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Engineering Society: The Role Of Intersectional Gender And Diversity Studies For A Sustainable Transformation On The Case Of Interdisciplinary Engineering Education

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ENGINEERING SOCIETY: THE ROLE OF INTERSECTIONAL GENDER AND DIVERSITY STUDIES FOR A SUSTAINABLE TRANSFORMATION ON THE CASE OF INTERDISCIPLINARY ENGINEERING EDUCATION

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ABSTRACT

Technological innovations are impacting societies in manifold ways and can accelerate a transformation toward sustainability. To enable a sustainable transformation through engineering, engineers educated to create technological solutions for global challenges must be educated in sustainability principles as postulated under 'Education for Sustainable Development' (ESD) in the Agenda for Sustainable Development. In technological fields, the ecological, as well as the economical perspective of sustainability, are often addressed, but as recent research has highlighted, sustainability needs to be addressed holistically; this means including the social dimension to a greater degree and applying an intersectional understanding of gender and diversity throughout all spheres of sustainability. It is therefore imperative for engineering students to learn and understand where gender and diversity are necessary for sustainability, how diversity dimensions intersect, and which intersections are particularly relevant for novel technologies and societal development. Accordingly, this paper sketches an interdisciplinary approach for applying intersectional gender and diversity studies in the context of a sustainable transformation of engineering education. We draw on our experience of having educated engineers accordingly for a decade at the GDI (Gender and Diversity in Engineering) at RWTH Aachen University. Selected examples from our teaching practice are presented and six general maxims are deduced that can make engineering education more sustainability-oriented, inclusive, and diverse. As we will conclude, fostering innovative and inclusive engineering education needs interdisciplinary teams adhering to our proposed six maxims to accelerate a gender- and diversity-sensitive sustainable transformation.

1 INTRODUCTION

Considering complex global challenges such as sustainable development, engineering education should transgress its disciplinary boundaries together with its classical reductionist focus on mere technical problem-solving (Takala and Korhonen-Yrjänheikki 2019; Sigahi et al. 2023). Accordingly, such challenges call for a new type of interdisciplinary educated engineers (Van den Beemt et al. 2020) that can cope with complexities, ambiguities, or uncertainties (Takala and Korhonen-Yrjänheikki 2019; Sigahi et al. 2023).

This is in line with the United Nations stressing that engineering, as an essential factor influencing sustainability, should integrate a gender-sensitive perspective of diversity and inclusion to foster a sustainable development that goes beyond a mere focus on ecological and economic factors (United Nations 2021). Correspondingly, researchers, educators, and practitioners must be enabled to discover and deal with complex intersections between gender and engineering as well as gender and sustainability (Khalikova, Jin, and Chopra 2021). Further, this signifies the need for educational initiatives that foster the development of critically reflective and socially responsible engineers (Steuer-Dankert et al. 2019). While practically-oriented research on engineering education has suggested how intersectional gender and diversity studies can improve engineering education (Leicht-Scholten 2019), there is less research focusing on how to integrate the intersection between gender and sustainability in the context of engineering education.

Having applied intersectional gender studies along with a broad understanding of sustainability in engineering education for more than a decade at the Institute Gender and Diversity in Engineering (GDI) at RWTH Aachen University, in this paper, we contribute to closing this gap by proposing six maxims derived from literature and our practical experience to lay the foundation for future developments in sustainability education.

2 METHODOLOGY

As a starting point, we will outline selected research findings on the relationship between gender, engineering, and sustainability that are to be considered for a holistic education that acknowledges intersectionality as a connecting anchor between these topics. After this, we briefly present two exemplary educational approaches that already put these intersectional and holistic understandings into practice. We then deduce six generalized maxims on how to apply an intersectional sustainability perspective to engineering education.

3 THEORETICAL BACKGROUND: ENGINEERING EDUCATION AND THE INTERSECTION OF GENDER AND SUSTAINABILITY

As we highlighted in a previous paper on the contribution of gender research to engineering education (Leicht-Scholten 2019) and illustrated referencing our teaching concept of “Expanding Engineering Limits” (Steuer-Dankert et al. 2019) developed in cooperation with Stanford University, integrating a perspective of intersectional gender

studies into engineering education fosters a form of critical reflexivity that allows students to understand sustainability holistically. To reach this, students must, in the first place, develop an understanding of the intersections of gender, understood as socially constructed roles, behaviors, and expectations, that are enacted based on culturally produced ideas of being male or female (Gildemeister 2010), and engineering. Students' development of holistic perspectives profits from learning about topics such as masculine-coded engineering cultures (Faulkner 2000), identities (Cech 2015), artifacts (Cockburn and Ormrod 1993), and processes (Male et al. 2018), that are prevalent in the context of engineering (Leicht-Scholten 2019) and that derive from the gendered culture of society in general (Carberry and Baker 2018). In doing so, students reflect on how these gendered realities generate privileges for white able-bodied heterosexual men in engineering cultures (Cech 2022). Accordingly, students discover that this not only leads to an exclusionary and often discriminatory educational and professional culture for female or other marginalized groups of engineers but also limits innovations that are needed to foster sustainable development of technology and society (Schiebinger et al. 2011-2020). To develop this kind of holistic understanding, students need a fundamental knowledge of the concept of *intersectionality* (Crenshaw 1991). This knowledge of intersectionality can be applied as a tool to recognize that different categories of social identities, such as race, gender, class, ability, and sexual orientation, intersect and create unique experiences of oppression and privilege (Crenshaw 1991) in the context of engineering (True-Funk et al. 2021) and sustainability (Khalikova, Jin, and Chopra 2021). With this at hand, students are enabled to apply a holistic understanding of sustainability that includes an intersectional understanding of gender and diversity, how gender and other intersecting identities (such as race, class, and sexual orientation) intersect with environmental sustainability, and how these intersections can be addressed comprehensively and effectively. This intersectional sustainability perspective acknowledges that people can experience multiple forms of oppression and discrimination simultaneously and that these intersecting experiences and identities must be considered when sustainability is the goal (Khalikova, Jin, and Chopra 2021).

Recent research has highlighted how gender and other factors intersect with sustainability. For example, women and other marginalized groups often bear a disproportionate burden of the negative impacts of environmental degradation and climate change, such as food insecurity, displacement, and health problems (Odrowaz-Coates 2021). Women are also often excluded from decision-making processes related to sustainability and conservation (Odrowaz-Coates 2021). Thinking of sustainability in terms of intersectionality requires acknowledging and addressing the interactions between societal inequalities and environmental degradation. This involves understanding that environmental problems, such as climate change and biodiversity loss, disproportionately affect marginalized communities, such as low-income communities and communities of color. At the same time, social justice issues, such as poverty, racism, and gender inequality, can also

contribute to environmental degradation (Prati, Cazcarro, and Hazra 2022). Such interdependencies are also becoming increasingly relevant in the context of digital transformation and Artificial intelligence (AI), where intersections between sustainability (Van Wynsberghe 2021), gender, and diversity (Buolamwini and Gebru 2018), are discussed in the context of a sustainable transformation of society and technology.

To address such intersections successfully, an inclusive and holistic sustainability approach that considers the needs and perspectives of diverse stakeholders, including those from marginalized communities, is necessary. This includes recognizing and addressing the differential impacts of environmental degradation and climate change on different groups and incorporating equity and social justice considerations into sustainability policies, practices, and education. Further, it means developing more inclusive and participatory decision-making processes as well as promoting the participation of marginalized groups in decision-making processes (Khalikova, Jin, and Chopra 2021; Odrowaz-Coates 2021).

Consequently, such a holistic perspective should be incorporated into educative approaches to foster the development of responsible engineers that can identify, dissect, and improve complex intersections among engineering, sustainability, and gender, to reach a sustainable future as requested by the United Nations (United Nations 2021).

4 APPLYING GENDER, INTERSECTIONALITY, AND SUSTAINABILITY IN ENGINEERING EDUCATION

The GDI at RWTH Aachen University is unique in Germany in its positioning as a bridging professorship between the Faculty of Civil Engineering and the Faculty of Arts and Humanities (Trujillo et al. 2023). With the research group's experience of having educated engineers for more than a decade, the interdisciplinary team of scientists at the GDI under the leadership of a political scientist focused on Gender and Science and Technology Studies (Gender STS), are pioneers in educating engineering students at the intersection of gender, diversity, engineering, and sustainability (Leicht-Scholten 2019; Decker, Winkens, and Leicht-Scholten 2022).

To offer a practice-oriented perspective deriving from this experience, in the following, we present two examples of engineering education developed and implemented by the GDI.

4.1 Teaching the Fundamentals: Lecture "Engineering and Society"

As stated, engineering education that aims to create technological solutions for global challenges must follow principles of sustainability, as postulated under 'Education for Sustainable Development' (ESD) in the Agenda for Sustainable Development (United Nations 2023). Oftentimes, the idea of sustainability taught focuses strongly on environmental and ecological sustainability but neglects the perspective of social sustainability and intersectionality. However, if engineers are required to build sustainable solutions, they need the tools to understand social structures and

communities and to reflect upon the impact of their work on society's environment (Bosen and Leicht-Scholten 2020; Walden et al. 2020). Therefore, engineers must be taught to critically reflect upon the intersectionality of factors of sustainability.

At larger technical universities in Germany engineering education most often includes teacher-centered lectures in front of hundreds of students with little to no active participation and reflection by the students. In contrast to this, the GDI lecture "Engineering and Society", which is a mandatory Bachelor's course attended each year by about 500 engineering students, utilizes participatory concepts of a flipped classroom and blended learning strategies. Through this, students learn about the importance of sustainability, (technology) ethics, and societal structures in their future engineering careers (Decker, Winkens, and Leicht-Scholten 2021). The course has been well-evaluated by students with an interest in the topics for its participatory and intersectional teaching approach to the topics of gender and diversity in connection with engineering and sustainability (Decker, Winkens, and Leicht-Scholten 2022).

4.2 Practicing Inclusion and Diversity in Engineering Education: BIOS

Engineering study courses often are challenging in the first years, with dropout rates among the highest of all courses of study and this disproportionately affects students from non-academic family backgrounds or with less social and cultural capital (Heublein et al. 2017). We propose that an intersectional understanding of sustainability should not just include what is taught but also who is taught. It is therefore imperative to make engineering education more inclusive and diverse.

For this reason, RWTH Aachen University and Aachen University of Applied Sciences jointly launched the cooperation project "A Good Start to Engineering Studies" in 2015. Building on the successful cooperation project, the independent cooperative study course "Civil Engineering with Orientation Semester" (German acronym: BIOS) was introduced in the summer semester of 2020 (GDI n.d.b).

The eight-semester Bachelor's degree course includes one extra semester, providing students with first-hand insights into the civil engineering courses at the two universities and helping them to decide which one fits best for them. Whereas one is a university of applied science with relatively small classes and a practical approach, the technical university of Aachen has larger cohorts, less direct interaction with teachers, and a strong research orientation. Being able to compare the teaching formats, facilitates an individual study decision for the type of university and engineering course for students. It aims to lower the barrier to studying at the university level, which could be particularly valuable for people with a migration background and "first-generation students" (GDI n.d.a).

Following the GDIs approach to teaching the fundamentals as early as possible, BIOS is one of only a few engineering degree programs in Germany that include a mandatory module on responsibly designed technology development.

5 RESULTS – THE GDI-APPROACH

Deriving from scientific literature and our practical experience, we now propose six maxims–that is, propositions generalized from our practical experience in combination with the theoretical state of the art–to follow to successfully apply interdisciplinary educational initiatives on the cross-section of intersectional gender studies, engineering, and sustainability:

1. Anchoring concepts firmly in disciplinary discourses and ensuring interdisciplinary iteration from the beginning–thereby ensuring theoretical integration with the existing disciplinary states of the art and developing new concepts that are more easily translatable into an interdisciplinary practice.

To be able to apply gender studies interdisciplinary, understand where diversity dimensions intersect, and which intersections are especially relevant for the given context, a fundamental understanding of the disciplinary, theoretical discourses on gender and diversity studies and social science methodology is necessary (cf. also Walden et al. 2020; Takala and Korhonen-Yrjänheikki 2019). However, conceptual frameworks only developed disciplinarily often come at the expense of interdisciplinary applicability. This is why we, following, amongst others Van den Beemt et al. (2020); Takala and Korhonen-Yrjänheikki (2019), propose that teams developing concepts to be applied interdisciplinarily should ideally be interdisciplinary from the start and include both disciplinary and scholarly expertise in gender and diversity studies as well as the sciences the concept is developed for. When teams that have fundamental knowledge in social sciences and gender and diversity studies as well as fundamental knowledge in engineering and natural sciences work together on the development and research of concepts, these concepts stand the challenges of interdisciplinary application. This is because interdisciplinary cooperation is already applied in the first sketches of the conceptual frameworks that are then developed further to be taught in interdisciplinary contexts, such as engineering education.

2. Translating disciplinary theoretical concepts into interdisciplinary contexts.

Through iteration in interdisciplinary teams, we translate the theoretical disciplinary state of the art into interdisciplinary contexts. For this, communication in an interdisciplinary team is essential. This is also where empirical data can be disciplinarily evaluated and interdisciplinary validated (cf. for example Bosen, Fuchte, and Leicht-Scholten 2023). This way, there is interdisciplinary communicative validation from the beginning of the conceptual development and even though concepts are still on a theoretical level at this stage, a first round of reviewing intersectionality is also provided, as stereotypes and disciplinary preconceptions are challenged. This step profits from diversity in the team, including as many diversity categories as possible.

3. Example-based communication of these translated concepts–thereby facilitating interdisciplinary understanding.

The theoretical concepts then need to be prepared to be communicated to teams from other disciplines and outside of academia. The challenge here is to not reduce the complexity of the concepts (Sigahi et al. 2023) because we have discovered that this does not lead to satisfactory results (Berg, Steuer-Dankert, and Leicht-Scholten, under review). To facilitate communication or teaching without having to dilute the theoretical concepts, we propose using examples that ideally come from the realm of the target group that is taught these concepts. This way, interdisciplinary compatibility is generated without compromising on the complexity of the taught concepts.

4. Case work–thereby facilitating interdisciplinary understanding and applying the concepts to the relevant interdisciplinary areas.

To illustrate the complexity of theoretical concepts and thereby make them more tangible (Sigahi et al. 2023) as well as to intensify this example-based communication of theoretical concepts, casework has proven a fruitful tool. Cases are examples that are given in greater detail and/or developed by the students themselves. They offer a concrete, multifaceted context for the theoretical concept to be applied by the students (Leicht-Scholten 2019). Students work over a longer period on these cases and develop and shape them. This way, they can shape the cases to their background, hands-on apply the theoretical disciplinary concepts interdisciplinarily, and, thereby, learn to deal with complexities, ambiguities, and uncertainties (also) outside their disciplinary boundaries (Takala and Korhonen-Yrjänheikki 2019; Van den Beemt et al. 2020).

5. Peer-group discussions–thereby encouraging individual reflection and facilitating a low-threshold exchange of the learned concepts in peer groups.

This might be combined with 3. Casework can also be executed as a separate step de-coupled from the casework. Students could be guided by guiding questions or design thinking methods (Leicht-Scholten and Steuer-Dankert 2020). Diversity and heterogeneity of peer groups are preferred and only minimal intervention by the teacher in the discussions at this stage is preferred.

6. Discussion and iteration – thereby re-iterating conceptual framework for new applications but also furthering state-of-the-art discussion in disciplinary contexts.

As a final step, it is imperative to encourage discussions across the peer groups and engage all students in a broader discussion but also to collect feedback so that lecturers may re-evaluate their concepts, starting again with phase 1.

6 DISCUSSION

We proposed a novel practical attempt to bring together research from intersectional gender and diversity studies and sustainability in the context of engineering education, acknowledging that engineering, and gender inclusion, play a crucial role in sustainable development (United Nations 2021; Khalikova, Jin, and Chopra 2021). While there have been attempts to better integrate the social dimension into sustainability discourses (Odrowaz-Coates 2021), there has been no interdisciplinary approach, rooted in both research and practice, that conceptualizes the

interdependencies between intersectional gender and diversity studies and sustainability studies in the context of engineering education. Accordingly, our proposed maxims help fill this gap and thus align with the United Nations' call for "new approaches within higher education and, possibly, even a fundamental reconceptualization of teaching and learning" (United Nations 2017, 5) in the context of education on sustainable development.

Our proposed maxims are generic in their current form. While this might limit their scope, it allows for adaptability to different contexts and improvements after application in practice. Correspondingly, their generic outline offers flexibility and adaptability and, therefore, aligns with the demands of fostering reflectivity, creativity, and innovativeness within the development of engineering education (Takala and Korhonen-Yrjänheikki 2019). This becomes apparent in the maxims *4) case-relatedness*, *5) participation,* and *6) discussion or iteration,* since these phases promote, when combined, a reflexive and collaborative hands-on practice demanding and fostering students to develop social skills (Lopes et al. 2015; Bairaktarova and Pilotte 2020).

The maxims *1) anchoring*, *2) translating* and *3) exemplarity* correspond to the demand for inter- and transdisciplinarity in the context of sustainability science and education (United Nations 2017; Van den Beemt et al. 2020). Because they, as also proposed by Sigahi et al. (2023) and Takala and Korhonen-Yrjänheikki (2019), extend the classical disciplinary engineering focus on sustainability by introducing relevant and contextualized insights on an intersectional and interdepended perspective on sustainability, and thereby foster complexity-thinking in a broader sense. This challenges engineering students' tendencies to reduce given issues to, e.g., mere technical aspects (Sigahi et al. 2023) and, accordingly, assists their "develop[ment] from technical problem-solvers to collaborative creators capable of defining relevant questions, and creating solutions, to complex transdisciplinary problems" (Takala and Korhonen-Yrjänheikki 2019, 175f.), such as sustainable development.

Accordingly, the proposed maxims of *1) anchoring*, *2) translating*, *3) exemplarity*, *4) case-relatedness*, *5) participation*, and *6) discussion* or *iteration*, offer guidance to educate engineers on topics of gender and diversity studies and sustainability while contributing to transforming engineering education towards sustainability by assisting the development of interdisciplinary competencies, critical complexity-thinking, adaptability, as well as collaborative social skills.

7 CONCLUSION

To engineer a sustainable and just future, interdisciplinary educational initiatives are needed that use case-based and participatory learning approaches to convey the interdependencies and intersections of gender, engineering, and sustainability. This requires interdisciplinary teams that can develop innovative teaching and learning concepts based on our proposed maxims of *1) anchoring, 2) translating, 3) exemplarity, 4) case-relatedness, 5) participation, and 6) discussion or iteration* as well

as further research on the introduced intersections between gender, engineering, and sustainability.

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