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Problems without Solution? Challenges of Climate Change and Sustainability in Engineering Education

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ABSTRACT

The issues of climate change and sustainability are urgent and critical concerns of our time. The rise of climate disasters, such as floods, droughts, forest fires, and hurricanes, poses a threat to the survival of humans, animals, and plants. Despite scientists having warned about the impending dangers of high CO2 emissions, particularly from the global North for many years, there has been no political or technical solution in sight.

Engineers are known for being problem-solvers, but what happens when the problem is complex and the consequences of technical interventions are hard to predict? In my paper, I propose measures to sensitize engineers to the complexity of climate change and sustainability. Based on the method of focused ethnography, I draw on Feminist teaching methods, my extensive teaching experience in the field of transdisciplinary gender research in science and technology studies, and my observations during the international "Winter school of ENHANCE on gender and diversity in science, technology and society" at Technische Universität Berlin in 2023.

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The paper concentrates on the content and pedagogical approaches that can be used to convey the complexity of the issue while fostering the development of critically reflective knowledge. By incorporating these measures, engineers can be better equipped to tackle the challenges posed by climate change and sustainability in a more holistic and thoughtful manner.

1 INTRODUCTION

1.1 Climate Change and Engineering’s Impact on Sustainability

Climate change has altered the Earth's climate system over the past two decades, resulting in long-term shifts in temperature, precipitation patterns, and extreme weather events. Greenhouse gas emissions from human activities, such as burning fossil fuels and deforestation, are the primary cause of climate change. These emissions lead to increased concentrations of carbon dioxide, methane, and nitrous oxide in the atmosphere, resulting in a warming effect known as the greenhouse effect. The impacts of climate change are severe. Over the past two decades, climate change has continued to intensify, leading to more frequent and severe extreme weather events and significant environmental impacts such as melting of glaciers and ice sheets, coral bleaching, and declining fish populations. However, there has also been increased awareness and action to address the issue, including the adoption of the Paris Agreement and measures to reduce greenhouse gas emissions and increase climate resilience.

In light of these facts, it must be stated that climate change poses a significant threat to the long-term sustainability of human societies and natural systems. Considering this, sustainable practices such as transitioning to a low-carbon economy, adopting sustainable energy sources, sustainable land use practices, sustainable transportation options, and sustainable manufacturing practices are crucial for reducing greenhouse gas emissions and ensuring the long-term sustainability of human societies and the natural environment.

Addressing climate change and sustainability in Engineering Education provides an opportunity to create a more sustainable and resilient future for people and the planet. Because sustainability and engineering are closely intertwined since engineers have a significant responsibility in designing and implementing solutions that advance sustainable development. With their knowledge and expertise, engineers can create technologies and infrastructures that minimize environmental impacts, conserve natural resources, and enhance social and economic conditions. Renewable energy technologies, such as wind, solar, and hydro power, are a crucial area where engineering can contribute to sustainability.

1.2 Gender, Diversity and Sustainability

Gender and diversity are important but nevertheless still under-thematized dimensions of climate change (Buckingham/Le Masson 2017). Not only are women predominantly engaged in the main energy-consuming tasks in the home, but gender and diversity also play a role at the sociocultural and technological levels. To this end, it is necessary to develop a broader perspective with respect to sustainability and to sensitize students to the (gendered) impact of their technological solutions. In the following, I list key points that have been largely ignored in technology research on climate change:

- A binary notion of gender makes it impossible to include queer, non-binary identity designs that cannot be easily categorized in adaptive designs. At the same time, queer people often live in areas threatened by climate change due to their social stigma.
- Intersectional analyses of the implementation contexts of technological solutions are indispensable to adequately consider the particular inequalities that for example affect women of color.

- Women, in particular from the global South, are often portrayed as victims in discourses on climate change. This perspective overlooks the fact that women form a heterogeneous group that is permeated by further dimensions of inequality. At the same time, the focus on women (from the global South) narrows the view.
- The important role that constructs of *white* masculinity play in determining individuals' carbon footprints is often overlooked.
- Studies show that women in leadership positions are responsible for implementing more sustainable solutions. However, most leadership positions are held by *white* men.
- At the same time, women are less likely to be involved in adaptation strategies and processes to develop technological solutions to climate change, as they are often unable to engage in participatory processes due to caregiving responsibilities.
- Technological solutions can profoundly change the lives of girls and women and, in the worst cases, help to re-stabilize asymmetrical gender relations.

As I mentioned elsewhere (Dornick, 2021), it is important to note that brief exposure to diversity and inequality issues may not sufficiently equip students with the ethical capabilities required to develop technological solutions for complex societal problems. To address this, Engineering Education should also aim to deepen students' understanding of power dynamics in society by teaching them about the gendered nature of technology and how power relations are manifested in material forms. The inclusion of gender and diversity skills in Engineering Education not only prevents exclusion and discrimination, but also promotes successful and sustainable engineering by rejecting individualistic approaches and the predominance of male professional cultures. To equip future engineers with the ability to address the intricate environmental, social, and economic challenges of our world, it is essential to teach sustainability in Engineering Education.

2 METHODOLOGY

2.1 Research Design

In the following I draw on the method of ethnographical observation. Ethnography is an approach to qualitative research that is used to investigate cultures and people (Flick 2007). It involves the systematic observation of social phenomena where researchers immerse themselves in the culture they are studying to gain an insider's perspective. Ethnography employs various data collection methods, such as participant observation, interviews, focus groups, and document analysis. The purpose is to gain a deep understanding of the culture from the perspective of those being studied, and to document the social and cultural practices and norms of the community. Ethnography is commonly utilized in disciplines such as anthropology, sociology, and other social sciences to study a broad range of subjects, including culture, social interactions, and power dynamics.

For the following study, I have oriented myself on the method of focused ethnography (Knoblauch 2001). Focused ethnography is a type of ethnographic research that focuses on a specific research question or phenomenon within a particular community or culture. It is often used when researchers have a limited amount of time or resources to conduct their research. Focused ethnography differs from traditional long-term ethnography in that it has a narrower scope and is conducted over a shorter period of time. The researcher may use a variety of qualitative data collection methods, such as interviews, observations, and document analysis, to gain an in-depth understanding of the specific phenomenon or research question. The findings from a focused ethnography study can provide valuable insights into the social and cultural practices of the community being studied, and can be used to inform future research and interventions. At present, ethnographic methods enjoy great popularity, especially in the social science-oriented areas of science and technology research, because they make it possible to take a detailed look at the practices of the making of reality.

2.2 Research Field

As a research field, I take as a basis my own extensive teaching experiences in the field of transdisciplinary gender research in science and technology, my observations during the international "Winter school of ENHANCE on gender and diversity in science, technology and society" at the Center for Women's and Gender Studies (ZIFG) at Technische Universität Berlin (TU Berlin) in 2023, as well as my analysis of learning journals of students in Engineering Education that had taken part in the learning module "Bue Engineering" at The Department of Machine Systems Design at Technische Universität Berlin (Dornick 2021). The main objective of "Blue Engineering" is raising awareness among students about their social and ecological responsibilities. This elective module has been available since 2011 and is worth 6 credits points in Mechanical Engineering, Information Technology in Mechanical Engineering, Transportation Engineering, Sustainable Management, and Industrial Engineering degree programs. Every semester, approximately 80 students participate in the four-hour seminar. Over the years, this module has been successfully adopted by other universities, including Hamburg University of Technology, Düsseldorf University of Applied Sciences, Berlin University of Applied Sciences, and Ruhr West University of Applied Sciences.

The faculty of "Humanities and Educational Sciences" at TU Berlin has a close association with the four faculties for technical and natural sciences, owing to the university's distinctive history (Profile "Humanities and Educational Sciences at TU Berlin", 2023). The ZIFG, following an interdisciplinary teaching approach, offers courses that are open to students from humanities and educational sciences, as well as technical and natural sciences. Students can earn ECTS points towards their BA and MA degrees or participate in specialized programs, such as "Gender Pro MINT" or ZIFG's gender certificate.

The courses observed in this study were taught by the author during the period from Winter term 2018 to Winter term 2023. The author mainly conducted participatory observations during class sessions. Evaluation was carried out during the last class of the term when each student provided oral feedback. The main focus of these courses was to enhance Engineering students' ability to act in a gender-sensitive and diversity-oriented way by deepening their understanding of intersectional forms of discrimination and co-constructive processes of gendering artifacts. The curriculum included topics such as Feminist philosophy and critique of science and technology, introduction to transdisciplinarity of gender studies in science and technology, gender, diversity and sustainability, and gender in Higher Education. Participants in the courses had diverse academic backgrounds, including "Engineering," "Computer Science and Design," "Culture and Technology," and "Gender Studies." The size of the classes varied from five to 35 participants. I consider both face-to-face and online courses. For synchronous sessions, the video conferencing tool Zoom was used. All sessions were assisted by an e-learning platform and, from 2020, also received support from various other online tools such as online pads, Wonder (a platform for working in working groups), Discord (a platform for meetings and chats), and online whiteboards (see Dornick 2020, for a detailed description of the module “Blue Engineering” and Dornick 2021 for a detailed description of my teaching practice).

3 RESULTS

3.1 Understanding Climate Change as a Complex and Multi-faceted Phenomenon

Let me start with an anecdote. In my presentation on Gender, Diversity and Sustainability at the international “Winter school of ENHANCE on gender and diversity in science, technology and society” at TU Berlin, I drew attention to the urgency of climate change and the need to take appropriate action to address it. The international students nodded, studied the overviews, and actively participated in the discussion session that followed. After a while, one student asked, "And what proposal do you have now for solving climate change?"

I resort to this anecdote for several reasons. First of all, because I was so surprised by the student’s question that this moment has impressed itself on me. Moreover, this anecdote seems to me like a vignette in which the difficulties and challenges of inter- and transdisciplinary understanding on climate change are revealed.

How on earth, I wondered, could students assume that one person, let alone me, a sociologist from Feminist Science and Technology Studies, could have found THE solution to climate change? But besides the naivety of the question, I also felt something like hope in that question. Hope, that there could be a solution, that it could be found, even that it had already been found. I looked into the room, which was filled with prospective engineers, and thought about what I should answer them. Was it perhaps a test question? Or was the question meant to provoke me? After all, I had criticized various engineering solutions. Could this question be serious? There were so many different levels to consider in developing actions on climate change. First and foremost was our understanding of climate change, of nature, of the survival of human civilization, followed by hypercomplex causal chains that constantly unfold as climate conditions change: Extinction of species, change of soils, loss of livelihoods.... I decided to put aside my fear and also my indignation and give a transformative response. I replied: “No, unfortunately, I must admit that I do not have a solution. It's even worse, I do not think there is ONE solution. Rather, I think there are many solutions and we must find them together. But, unfortunately, at the moment it doesn't look like all the energy is being put into finding solutions”.

Following on from this anecdote, I would like to emphasize that my teaching practice in Engineering Education has shown that it is essential for engineers to gain a more complex image of the world. That means, that, besides the social and ethical dimensions of technological issues, engineers that are concerned with sustainability need knowledge about *naturecultures*. Donna Haraway, a feminist scholar and philosopher, coined *naturecultures* to refer to the interconnectedness and interdependence of humans and the nonhuman world (Haraway 2016). Usually, "nature" refers to the nonhuman world and "culture" refers to human society. By using the term *naturecultures*, Haraway overcomes this separation and points out that humans are shaped by and are an integral part of the natural world, which is also influenced by human activities and culture. This perspective makes it possible to consider the significant impacts of human activity on the natural world, including pollution, habitat destruction, and climate change. Furthermore, and this seems to be crucial especially for the Engineering Education, a broader perspective on the relationship between humans and the environment can be developed following the epistemological concept *naturecultures*, which goes beyond the idea of nature as a resource to be exploited for the benefit of humans.

Engineers are problem solvers, and that is an important quality. It seems to give them the confidence to see problems as solvable and to approach them with the energy they need. However, as a social scientist, I also see a drawback in reducing the complexity and multi-faceted nature of the world to manageability for engineers. With such an approach, solutions can be found, but these solutions often do not fit the problems posed.

3.2 Understanding Climate Change as a Dealing with "Situatedness"

Feminist epistemology, namely Donna Haraway and Sandra Harding, have drawn attention to the fact that knowledge is always situated (Haraway 1988; Harding 1991). Knowledge, according to this understanding, is shaped and influenced by the specific circumstances and environment in which it is produced or used. The epistemological concept of situated knowledges thus makes it possible to incorporate into the research process the importance of the social, cultural, historical, and political factors that shape knowledge production and use. The advantage of this concept is that it recognizes that knowledge is not created in a vacuum, but is always embedded in powerful structures. Knowledge is also influenced by the unique situations, experiences, and agency of the individuals or communities involved.This perspective, which does not discount the importance of understanding the social and cultural context in which knowledge is created and applied, recognizes that different perspectives and experiences can lead to different forms of knowledge. By understanding that knowledge is situated, students can develop a more realistic understanding the complexity of the world and work toward more inclusive and equitable ways of producing and applying knowledge. This insight, I argue, is central not only to feminist or social science research, but also to more sustainable scientific and technological research.

In my teaching practice, I therefore attach great importance to critically reflecting with the students on the epistemological foundations on which the research is based (Trojer, 2014). In doing so, I want them to understand that developing sustainable solutions is not about developing something particularly technically innovative or sophisticated, but rather about understanding the situatedness of the technical solution as much as possible in order to be able to take this into account when developing possible solutions. In addition to reflecting on the epistemological foundations on which research is based, it is helpful for students to gain insights into more-than-technologically oriented perspectives on climate change problems, or perspectives that address social-cultural aspects in addition to technological ones. Ideally, these are studies critical of power and domination that reveal the intertwining of technological artifacts with the situatedness of individuals and social norms and discourses.

3.3 Critical Reflection – Engineers' tool for Sustainability

When we think of engineers, we usually imagine them designing artifacts on computers, building something, screwing on devices. Perhaps they also program machines or manufacture innovative parts. But what if we added critical reflection as a tool to the engineers' toolbox? I argue that critical reflection on practices of power and domination is central to engineers who want to develop sustainable technologies. My teaching practice made clear, that sustainability has to be understood less as a learning object than as an epistemological perspective. According to that, thinking about sustainability requires the ability to critically reflect on debates, discourses, and paradigms about nature, culture, and technology. This presupposes a discursive understanding of reality, a critical understanding of sociality in terms of power and domination, and a co-constitutive understanding of *naturecultures*. As I have made clear elsewhere (Dornick 2021), learning critical reflexivity is an uncomfortable and difficult process. Moreover, learning critical reflexivity requires engaged learning (hooks 1984). Students must learn to raise questions. This means not only that debates, discourses, and paradigms become in some way foreign to them, but also - especially when it comes to questioning identity categories, such as gender, class, *race* - that students become unsettled. To teach unsettling topics requires a safe and trustworthy learning environment that allows students to activate and practice "free speech, dissent, and pluralistic opinions" (hooks 2010:16), that also considers learning as an embodied process (Thompson 2017). It requires a trusting "interactive relationship between student and teacher and needs a trusting "interactive relationship between student and teacher" (hooks 2010: 19), that motivates intrinsic experimental learning. A good culture of error is essential, as critical reflection leads to uncharted territory. An indispensable factor for this form of learning is time. Students need time to understand and transfer what they have learned to their discipline. As Spelt et al. (2009) point out: “Interdisciplinary thinking does not occur spontaneously, it can take a considerable amount of time for students to achieve an adequate level of expertise in its practice.” It is therefore imperative that the learning process be designed in such a way that students are given time to converse with each other, to communicate in a trusting manner. Only in this way can transfer-knowledge emerge.

4 SUMMARY

The issues of climate change and sustainability are urgent and critical concerns of our time. Engineers play a central role in addressing and adapting to climate change. However, the problem is complex, and the sociocultural consequences of engineering actions are difficult to predict. Therefore, I focused my paper on the content and pedagogical approaches that can be used to convey the complexity of the issue while encouraging the development of critically reflective knowledge. I have argued that it is important for engineers to form a more complex picture of the world. That is, engineers studying sustainability need knowledge of *naturalcultures* in addition to the social and ethical dimensions of technological issues. Besides, students need to knowledge about the epistemological and power-laden foundations of research and the situated nature of the issues. It is important that students gain insight into non-technologically oriented perspectives on climate change issues. Most importantly, it is essential to convey that sustainability is not so much an object of learning as an epistemological perspective and that the ability to critically reflect on technology is therefore critical.

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