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Work in Progress: How do Students Describe Engineering and Engineers After Taking a Sociotechnical Energy Course?

Marissa H. Forbes (Research Associate)

Susan M Lord (Professor & Chair)

Susan Lord is Professor and Chair of Integrated Engineering at the University of San Diego. She received a BS from Cornell University in Materials Science and Electrical Engineering (EE) and MS and PhD in EE from Stanford University. Her research focuses on the study and promotion of diversity in engineering including student pathways and inclusive teaching. She has won best paper awards from the Journal of Engineering Education and IEEE Transactions on Education. Dr. Lord is a Fellow of the IEEE and ASEE and received the 2018 IEEE Undergraduate Teaching Award. She is a coauthor of The Borderlands of Education: Latinas in Engineering. She is a co-Director of the National Effective Teaching Institute (NETI).

Gordon D Hoople (Assistant Professor)

Diana Chen (Assistant Professor of Engineering)

Joel Alejandro Mejia (Dr.)

Dr. Joel Alejandro (Alex) Mejia is an Associate Professor with joint appointment in the Department of Biomedical and Chemical Engineering and the Department of Bicultural-Bilingual Studies at The University of Texas at San Antonio. His current work seeks to analyze and describe the assets, tensions, contradictions, and cultural collisions many Latino/a/x students experience in engineering through testimonios. He is particularly interested in approaches that contribute to a more expansive understanding of engineering in sociocultural contexts, the impact of critical consciousness in engineering practice, and the development and implementation of culturally responsive pedagogies in engineering education. He received the NSF CAREER Award for his work on conocimiento in engineering spaces.

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Abstract

The University of San Diego (USD) integrated engineering department offered a new sociotechnical energy course for second-year students in 2020; the course ran for a second time in 2021. The *Integrated Approach to Energy* course differs from traditional engineering energy courses by introducing students to modern energy concepts through a sociotechnical paradigm, informed by culturally sustaining pedagogies (CSPs), and emphasizing examples and learning experiences that deviate from the traditional masculine, White, Western discourse. For this case study, we interviewed students who had taken the course to explore whether and how their conceptions of engineering and engineers included sociotechnical elements. In this work-in-progress, we share some preliminary findings that emerged from the four interview themes: 1) Why Engineering? (student motivations for studying engineering), 2) What is Engineering? 3) Who are Engineers?, and 4) What Engineers Do. The students had burgeoning conceptions of engineering/engineers with traces of sociotechnical perspectives. These preliminary findings reiterate that students will not simply 'get' sociotechnical engineering after a single course experience. If we want students to truly integrate these concepts into their own conceptions about engineers/engineering, we must do the same as an engineering education collective and integrate them fully into the entirety of their engineering education experiences.

Introduction

The University of San Diego (USD) integrated engineering department offered a new sociotechnical energy course for second-year students in 2020; the course ran for a second time in 2021. We shared about this *Integrated Approach to Energy* course, including the pedagogical approach and student outcomes in previous publications [1-5]. The course objectives are as follows:

1. Identify, formulate, and solve engineering problems related to a range of energy concepts (e.g., efficiency, heat, work, and appropriate units).
2. Categorize types of energy using appropriate engineering terminology (e.g., mechanical, internal, solar, electrical, chemical, and nuclear) and perform calculations related to energy transformations.
3. Explain the fundamental operating principles of the most common types of electricity generation in California (e.g., natural gas, solar, hydroelectric, nuclear, and wind).
4. Describe contemporary challenges caused by or related to energy resources, such as economic impacts, sociopolitical tensions, and environmental impacts.
5. Explain how various methods of both passive (e.g., evaporative cooling) and active (e.g., electric, fuel-powered, heat pumps) heating and cooling in buildings work.
6. Analyze how the natural environment (e.g., tree shade, sun angles) and built environment (e.g., windows, insulation) impact heat transfer into and out of buildings, with consideration for cultural and climatic contexts.
7. Apply concepts from class to inform decisions about energy consumption or conservation in your everyday life.

The course differs from traditional engineering energy courses by introducing students to modern energy concepts through a sociotechnical paradigm [6-18]. Instead of a myopic focus on the technical elements of engineering (i.e., the dominant historical discourse), the sociotechnical paradigm equally values the social elements. The supposition is that one can't design well nor ethically without doing so within social contexts. For this course, one vehicle we used for this approach was the PESTLE framework, which supported students in conducting energy analyses within Political, Economic, Sociological, Technological, Legal and Environmental contexts [33]. The course is also informed by culturally sustaining pedagogies (CSPs) [18-21], which acknowledge the students' home and community cultural and linguistic practices as assets, and actively welcome them into the classroom. Specifically, for this course, we emphasized examples and learning experiences that deviate from the traditional masculine, White, Western discourse [22-32], and created an environment where the ways of being, knowing, and doing of communities of color were acknowledged and made part of the curriculum. For this case study, we interviewed students who had taken the course to explore whether and how their conceptions of engineering and engineers included sociotechnical elements. In this work-in-progress, we share some preliminary findings that emerged from the four interview themes. The students had burgeoning conceptions of engineering/engineers with traces of sociotechnical perspectives.

Context

The campus and department contexts for this course are highly supportive of this effort to reimagine engineering education. USD is an independent, private Catholic university committed to the formation of values, community involvement, and preparing leaders dedicated to ethical conduct and compassionate service [34]. The integrated engineering (IntE) department works to have all student engineering course experiences aligned with the sociotechnical paradigm, to educate engineers who are prepared to ethically design for a sustainable future. IntE students complete the university liberal arts core, a sequence of sociotechnical engineering courses, and a concentration of their choosing [35]. The majority of students who participated in this study were pursuing the sustainability concentration, however students can also choose a concentration in biomedical engineering, embedded software, law, or an individual plan of study.

Methods

In Spring 2021, we interviewed five students (out of the nine enrolled in the class) at the end of the course using a semi-structured protocol that probed their motivation(s) for choosing an engineering major, as well as their perceptions about engineering and engineers. We asked the students:

- Q1: Why did you choose to major in engineering?
- Q2: How do you define engineering?
- Q3: Please describe an engineer.
- Q4: What kind of problems do you think engineers might solve?
- Q5: What differentiates engineers versus non-engineers?

Our purpose was to explore whether students articulated sociotechnical perspectives in their responses after their experience in this sociotechnical energy course. We analyzed the interview transcripts using a hybrid deductive and inductive thematic analysis approach [36]. Our research questions and the specific nature of our interview questions informed our preliminary proposed themes. We then went through an iterative process of reading the interview transcripts to map them to the themes and adjust the themes as informed by the data. We finalized four themes, which map to the interview questions as follows: 1) Why Engineering? (i.e. personal motivations for pursuing an engineering degree (Q1), 2) What is Engineering? (Q2, Q4), 3) Who are Engineers? (Q3, Q5), and 4) What Engineers Do (Q4, Q5). As this work is in progress, here we share our salient, preliminary findings about each theme.

Results and Discussion

Why Engineering?

In discussing their motivations for studying engineering, the students highlighted affinities for the technical and quantitative aspects of engineering, including math and science, and the analytical skillsets. For example, one student referenced his childhood love of Legos, a robotics club, and playing with breadboards as indicative of his predisposition to enjoy engineering. In another student's words, "I didn't really know what I wanted to do, but I've always been good at math and science. I knew that I did not specifically want to do science. [Engineering] seemed like something that I could combine my skills into." Similarly, a third student said, "I'm very into math and science… I really wanted to become more analytical and a critical thinker because I like to challenge myself."

What is Engineering?

The students described engineering as a results- and solutions-oriented practice, with an emphasis on problem-solving. They highlighted the notions of creating, innovating, and building. For example, in one student's words:

> *Engineering, it's not just building, it's like an innovative, hands-on approach to creating, building things…a very analytical, hands-on approach to how we get literally all the products that we have now. Yes, like creating things that we just use in the world.*

This description brushes up against the sociotechnical paradigm by identifying engineering as 'not just building' without really going into the paradigm. We heard numerous similar 'brushes' from the other students. In some instances, this was conveyed by expansive, open, and inclusive—yet vague—statements about engineering, such as another student's sentiment that, "there's not a really set barrier to what [engineering] could be. It can be like art, it can be everything." The generality and nebulous nature to many articulations reflect the early stage that these students are in on their engineering education journey [37] (all but one had just finished their second year). We are hopeful that these expansive statements are early indicators that the students are developing engineering conceptualizations that can't be boxed, and that they are growing into multifaceted notions of engineering that are synchronous with the sociotechnical paradigm. In any case, the prominent sense gained from reflecting on the student descriptions about engineering was that they are peeking into the windows of this new paradigm but have not yet opened the door and gone inside.

Who are Engineers?

As was the case in their descriptions of engineering, students skewed towards action- and solutions-oriented descriptors when talking about engineers. For example, one student emphasized the 'doing' in engineering by contrasting engineers and scientists:

> *I think the difference between [an] engineer and, for example, a scientist is, the scientist has the scientific method and they have all these hypotheses. Engineers are more along the lines of just do, then fix, and then try again…I think the try and do and then restart, and try and do again is the main difference and thought process between this and most other professions.*

Like the openness conveyed in their descriptions of engineering, the students were similarly fluid and open in their concepts about engineers, and often were grasping for the wording that would convey their ideas. In the words of one student:

> *I see engineers as very fluid. I don't think there's a set mold to them necessarily. I feel like other people perceive them just like quiet people who are narrow-minded right into their work, but I don't know…My experience has been super different. I think there isn't really a set mold for an engineer.*

Often, when defining a new and complex concept, its easiest to start with what that thing is not and then move towards describing what it is, and we found the students often describing who engineers are not. We must also remember that, though these students have heard their instructors describe engineering/engineers to them many times, they likely have had few or no situations where someone has asked them to describe it themselves.

What Engineers Do

The students emphasized "people" when reflecting on how engineers spend their time, more so in describing working with people, rather than benefitting them. For example, one student stated:

> *I think that they probably talk with so many different types of people, not only engineers, but maybe clients, maybe supervisors. They talk to so many different types of people because they have so many different types of problems to solve.*

The last part of the aforementioned quote and its reference to engineers solving problems was a sentiment echoed numerous times across the student responses. The students also thought out-loud about the types of problems that engineers might solve, which often was expressed as broad and emerging conceptualizations, as depicted by the following two quotes:

> *I think they could solve any kind of problem. I don't think it would necessarily have to just be limited to technology or with what people would, I guess, stereotypically think engineers would do.*

> *It can be specific technical things, but also like…because I took the class last semester [that] is more focused on humans because we work with the blind community center,*

and innovations that can help people and think about the communities that you're trying to help, and what they specifically need and not just what you think they need.

Engineering is people- and solution-oriented, and the students have integrated these concepts into their understanding of what engineers do. Their responses hint at engineering as something more, although what that something might be is still being defined.

An Integrated Approach to Sociotechnical Engineering

These preliminary findings convey a theme that we are reminded of again and again from our studies, that students will not simply 'get' sociotechnical engineering after a single course experience [4][11]. We cannot reimagine engineering education by infusing a traditional degree program or course of study with isolated encounters with a different paradigm. If we want students to truly integrate these concepts into their own conceptions about engineers/engineering, we must do the same as an engineering education collective and integrate them fully into entirety of their engineering education experiences. Otherwise, we propagate the notion that some engineers/engineering do sociotechnical engineering, or just do it sometimes, in certain contexts; but, others can choose to just do 'regular' technical engineering and leave out this 'soft' stuff.

Next Steps

The integrated engineering department faculty continues to study, learn from, and iterate our already-established sociotechnical curriculum, as well as expand those offerings. For example, we plan to examine whether the student outcomes from this cohort and future cohorts reflect more integration of the sociotechnical concepts over time as we iterate the design of this energy course. Additionally, in Fall 2021 we designed a new sociotechnical Photovoltaic Solar Energy course that will be offered to third- and fourth-year students in Spring 2022. Informed by CSPs, the course is designed to be relevant to the students' lived experiences, and the learning about technical elements of solar energy will be coupled with a focus on solar energy projects on campus.

In designing the course, we studied the university's Energy Master Plan, learned about the current state of solar energy on campus, and identified four potential new solar projects. The 14 students in the class will be divided up into four teams, with each team conducting a feasibility assessment for their solar project over the course of the class. Students will start by exploring the solar we already have on campus. Once familiarized with the current system, we will guide the students in completing their assessments of the new projects through four, two-week phases, with each phase focusing on a different sociotechnical analysis for their project: 1) social, 2) technical, 3) economic, and 4) environmental. The final phase, 'integration,' will support the students in integrating their analyses from each phase and making final, all-class recommendations to USD about how to proceed with solar energy investments on campus. We plan to share our findings from this course in 2023.

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