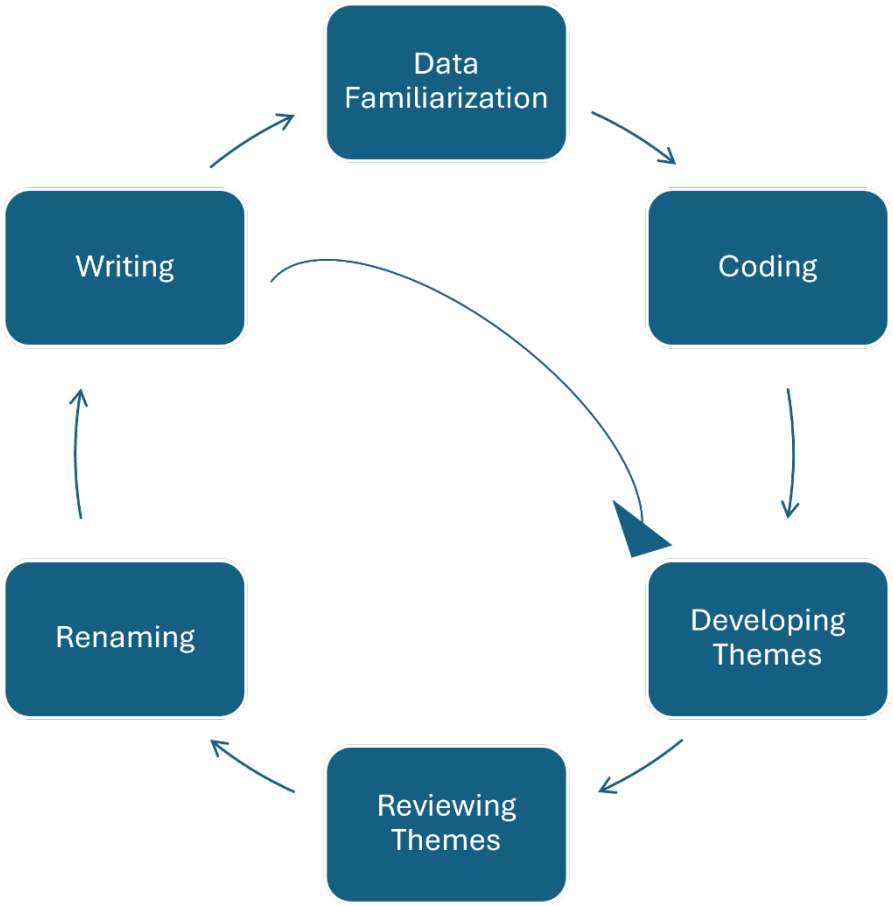

Figure 1: Six-Phase reflexive thematic analysis based on Braun and Clarke (2022)

Results and Discussion

This chapter presents the findings from our thematic analysis addressing the research question: How do STEM students experience interdisciplinary collaboration on social innovation?

Overall, students described their experiences with interdisciplinary collaboration on social innovation as highly instructive. The collaborative process enhanced creativity and incorporated a broader range of perspectives. Students characterized the experience as intensive and enriching, particularly in preparing them for their future professional lives. The challenges and advantages of group work were examined in detail, focusing on two levels: one related to social innovation and the other pertaining to personal experiences. Several students reflected on how challenges can ultimately yield benefits, both for innovation and personal growth.

The analysis resulted in three key themes, which are discussed in detail in this chapter (see Figure 2). The first theme, **"Why interdisciplinarity is so frustrating",** captures students' feelings and experiences within their groups, emphasizing their challenges. The theme **"When challenges become benefits"** captures students' perspectives on the benefits of interdisciplinary collaboration and particularly emphasizes how challenges can lead to benefits. Finally, the third theme, **"Results in better social innovations"**, explores the degree to which interdisciplinarity influences the outcomes of innovation. To differentiate between the students' reflections and at the same time maintain anonymity, the individual reflections were given numbers from 1-83. Each reference is followed by a number (1-83) and a page number on which the corresponding sections can be found.

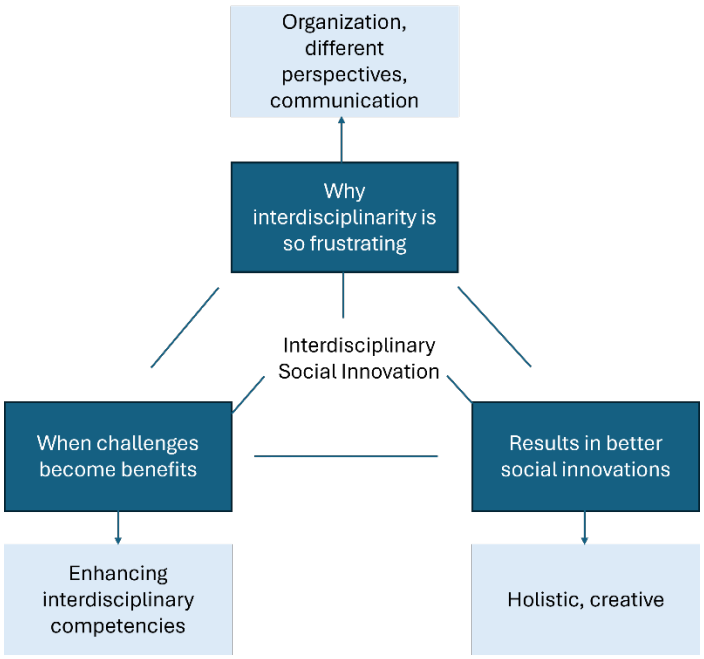

Figure 2: Developed themes during thematic analysis

Why interdisciplinarity is so frustrating

A common theme in nearly all reflection papers was the exploration of the challenges and advantages associated with interdisciplinary collaboration. While each group faced distinct difficulties, it is evident that challenges were a universal aspect of the experience. The findings indicate that students encountered obstacles when working in interdisciplinary teams due to three points: 1) Organizational challenges, 2) Different perspectives, logic, and experiences, and 3) Communication Challenges.

Organizational Challenges:

The **organization** of the group work was one of the biggest challenges. Many students stated that it was difficult to arrange meetings, especially *'due to the timing of the different study plans and working hours of the members*' (S14: 4 - 4). Of 83 reflection papers, more than 20 students reported difficulties finding suitable time slots to work together. Particularly, the '*inter-university collaboration*' (S21: 5 - 5) within the course complicated the organization, as '*curricula'* (S14: 4 - 4) and locations varied. The groups met these challenges in different ways. For some groups, the challenge persisted throughout the semester, leading to frustration; other groups switched to online meetings, while a few successfully divided their tasks so that the coordination efforts were minimized or conducted within smaller teams. That interdisciplinary work requires more effort and organization is also broadly discussed in the literature and is, for example, in line with the research of Leahey, Beckman, and Stanko (2017) or Podgórska and Zdonek (2024). To help students deal with this challenge, the seminar was adapted to offer opportunities for collaboration during lecture times at a fixed location.

Different perspectives, logic, and experiences:

Another challenge was the students' **different perspectives, logic, and experiences**. Many students were working in interdisciplinary groups for the first time. This is underlined, for example, by the following statement: '*Different backgrounds, cultures and disciplines on the essential questions of the future are rarely brought together in an interdisciplinary way during studies*' (S20: 4 - 4).

Furthermore, the students highlighted the significance of understanding individual strengths, as this knowledge '*would have facilitated the allocation of tasks and roles*' (S47: 6 - 6). This need arises from the challenges posed by the differing levels of knowledge and prior experience among group members. Significant disparities in individual knowledge regarding content areas such as sustainability and innovation were observed, as well as in scientific research skills (S34: 5 - 5) and in familiarity with widely used software applications like PowerPoint (S36: 7 - 7). Moreover, differences in group work experience were also noted as one student remarked: '*In terms of working as a group and the collaboration process, I noticed that we architecture students had significantly more experience in meaningfully distributing tasks within a group, and we were possibly more aware of the responsibilities that group work entails*' (S08: 7 - 7). The differences observed between the disciplines align with Kolmos, Holgaard, and Routhe (2025), who distinguish between three dimensions of interdisciplinary collaboration, namely knowledge, culture and learning. All of these dimensions were also addressed by the students in their reflections. Combining the group members' different perspectives and experiences was seen as a challenge. Students said it was sometimes difficult to unite different perspectives to find a common solution. This became clear, among other things, during the topic identification process, as *'different professional backgrounds resulted in different requests for focal points'* (S21: 6 - 6). Different perspectives within the groups resulted in the need to make compromises. As a result, *'not all members can always be made happy*' (S47: 6 - 6). The following expression exemplifies this: *'Ultimately, we decided on a topic that only partially met my interests and requirements for this group work' (S09: 14 - 14).*

The necessity of making compromises implies that not all opinions and wishes can be fully accommodated. This in turn entails the risk of conflict, as dissatisfaction can arise when people have to make compromises. How this dissatisfaction was handled influenced further collaboration within the groups. For some groups, the need for compromise led to the idea generation being '*longer and more discussion-heavy'* (S21: 6 - 6).

Communication Challenges:

Several statements highlight that group **communication** emerged as one of the most significant challenges. One student summarized, for example, that '*one of the biggest challenges in interdisciplinary collaboration is communication*' (S07, p.7). This aligns with previous research, which suggests that communication is a major hurdle in interdisciplinary teams (MacLeod 2018). A key difficulty lies in the diverse professional language used by team members, resulting in a need to *'explain the subject-specific content and research topics and methods to fellow students from other subjects*' (S35, p. 4). Students reported that due to the interdisciplinary group composition, there were many different terminologies and methodological approaches, '*which first have to be exchanged and understood before one is able to combine them in productive work*' (S07, p. 7). Language barriers in interdisciplinary teams are also discussed as a challenge in other studies. Among others, Bertel et al. (2021) highlight challenges concerning differences in academic language in interdisciplinary megaprojects, a topic also addressed by Kolmos, Holgaard, and Routhe (2025), who emphasize the need for a common academic language basis. Besides, Daniel et al's. (2022) results show communication challenges within interdisciplinary settings. A specific challenge lies in articulating one's own knowledge in a way *'that others can understand and apply it or put it into context. It is challenging to abstract and reproduce one's own internalized knowledge in a manner that it is equally understandable for everyone, as there is never complete information regarding the level of knowledge and the receptiveness of the team members*' (S16, p. 7). This finding aligns with prior research that highlights students' difficulties in transferring skills from one context to another (Kolmos et al. 2024;

Kolmos, Holgaard, and Routhe 2025). It is reiterated multiple times that finding a "common denominator" is crucial for effective group work. In summary, one student reflects: *'A very present challenge here is the chosen language. What sounds like a triviality can significantly disrupt the flow of work due to misunderstandings. I have learned from this to pay more attention to using language that is understandable across disciplines'* (S51, p. 9).

Many students experienced working alongside peers from entirely different fields for the first time during the seminar and quickly realized that professional languages can lead to communication challenges. These differences can make communication more complex, as fundamental concepts must first be clarified in order to establish a shared knowledge base. To deal with the language barriers, students emphasized that consistent and effective communication is essential to prevent members from various disciplines from simply working alongside each other rather than collaborating as a cohesive team. As one student summarized: '*Project success can only be achieved through constant communication. 'However, this challenge also presents a great opportunity for interdisciplinary work. Good communication can broaden the perspective beyond one's own telescope and enrich one's own work'* (S43, p. 7).

When challenges become benefits

In addition to challenges, the benefits of interdisciplinary collaboration were also discussed in the reflections. The following three points were highlighted as the greatest benefits: 1) gaining new experience, 2) learning from others, and 3) interdisciplinary competencies.

Gaining new experience:

Many students described the interdisciplinary collaboration on social innovations as **a '*new experience*'**. The analysis shows that students have little or no experience of interdisciplinary collaboration. The students called it '*a unique experience*' (S36, p.10) or '*a truly new and valuable experience*' (S44: 7 - 7). One student summarized that *'there were no (comparable) seminars in my normal course of study so far, so it was a really new and valuable experience for me'* (S44, p. 7). The students' answers are consistent with previous studies e.g. by Kolmos et al. (2024) which show that interdisciplinarity is not yet sufficiently present in engineering studies. In light of the impact of interdisciplinarity on innovation and entrepreneurial thinking, students must gain relevant experience and develop interdisciplinary competencies before entering the workforce. Universities, in particular, play a crucial role in this context - especially when it comes to social innovation. Against the background that universities play an important role in promoting social innovation (Unceta, Guerra, and Barandiaran 2021; Bayuo, Chaminade, and Göransson 2020), the results are relevant in that they could indicate that both interdisciplinarity and social innovation have so far been poorly integrated into the curricula of STEM students. Other studies have shown similar results, for example, that social innovation has not yet been holistically integrated at technical universities (Berg-Postweiler and Leicht-Scholten 2024). The analysis of the reflection papers also underlines that there is a consensus that the course has been a new experience, important for their future work in STEM fields. Especially against the background of later professional life, where interdisciplinary work is required, some students state that the course is '*good practice for their later professional life*' (S48, p.7) or that the '*group work in this seminar was a simulation of my later professional environment on a small scale*' (S43, p.6). Individual students are also able to relate the experiences of group work to specific future work situations: *'However, this also provided important insights and practical experience for working in such interdisciplinary groups, which are particularly important for the future, as interdisciplinary*

cooperation is essential in the context of larger projects (for example in the design of chemical plants) and, in this respect, target-oriented communication with each other is a key component' (S03, p. 5).

Learning from others:

The students saw a benefit of interdisciplinary collaboration on social innovation in the opportunity **to learn from each other**. Students stated that they were able to get to know different approaches to problems. Gaining insights from diverse disciplines and backgrounds deepened the students' understanding of critical topics such as sustainability, transformation, and social innovation. Many students expressed that they learned something *'new'* (S35: 4 - 4), which will also benefit them during their studies and in their *'later career'* (S26: 8 - 8). Reflections show that students are increasingly motivated to seek out interdisciplinary experiences in their studies and future career, and that *the 'interdisciplinary collaboration has become a real learning process that has enriched me not only in my studies, but also in my private life'* (S37, p.8). Besides, the interdisciplinary work enabled students to expand their specialist knowledge while also acquiring insights into other fields. An extract shows the extent to which these different approaches influenced idea generation: '*While some showed a very systematic and causal approach, others had more of an overview of the whole and still others found it easy to work out and think through details in great detail. This not only led to a wide range of ideas and suggestions, but also to a mostly complementary way of working as a whole'* (S03, p.4).

Getting to know different approaches but also '*looking at ideas and solutions from different angles*' (S36, p. 10) opened up new perspectives for the students and the finding of solutions. Statements about getting to know and gaining new perspectives were mentioned very frequently by the students. Working together with different disciplines, but also with different universities, leads to the *'project and one's own horizon becoming more multifaceted [...]*' (S20, p.4) and through the *'meeting of different personalities and study programs, there were many views from the most diverse perspectives'*. (S27, p.9). Others stated that the interdisciplinary collaboration allowed them to *'think outside the box'* and *'experience at first hand the extent to which coherent results can be achieved when diverse, cooperating actors with their different perspectives work on a project*' (S11, p.9). However, this also implies the need to engage in this collaboration and to allow other perspectives as one student expressed: *'Opening up to other perspectives, revising one's opinion and finally finding a compromise on the matter was what made interdisciplinarity so appealing to me*' (S40, p.6). Mutual learning in interdisciplinary teams, and in particular learning from other disciplinary perspectives that lead to an integrative process, is a criterion of interdisciplinarity (Mcnair et al. 2011). The fact that the students emphasized this point several times in their reflections shows the successful composition of the interdisciplinary groups and the genuine experience of interdisciplinarity. It is also transferred that it is *'indispensable, especially against the background of current challenges, to include different points of view and to supplement one's own knowledge with the knowledge and ideas of others*' (S61, p.7). Bringing the different perspectives together also had a positive influence on finding solutions. Among other things, this led to a *'broader and deeper understanding of complex issues such as sustainable transformation*' (S29, p.7) and *'had a positive impact on the final result*' (S16, p.6). For instance, students noted that they took a closer look at the social dimensions of their innovation as part of the project. One student specifically remarked: '*My learning that I was able to achieve is that for a social innovation we need to build an understanding of homelessness and poverty in order to be able to put a complex idea into practice'* (S15, p.24).

STEM students **gained valuable insights** from social work students, allowing them to encounter new ways of thinking and diverse perspectives. For instance, one student noted that during group work, he came to the realization that 'a*ctions I believed would reduce social inequality are actually not effective.*

The primary misunderstanding was that my definition of 'social inequality' differed from the actual concept' (S17, p. 7). Such insights and interdisciplinary learning contributed to a broadening of the students' perspectives. This broadening of perspective is particularly relevant against the backdrop of current global challenges. Students, especially engineers, need to understand the impact their work has on society and the social responsibility they bear as engineers, in addition to their professional skills (Beagon et al. 2023; Kolmos 2021).

Interdisciplinary competencies:

Regarding interdisciplinary competencies, the students stated above all that they have learned **interdisciplinary work as an important competency** and were able to broaden their '*knowledge and experience*' (S07, p.7). Many students expressed feeling more confident in interdisciplinary settings following the seminar. Compared to interdisciplinary competencies in literature (Schijf, van der Werf, and Jansen 2023; Lattuca et al. 2017), the reflections show that students tend to be able to develop interdisciplinary understanding in the context of the seminar. Given the six elements of interdisciplinary understanding (Schijf, van der Werf, and Jansen 2023), the reflections indicate that students enhanced their knowledge of disciplinary paradigms and interdisciplinarity. This includes an understanding that tasks should be allocated within a team based on the knowledge and strengths of each individual. For instance, one participant highlighted the importance of dividing '*tasks according to the strengths of the participants'*. (S47, p.6). In addition, connections were made between different disciplines. One student, for example, summarized: *'Approaches to solving the climate crisis from a purely scientific-technical perspective are helpful, but only one-dimensional and not directly goal-oriented. Cooperation between economic, ecological and social values is needed to overcome the climate crisis*' (S25, p. 4). This could indicate that, after the seminar, students are aware of the connection between STEM and social aspects - a characteristic of knowledge of interdisciplinarity (Schijf, van der Werf, and Jansen 2023). Communication and collaboration, in particular, were expanded. For example, students learned to share their knowledge in a way that even non-experts can understand. Working together in interdisciplinary teams was also practiced as part of the seminar, and students feel well prepared for further interdisciplinary work after the seminar. The course supported students in preparing for later interdisciplinary collaboration by *'offering a good opportunity to prepare for professional work in interdisciplinary teams, which is rarely offered in the courses anchored in the curriculum*' (S35, p. 4).

The interdisciplinary module not only enhanced the students' interdisciplinary understanding but also fostered their entrepreneurial competence. Among others, Klapper and Tegtmeier (2010) discuss the potential of interdisciplinary learning in the context of entrepreneurial intention and competence. Additionally, the results of the reflections show that students could imagine realizing the developed ideas and starting a startup: *'Moreover, there is a willingness to implement our idea in practice (contact with the Incubator Lab at RWTH Aachen)*' (S15, p. 28). Another student noted that *'many interesting people have been to the course events, especially their commitment to self-employment was very inspiring for me, as I often do not see the "real" connection to my goal/path due to the extensive theoretical knowledge within my studies. This prompted me also to contact the Founding Center of FH Aachen*' (S27, p. 4). Other students are *'increasingly interested in startups and the possibility of founding one*' (S44, p. 5), '*in impact investing and the sustainable strategy of companies more than in starting their own business*' (S51, p. 5) and were thus able to engage with how to found a company - *'competencies that I have painfully missed in my previous learning plan*' (S51, p. 5). Given the increasing number of high-quality startups by engineering and science university graduates (Åstebro, Bazzazian, and Braguinsky 2012; Colombo and Piva 2020) there is a need for universities to teach

necessary competencies and to stimulate entrepreneurial thinking. Studies show that entrepreneurship education has not yet been fully implemented across all STEM curricula (Duval-Couetil, Reed-Rhoads, and Haghighi 2012). However, due to institutional requirements from organizations like the NSF and ABET, the number of such course offerings has significantly expanded (Zappe, Cutler, and Gase 2023). Nevertheless, our results indicate that for many students, the course was a one-time experience. Our findings underscore the importance of combining interdisciplinarity and innovation in educational practices as students can gain valuable experiences and skills that are relevant not only for innovation in general, but especially for social innovation.

Interdisciplinarity results in better social innovations

There was a consensus among the students that interdisciplinarity fosters **better and more comprehensive social innovations**. Deeper discussions led to '*holistic solutions*' (S17, p.7) that cover a wide range of perspectives and led to problems being tackled '*more comprehensively and effectively*' (S07, p. 7). By integrating diverse perspectives, interdisciplinary collaboration has the potential to generate '*mature and far-reaching solutions*' (S57, p.7). The reflections indicate that many students became aware of how interdisciplinarity influenced the solutions. In particular, it was recognized that interdisciplinarity contributes to the development of holistic solutions, highlighting important benefits of interdisciplinarity (Vantard, Galland, and Knoop 2023). Numerous students expressed that creativity and potential for innovation were notably enhanced by interdisciplinary collaboration. Ideas were developed that '*we might not have found as individuals*' (S37, p.8). Students recognized that the greatest strength of collaboration lies in its ability to foster more innovative solutions: *'Combining knowledge and methods from different disciplines can develop solutions that go far beyond the horizon of a single discipline'* (S07, p. 6).

These results underscore how **practiced interdisciplinarity influences social innovations**, as social innovation requires interdisciplinary approaches that bring together people with diverse competencies (Carayannis and Morawska-Jancelewicz 2022) – the students also recognized this. Interdisciplinarity positively impacts social innovation and the process of finding solutions, enhancing one's own '*problem-solving skills*' (S07, p.7). The students discussed problem-solving competency in interdisciplinary teams in particular. Through various approaches and knowledge, problem-solving capabilities are enhanced, leading to the development of more holistic social innovations. The reflections show that students were surprised by the solutions the groups generated, noting that they would not have considered these ideas individually. Despite all students working on the same task, no two groups arrived at identical social innovations. As one student expressed, *'The exciting thing was that the concepts were not very similar, and each group developed its concept' (S61, p. 8).*

In their reflections, the students consistently highlighted **the interplay between the challenges and opportunities of interdisciplinary collaboration**, leading to more creative solutions. They noted that: '*Discussions in which people talked at cross-purposes, therefore, gave our creative thoughts and ideas a good voice*' (S44, p. 7). Additionally, some excerpts emphasize that it is crucial not only to merge different disciplines but also that '*the combination of different ideas and approaches ensures that these teams usually have innovative approaches that can lead to unique results*' (S23, p. 6). One student summarized this: *Combining ideas and expertise can lead to synergy effects and improve the quality of the results so that unconventional solutions can be found that open up new possibilities'* (S26, p. 6).

In the face of global challenges in particular, unconventional social and technical innovations are needed. Students recognized that different disciplines are important, and all group members brought their own experiences, ideas and backgrounds that can contribute to broader social innovations. Several

statements highlight the need for interdisciplinary collaboration in addressing global challenges. Students emphasized considering issues holistically, especially against the background of '*complex questions and problems that will have an important significance in the present and future*' (S26, p. 6). Students summarized that interdisciplinary collaboration '*contributes to a more sustainable world that will face ever stronger and greater challenges in the future*' (S59, p.7). Interdisciplinarity is seen as '*essential*' (S61, p. 7) for addressing current challenges to include different perspectives. The necessity of interdisciplinary collaboration to tackle global challenges is also extensively discussed in the literature, as current challenges are too complex to be solved by a single discipline alone (Morawska-Jancelewicz 2022; Kolmos et al. 2024; Cinar and Benneworth 2020). This also became apparent to the students during the seminar.

In addition, the students' reflections show that working on current, real-world challenges increases the students' motivation - a fact that is in line with previous research showing that working on real-world problems can enhance motivation (Bertel et al. 2021). They stated that the work does not feel like *'other lectures, some of which are without variety'*. (S05, p.7). The fact that the ideas developed have the potential to *'bring about real change'* (S37, p.8) has led to more effort being put into the project.

Conclusion, Implications and Limitations

This study investigated how STEM students at two technical universities experience interdisciplinary collaboration on social innovation. The motivation for this investigation was twofold. First, there is a recurring call for interdisciplinarity between STEM students and students from social science and humanities. Secondly, research indicates that social innovations have not been fully integrated into technical universities' teaching processes. So far, there is little research that connects social innovation and interdisciplinarity in STEM education, examining how STEM students perceive this collaboration. To address this gap, we conducted a thematic analysis of 83 reflection papers submitted by students participating in an interdisciplinary, cross-university course offered by three German universities. The results indicate that STEM students experienced both the challenges and benefits of interdisciplinarity while cultivating essential competencies for future collaboration in interdisciplinary teams.

In line with previous research, our results indicate that students struggle with interdisciplinary collaboration (Kolmos et al. 2024; Bertel et al. 2021; Podgórska and Zdonek 2024). Students experience organizational difficulties and challenges due to different perspectives and experiences; however, communication has been identified as the primary challenge, a finding that aligns with previous research (MacLeod 2018). They struggle to present their expertise in a way that is comprehensible to peers from different disciplines. To establish a common basis, terms and concepts had to be defined at the beginning. Recognizing this challenge is crucial when designing interdisciplinary courses. Students often find it difficult to translate their knowledge to other fields (Kolmos et al. 2024; Kolmos, Holgaard, and Routhe 2025). The results underline the importance of practicing such interdisciplinary skills during their studies. The course was structured to require students to manage themselves within their groups and create a basis for collaboration. While there was an opportunity to discuss issues with supervisors, this was rarely utilized, as students generally succeeded in overcoming challenges independently. We recommend maintaining this autonomy in groups for future interdisciplinary projects to provide similar learning experiences. Nevertheless, regular opportunities should be created for the groups to meet with supervisors. We facilitated this by offering several in-person work sessions throughout the semester, during which groups could work on their solutions and receive direct supervisor feedback if they had questions. Given the necessity for

students to work in interdisciplinary teams in their future careers and the persistent communication barriers they may face, they must develop the ability to communicate across different disciplines early on and tailor their knowledge accordingly. Besides, our course used a PBL approach, which, despite the benefits, presents certain challenges, too. The process of self-directing and organizing one's own learning can be challenging for students and managing interdisciplinarity in groups can also cause complexity and uncertainty (de Graaf and Kolmos 2003).

In addition, students reported an expansion of perspectives and opportunities for mutual learning within their groups. They were able to enhance their problem-solving skills, and for some, the seminar inspired or strengthened their desire to start a business. Furthermore, the seminar highlighted students' awareness of the importance of social innovations and interdisciplinary collaboration in addressing grand challenges. The results show that the seminar was the first experience for many students working in interdisciplinary teams on social innovations. Particularly in light of grand challenges that require interdisciplinarity and social innovations, students should be able to gain experience in these areas during their studies. The results show that through the course, students have recognized the importance of interdisciplinarity for more holistic and far-reaching social innovations. In addition, students report that their creativity and innovation potential have been strengthened. Overall, the results show that linking interdisciplinarity and social innovation in STEM education helps students at universities to understand the importance of innovation in general and especially social innovation as well as the relevance of interdisciplinary collaboration in the innovation process. Thus, our results are important in the context of the role of universities to foster social innovations. There is a call for universities to promote interdisciplinary collaboration for social innovations (Tjörnbo and McGowan 2022; Bayuo, Chaminade, and Göransson 2020). However, our results indicate that this has not yet been considered, as students reported few experiences with such courses. The results also confirm current studies (Kolmos et al. 2024), indicating that projects in engineering education often remain confined to a single discipline. In particular, the collaboration of three universities within the seminar framework further enhanced interdisciplinarity. Students from these institutions brought diverse academic disciplines and varying experiences with group work, academic demands, and examination standards.

Based on our findings, 1) interdisciplinarity and social innovation are still inadequately represented in academic curricula, and 2) collaborations across universities in course offerings could significantly enhance group diversity. This diversity arises not only from varying academic backgrounds but also from differing experiences, teaching methodologies, and expectations. These distinctions enable students better to navigate the challenges and advantages of interdisciplinary collaboration. Besides, our results confirm that working on real-world problems increases motivation (Bertel et al. 2021). In the sense of transdisciplinary approaches, external stakeholders could also be integrated into group work. This could lead to more diverse group compositions, making social innovations more holistic. The findings suggest that for some students, the desire to start their own business was either reinforced or cultivated through the event. Therefore, it is essential to establish a connection between the course and transfer centers. One limitation of the current course framework is that the social innovations developed often do not progress beyond the end of the semester. To address this, we plan to encourage the further development of social innovations in the future. To support students in transforming their ideas into real applications, we will establish connections with innovation and transfer centers at universities.

Like any study, our analysis has specific limitations. First, we used a case study, so the results cannot be generalized, especially due to the small sample size. By analyzing 83 reflection papers from STEM students, our results cannot be applied to the entire student body inside and outside the two universities.

Due to the research question, only reflections from STEM students were considered. Further research should also explicitly consider the experiences of social work students. In addition, the course is an elective, which means it will likely be chosen only by students interested in the content. The study has a strong local focus and pertains exclusively to students at two specific German technical universities. The results could differ since universities and countries' teaching and learning methods vary. In addition, the interdisciplinarity should be further increased by involving students from other disciplines. Further studies could investigate similar courses that bring together different disciplines and universities within a country and students from different countries. Moreover, there is a risk of bias in reflections as part of the examination performance, even if ungraded, due to the social desirability bias (SDB). SDB is an acknowledged limitation in qualitative research (Bergen and Labonté 2020) and can significantly impact the results of a survey. Reasons for SDB can vary and depend on factors such as social norms, impressions or benefits that may result from answering in a certain way (Lee and Sargeant 2011). SDB can be minimized by methods such as randomized response techniques or indirect questioning (Fisher and Katz 2000). As in this study, the reflection papers were not graded, SDB might have been limited. However, tendencies based on SDB possibly still influenced the findings. Future studies should employ a mixed-methods approach, using reflections, interviews, questionnaires, or participant observations to obtain further results. In this step, not only should the experiences of STEM students be taken into account, but also those of students from other degree programs. Nevertheless, our findings are relevant as they offer valuable insights into the challenges and opportunities that STEM students, in particular, perceive in interdisciplinary collaboration focused on innovation and social innovations.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT and Grammarly in order to improve the readability and language of the manuscript. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Ethics Statement

According to the guidelines of the Interfaculty Ethics Committee of RWTH Aachen University, the nature of this research does not require formal ethical approval. All data were processed in accordance with informed participation and the principles of confidentiality.

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