2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34565

Mind the Gap: Exploring the Exploring the Perceived Gap Between Social and Technical Aspects of Engineering for Undergraduate Students

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Dr. Gordon D. Hoople is an assistant professor and one of the founding faculty members of integrated engineering at the University of San Diego. He is passionate about creating engaging experiences for his students. His work is primarily focused on two areas: engineering education and design. Professor Hoople's engineering education research examines the ways in which novel approaches can lead to better student outcomes. He is the principal investigator on the National Science Foundation Grant "Reimagining Energy: Exploring Inclusive Practices for Teaching Energy Concepts to Undergraduate Engineering Majors." He has also co-developed a unique interdisciplinary course, Drones for Good, where engineering students partner with peace studies students to design a quadcopter that will have a positive impact on society.

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Abstract

Within engineering education, there is a perceived distinct binary separating social and technical thoughts. Students often describe engineering work in terms of technical matters such as doing things faster, cheaper, or more efficiently, while disregarding the social contexts and social costs of these decisions. This study examines students describing their decisions to major in engineering, and how a department and classes designed specifically to tackle the sociotechnical divide in engineering influenced students' perception of engineering. In this study, we highlight how students emphasize the distinction between social and technical contexts in their thinking as they conceptualize what it means to be an engineer. The University of the Borderland (pseudonym) created a new energy class, with the goal of examining the global energy landscape and considering contemporary sociotechnical challenges related to energy. The course was developed to provide an "integrated" approach to energy concepts that crossed disciplinary boundaries. We collected data from interviews to explore how students described their decision to major in engineering and tensions with subsequent descriptions of what is engineering. Preliminary results indicate that the sociotechnical divide still exists in the engineering culture amongst these students. Although students talked about social aspects of engineering work, these are seen as lesser, rather than a fundamental part of, engineering problem solving. Students continued to make a distinction between "soft" skills and engineering skills, while simultaneously describing the "soft" skills as necessary to be a "good" engineer.

Introduction

In 2004, the National Academies of Engineering released the "The Engineer of 2020: Visions of Engineering in the New Century" report in an effort to highlight the role engineers would hold in our future society [1]. A topic of discussion was the impact of the engineer on societal changes, focusing mainly on the importance of incorporating social contexts into engineering. The National Academy of Engineering envisioned an era of engineering education that resulted in engineers that are "leaders, able to balance the gains afforded by new technologies with the vulnerabilities created by their byproducts without compromising the well-being of society and humanity" [1, p. 19]. However, as we move past 2020, it is important to question whether or not we have successfully developed the characteristics of the engineer of the new century.

Although the increasing changes in society mentioned in the report have likely surpassed expectations, engineering itself is not keeping up with societal changes due to the continued curricular focus on technological aspects. There are an increasing number of undergraduate engineering programs that have purposefully tried to integrate social or humanitarian aspects into the curriculum, such as Colorado School of Mines, University of San Diego, and Drexel University among others. Nonetheless, the number of programs that offer this type of curriculum is still low. While improvements to incorporating social aspects into engineering education have been made across universities, finding the interconnectedness between the social and technical is still an issue engineers struggle with. At present, this sociotechnical dualism [2] is consistently laced into engineering curriculum, passed from professor to student. The dominant discourse in engineering education continues to perpetuate the idea that there is a separation of the social and the technical, and that as objective professionals there is a clear demarcation between the two [3]. As engineers, we are rarely expected to analyze the social impact of our designs. We are taught to be emotionless, objective, and impartial [4]. When solving problems in class, the social dimension is rarely integrated into the process, reducing problem solving to measurements, calculations, and costs. An approach to integrate the social and technical in engineering, in favor of the development of a critically conscious sociotechnical engineer, is to alter the curriculum by incorporating social aspects at the forefront, rather than as an afterthought. In this paper, we write from our perspective as undergraduate engineering students and research assistants to describe how engineering experiences and perceptions of engineering form and change due to institutional and curricular changes currently happening at our university.

This paper seeks to describe how engineering students continue to demonstrate attitudes that place social and technical context hierarchically. That is, students place more importance on some of the technical aspects of engineering. We argue that, despite the efforts to create a learning environment that promotes a sociotechnical understanding of engineering, one class may not be enough to accomplish these goals given that engineering discourse and narrative continue to dominate how engineering is framed for students.

Positionality

Engineering programs around often compete to call their program the "best engineering program." However, more often than not, the value of the program is determined by the "rigor" of the technical side of engineering [5]. We believe that if "the best" engineering program does not include the social implications of engineering problem solving, it cannot shape the best version of future engineers.

As current engineering students, and lead authors of this paper, we acknowledge the divide that exists between the technical and the social aspect of engineering in the classroom. We have taken classes with professors who solely focused on the technical aspects of the major, as well as classes with faculty who truly try to bring social issues to the forefront of problem solving. Being students of the same major, concentration and gender, as well as being Latinx, we clearly have many similar biases and interpretations. As part of undergraduate careers, we have learnt to accept our ever changing definitions of what it means to be an engineer. In our own previous interviews as study participants in 2019 and 2020, we stated our own definitions of engineering:

> *In my opinion, I don't think engineering can really be accurately defined because I think it's changing all the time, and it's changed over time, and it can be applied in so many different ways that it's so broad and worldly. I don't even know how I can use words to describe it because it's in everything we do, I feel like, at this point - even if we don't know it - and in so many different contexts and seen in different ways [Regina].*

> *I don't think I could define it as a single thing, I think, in just my three years here my definition of what that means has changed so many times that it's still changing so I don't think I could define it as a single thing. I think that's part of the integrated aspect of it is just incorporating every piece of knowledge that you get, whether it's from an engineering class or a non-engineering class to your personal development and growth and hopefully makes me better as an engineer. Yeah, I don't think I could pinpoint a single definition [Mireya].*

We understand that it is hard to define what an engineer is, looking at interviews we have done in the past, it is evident that our own identities as engineers are continuously changing. In the current state of engineering culture and education, it seems as though we often forget who we are designing and working for. To become a better engineer, we believe it is important to integrate the social aspects of engineering into our approach to problem solving, which requires constant change.

As students, we too still struggle with defining engineering, as well as our responsibilities and roles as engineers. We however, agree with the literature that highlights the importance of bridging the divide between the social and technical dualism that exists throughout the formation of the engineering identity in school and is reinforced once engineers enter the workforce.

The Socio/Technical Dualism

The socio technical dualism that prevails within the identity of an engineering can be seen within the culture of engineering in various forms: from the distinction of gender within the classrooms to the technology centered vs. people centered engineering practices [2]. This distinct binary contributes to the disregard of social contexts in engineering, in favor of describing engineering work in terms of technical matters, allowing the continuation of the belief that an engineer's job is to focus on just technical aspects of the problem and actively exclude the social contexts of these [2]. These dualisms are so embedded in the practices and teachings of engineering that the separation of social and technical aspects engineers face every day seems natural. The reductionist nature of engineering problem solving is an asset praised in the classroom, rather than questioned.

Engineers both generate and perpetuate the separation of “hard” and “soft” skills, prioritizing the “hard” skills above all else. One of the attributes to this divide (which we will refer to as a mindset) is the persistence of seeing engineering as purely apolitical, due to the perceived objectivity of engineering work [3]. Once social aspects are considered in the engineering design process, there is a perception that engineering work would then become political [3, 6, 7]. Not only does this mindset contribute to the neglect of social contexts but it also perpetuates the idea that engineers are to bear no responsibility for their work [3].

The idea of engineering objectivity also contributes to how rigor is conceptualized [3, 5]. The logic sometimes used is that if engineering is an objective field, then rigor must be present to provide that objectivity [5]. The values deemed important in engineering education tend to be those that are considered to be the most rigorous, such as mathematics, physics, and programming. There is a widespread belief in education that in order to be a successful engineer, a student must be able to excel in the most rigorous of fields while at the same time ignoring the fact that engineering work does not happen in a vacuum.

An Integrated Approach

The solution implemented by The University of San Diego - of which we are students - to better integrate social aspects into the engineering curriculum was to offer an energy class in which these aspects were brought to the forefront of the problem solving process. The university’s engineering faculty were determined to make a change in what is taught and how energy concepts are taught to students, moving from the traditional thermodynamics or circuits courses in favor of an interdisciplinary understanding of energy topics. The class aimed to integrate liberal arts into the engineering curriculum by encouraging students to look at the contexts of the problems as an essential piece to its solution. The aim was to use scenarios that combine the aforementioned social contexts with technically demanding work to result in a model for socio technical thinking. In this case the PESTEL framework was utilized (political, economic, social, technical, environmental, and legal) [8, 9]. Using a PESTEL framework allows students to go beyond a technical interpretation and further develop their critical thinking skills. An important aspect of the class was to not diminish the importance of technical expertise, but emphasize that consideration is a necessary component in order to solve the complex problems faced in the field of engineering.

The initial implementation of the class was in the Spring semester of 2020. The class is a sophomore level course required for integrated engineering students moving forward. The Spring class consisted of 18 students, 17 being second year students, one being a third-year student. The class included6 women and 12 men taught primarily by a White male professor who has conducted research on socio technical dualisms that exist in engineering in the past. The course description stated in the syllabus:

> *Ever wonder what "energy" really is? In this course you will learn the engineering behind both energy production and consumption. Our discussion of energy production will be grounded in a California context and highlight the fundamental operating principles of solar, wind, and natural gas power plants. We will also examine the global energy landscape and consider contemporary sociotechnical challenges related to energy. When thinking about consumption we will focus primarily on the residential and commercial sectors. You will learn a systems approach for analyzing energy consumption within buildings that can be applied to anything from your own home to a large manufacturing plant. By the end of the semester you will be able to identify, formulate, and solve a range of engineering problems related to energy [10].*

Methodology

This is an exploratory study is part of a larger study that seeks to describe how culturally responsive pedagogies impact the teaching and learning of energy concepts [8, 9, 11]. This paper focuses on the conceptualizations and contractions students encounter as they try to describe engineering. Throughout the semester, data was collected through classroom observations, interviews and students' responses to prompts. As the semester drew to an end, an optional student interview was offered to the students to explore the degree of success of the integration of social and technical aspects of problem solving. As part of this paper, the data collections primarily focuses on the students' responses to the interview questions. A total of 11 interviews were conducted by the end of the semester, in which they were asked a variety of questions regarding the class material covered throughout the semester and their perceptions of engineering. It is important to mentioned that it was during this time that the university was asked to transition to emergency remote teaching (ERT), and the interviews were conducted over Zoom.

After the data was collected, the two four authors analyzed the data using a deductive approach [12] to qualitative research with the help of the principal investigators in this study. Initially, the coding was done following a list of a priori codes obtained from current literature [2, 6, 13]. These codes were given a definition and refined after a series of group discussions to ensure inter rater reliability. The codes were then synthesized to identify the ways in which the students framed engineering within the context of the social/technical dualism [2].

Findings

The data showed that students provided convoluted responses in regards to the social aspects of engineering. While in many cases, they mentioned both the social and the technical aspects relevant to engineering, students eventually focused more on technical aspects of problem solving such as the building of technologies and defining efficiency in terms of cost or even availability of resources. When the social contexts of the problems were brought forward, it was done so in a way that still placed communities as “needing help” rather than a valuable source of information.

In the interview, students were asked what they would need to build a hypothetical power plant. By looking at the order in which they prioritized the aspects of the plant, we found that while students acknowledged the presence of non-technical pieces of the problem solving process, they focused on the cost, efficiency, environmental impacts, and the types of energy over the social contexts of the plant itself. For example, one of the student’s answer prioritized technical aspects,

> *[Student] said some technical things like this is the flow rate of the nearby river and I said a hydroelectric dam which is, in hindsight, way too expensive for just powering a little home. So I think my question would have been more along-- well, the first one, what's your budget? Because I think he said you have as much money as you want, but the other one, just what do you think would look most attractive [in your town?] or near your home? Because a dam can destroy wildlife and eventually cause landslides, I think. I've been learning about this stuff in my natural disasters class. But I think having a windmill or something which is colored to look like a tree or something, could be a lot more attractive than this ugly dam that also messes up the water flow and stuff. So I probably asked the user-- I mean, I'd do all the calculations for him and say, "This is what it would cost you for solar, wind and hydroelectric and this is approximately how big they'd be and we'd probably want to put it in this part of your backyard," and see what the user chooses.*

In this excerpt, the student does seem to think broadly about this particular engineering project (i.e., the construction of a dam) but consistently focuses on monetary constraints, the environment, or the calculations that need to be made for the design. While it is clear that engineering practice does require these considerations, the social context continues to be sidelined.

Throughout the data, we found that the students' personal definitions of what their engineering identity is, is closely related to what they prioritize when it comes to problem solving. To students, being an engineer was synonymous with building things and solving equations with numerical based problems. They can pinpoint communities that they have an interest in being involved with, but the divide between the creation and application of problems is still seen as two different spheres. When asked to define engineering, these were some of the students’ responses:

> *So not necessarily making new solutions because that's what I thought it was when I came into college and then I realize that a lot of it is just not reinventing the wheel, seeing what's worked for other people, but just in general, making stuff more efficient and sometimes, there's not an issue and you just decide there is and you can improve it a little bit because if we didn't push ourselves then-- I don't know. That's kind of how I look at engineering.*
>
> *What comes to my mind first is the solving of problems, I guess. That's what I would say.*

You can really solve a lot of things with engineering, not just-- social problems you can-- I mean, I guess that stuff. I mean, obviously, you can think of bridges and transportation and infrastructure and stuff, but there's a lot of-- a lot of quality of life stuff can be applied. You could really say that applies to almost any aspect of life.

Another student perpetuated the idea of engineering being a more “rigorous” major that a student must be specifically qualified for,

I'm definitely not the smartest person so I don't know what qualifies me to become an engineer but for some reason, I just kind of had a feeling that I wanted to do it and I thought I'd be successful at it.

While many students acknowledged the importance of social aspects in engineering work, this importance is not necessarily embodied in their answers. The students often contradict themselves throughout their interviews. For example, mentioning they chose engineering due to affinity for math and science, only to later describe their least favorite part of the course to be the equations and calculations, such as the following student:

I guess the calculations because they're just not as fun to do like talking about the social and economic effects more than just figuring out how much work needs to go into a system.

Another student specifically mentioned their support of emphasizing the sociotechnical in engineering:

I've always been super interested in having hands-on learning and I've always really liked math and I just really like the idea of engineering being used broadly. I know Dr. Hoople uses the term socio-technical. So that's something I believe heavily in and just seeing the power of what engineering can do for good for the society as well as just kind of the large breadth.

Interestingly, this student neglected to mention social aspects in later questions of the interview, which was most notably in the test problem involving the hypothetical power plant.

Discussion

From our investigation, we found that students were able to acknowledge the social impact associated with engineering. However, the social aspects of problem solving are still seen as “part of the puzzle” rather than a fundamental part of it. In the interviews, students would emphasize the importance of social impact, though their thoughts later in the interviews and problem solutions clearly did not embody those ideas.

As researchers, we acknowledge the gravity social aspects hold on engineering work, and the importance of prioritizing those aspects in engineering curriculum. However, as current students, we fully understand the difficulty in maintaining this mindset throughout our undergraduate studies. As expected, having only one or two courses that challenge the dominant discourse is not enough. In the majority of our engineering curricula, we aren’t expected to consider non-technical components. We calculate a statics problem without knowing a truly useful application, or who is impacted if our calculation is wrong. We plug numbers into calculators without realizing their meanings. Even outside the classroom, you won't hear anyone complain quite like an engineering student on their way to a humanities class to fill a graduation core requirement. With this as the standard in most engineering education, we can't expect students to stop prioritizing the technical. It could also be said we as individuals are contributing to the dualism by referring to it as social *and* technical aspects of engineering instead of sociotechnical.

It is our belief that this course was successful in prioritizing social aspects in engineering education, and gave the opportunity for students to incorporate those aspects into engineering solutions. There's more work to be done to mitigate the sociotechnical divide within engineering culture. While one course may open the door, students need further encouragement to be more socially minded engineers. It is built into our engineering culture to undermine nontechnical curriculum, and the only way to work against that is to emphasize nontechnical aspects of engineering more frequently. There cannot be solely one class that emphasizes sociotechnical problem analysis, it should be all engineering classes, at least in some capacity. The classes that are more outrightly focused on closing the gap should be required as early as possible in a student's college career to encourage a sociotechnical mindset from the start which can subsist through the rest of their engineering coursework.

While the effort to integrate social aspects into the classroom was well planned and intended, there could have been issues in the way those aspects were addressed by the professors of the course. In future studies, we'd encourage investigators to analyze the impact of educators on engineering identity. Professors may be acting as gatekeepers of engineering discourse, due to power dynamics in the classroom. For example, in the energy class, when the professor talked about an artifact that was located outside the building to harness solar energy, he mentioned "I am not worried about this falling over someone" followed by a whole explanation of manufacturability costs, the students were quick to accept it as part of the engineering discourse and not question it. There were no follow up questions related to why it was a not a concern but the cost of the artifact became more important than a human life, for example. Perhaps this is due to a belief that to "get the grades" students must emulate what professors say/do, while in student-filled group discussions students may be more inclined to ideate further from the educator's words.

Conclusion

In recent years, the social aspects of engineering have been brought to the forefront of engineering education. While schools throughout the country have attempted to incorporate them into their curriculum, it is evident that there is still a lot of work to be done.

Although the energy class at The University of the Borderland had flaws, it was a good attempt at bridging the divide between the social and technical aspects of engineering. The data identifies the emergence of sociotechnical thought in the students' conceptualization of engineering, but also shows that the divide is still present in the minds of future engineers. While students made attempts to integrate the social pieces of problems, they ultimately guided their answers to technicalities such as cost, efficiency, etc. As such, it is important for institutions to further research the best ways to highlight the importance of social implications than engineering inherently has.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. 1836504. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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