Recentering the User: How an Inclusive Design Class Pushes Students to See Beyond Their Own Experiences

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Abstract

The purpose of this ECSJ-DEED joint technical session practice paper is to disseminate the successes and challenges of implementing an inclusive design mechanical engineering elective. Grounded in a human centered design framework, the inclusive engineering design course focused on (1) the value of a human-centered design approach, (2) the intersection of social justice and design thinking, and (3) the implications of design choices on historically marginalized groups. Course artifacts, student reflections, and instructional team reflections are used to understand the growth in mindset of the students and instructor through this course. Additionally, these resources are used to present key learnings for future implementation.

This project focused on examining systems. Groups historically excluded from engineering, including people of color, disabled, LGBTQ+, and women, were recentered through the human centered design process. Students evaluated engineering systems for exclusion and ideated on the source of these design flaws. In doing so, they built a framework for an inclusive design process and implemented guardrails to mitigate the risk of future exclusion. Students reported in self-reflections that the methodologies pushed them to decenter their own experiences in the course design project, opening themselves up to problem definitions and innovative solutions they previously lacked the perspective to find.

The pedagogical choices in this course development were grounded in anti-deficit teaching practices. The paper describes the course structure, assessments, and key activities the students experienced. The instructional team attempted to create an environment to develop cultural competencies in students. This was done by bringing discussions of social justice, equity, and inclusion into an engineering course. Student reflections indicated this course content to be unlike others in their curriculum. Instructor reflections observed a growth in students' language around diversity, equity, and inclusion and their willingness to engage in social justice work. The authors believe this to be a critical gain in student cultural awareness that can translate beyond the course.

1 Introduction

Engineering often promises neutrality and "objectivity" within the design process [1], [2]. The promotion of this "objectivity" within engineering educational environments often breeds feelings of isolation, and a lack of belonging and identity, all associated with the attrition of women and students of color along the STEM pathway [3], [4], [5]. There is an opportunity in engineering education to approach design through a social justice lens to remove the mask of neutrality. There are a wealth of examples of exclusionary engineering environments and product design choices that perpetuate systemic issues, such as pulse oximeters [6], automobiles [7], and machine vision [8]. This practice paper describes the development and teaching of an inclusive design course in mechanical engineering. The course builds upon a framework of human centered design to push students to center the experience of users and stakeholders, while equipping them with the skills to identify exclusionary practices in engineering and combat them.

Many resources for inclusive teaching practices broadly focus on course design and faculty-student interactions. For example, the structure of the syllabus can ensure that all students are supported in their learning; and, including a statement about diversity and inclusion within the syllabus helps set a foundation for the classroom [9]. Resources on best practices for inclusive pedagogy in higher education have been compiled [10]. However, in the engineering environment the promotion of "objectivity" has been used to dismiss the relevance of inclusion discussions in the classroom [11].

To approach inclusion within an engineering design class, human centered design was chosen as it focuses on the lived experiences of users and stakeholders, including those from historically excluded groups. Human centered design focuses on an iterative process for centering the user and stakeholder in a design. The steps are generally as follows: (1) empathize, (2) frame, (3) ideate, (4) prototype, and (5) feedback [12]. In the first step, designers are expected to empathize with users and stakeholders through first-hand conversations and observations. The goal of this step is to identify pain points and design opportunities. In the frame step, designers identify a problem statement, often formulated as "how might we." Subsequently, designers ideate solutions, create low-level prototypes, and get user and stakeholder feedback. The process is non-linear and iterative. It is intended to create divergent and convergent solutions. Human centered design has been used as a means to teach inclusive design with respect to disability in human factors engineering disciplines [13]. Dong describes challenges for integrating inclusive design into curriculum, namely class size limitations and user integration into course materials [14]. In this practice paper, human centered design is the design framework chosen as it allows for a user-first approach to engineering design, often missed in undergraduate curriculum, while providing a scaffolding for connecting the implications of engineering to social justice.

2 Course Design

2.1 Instructor Team Positionality

The instructor team was comprised of two individuals: a faculty member and an instructional designer. The faculty member is an assistant professor of mechanical engineering. She primarily teaches mechanics courses and has research experience in the realm of additive manufacturing and STEM equity. She identifies as a white woman. The staff member is an instructional designer in the college of engineering. They have a background in education, primarily at the secondary level. They identify as a white, non-binary person.

2.2 Course Layout

The course of interest was a 15-week mechanical engineering elective cross-listed as a senior-level and graduate-level course. The class met for two 75-minute sessions per week. There were 26 students enrolled in the course, 23 of which enrolled in the senior-level section. The results herein are focused on the undergraduate students.

The course was divided into one-week topics, detailed in Table 1. Weeks 7-8 and 14-15 were reserved for project worktime and presentations. Week 13 was a university break. Students were required to review prep materials, including readings, videos, and podcasts, before the first lecture in a week. A five-question comprehension quiz was leveraged to improve engagement with the prep materials. The in-class sessions were comprised of discussions, lectures, activities, and worktime. Course assessments included homework, quizzes, three projects, and engagement.

The learning outcomes for the graduate and undergraduate students and the corresponding course activities were detailed in Table 2.

Table 1: Course module topics for a biweekly, senior elective.

Week Number	Module Topic
1	Human Centered Design
2,3	Inclusive Design (Universal Design)
4	Sustainability
5	Adaptive Technologies
6	User Experience Design
9	Algorithmic Bias
10	Medical Devices
11	Infrastructure
12	Improving Design

Human centered design was the framework for which subsequent course topics were presented. The students were often pushed to understand existing engineering designs through the lens of a human-centered approach. For example, during week 11, the students partnered with transportation engineering students to observe a pedestrian and vehicle heavy intersection adjacent to the university. Each group was assigned a user (e.g., pedestrian, bicyclist, bus driver, disabled pedestrian, car driver) to observe and conduct an empathy map. Subsequently, the students proposed redesigning the intersection, advocating for their user in a town hall style debate.

The instructional team chose to anchor the course in human centered design to reinforce the relationship between understanding the real needs of a user-group and creating an effective solution to a real problem. Additionally, this framework provided a landscape to explore the experiences of individuals commonly left out of the engineering design process and equip the students with the tools to mitigate that risk moving forward.

Table 2: Learning outcomes for the undergraduate (UG) and graduate (G) students and the course activity for which the outcomes are mapped.

Learning Outcomes	Graduate (G) Undergraduate (UG)	Course Activities Evaluated
Define diversity, equity, and inclusion with respect to engineering design.	G, UG	Quiz, Homework, Project 1 Reflection
Articulate the principles of human centered design.	G, UG	Homework, Projects 1 and 2
Evaluate designs for engineering inclusivity.	G, UG	In-Class Activities, Homework
Implement an engineering design leveraging the inclusive design frameworks.	G, UG	Projects 1 and 2
Communicate orally and written about engineering design and inclusion.	G, UG	Homework, Projects 1-3, Project Reflections, In-Class Discussions
Design a working manual for inclusive design in an engineering subdiscipline.	G	Homework, Project 3
Evaluate engineering designs through the use of peer-reviewed journal articles.	G	Projects 1-3

2.3 Course Activities

Each module described in Table 1 was structured with 30 minutes of pre-lecture materials and two 75-minute class sessions. Typically, the first class of a week period focused on content and the second on an activity. The content sessions included approximately 30-minute lectures with discussion breaks interspersed presented by the instructor or an interdisciplinary guest speaker. The balance of the session was used for small group activities and large group discussions that relate to the module topic. The activity session was reserved for longer format interactive activities, including design workshops and product evaluations.

A representative module on adaptive technologies is presented herein. Prior to class, students were required to read articles on discussing disability [15] and the intersection of occupational therapy and 3D printing [16], watch a video on adaptive accessories for Microsoft products [17], and listen to a podcast on how design thinking was used for the development of Braille [18]. The first-class session of the week was co-taught by the instructor and a guest lecturer from the Occupational Therapy (OT) department at the institution of interest. Students were immersed in the OT learning environment which included simulated health and home settings. The OT faculty member taught about the use of individualized and general adaptive technologies for her patients, including the role of an engineer in the design and treatment process. Subsequently, the students were provided with assistive devices, such as swivel utensils spoons and long-handle toilet aids, that currently fail to meet the patients' needs, see Figure 1. Students were tasked with interviewing the occupational therapists to better understand the need and providing design solutions to improve the product. Students presented their designs at the end of the first session.

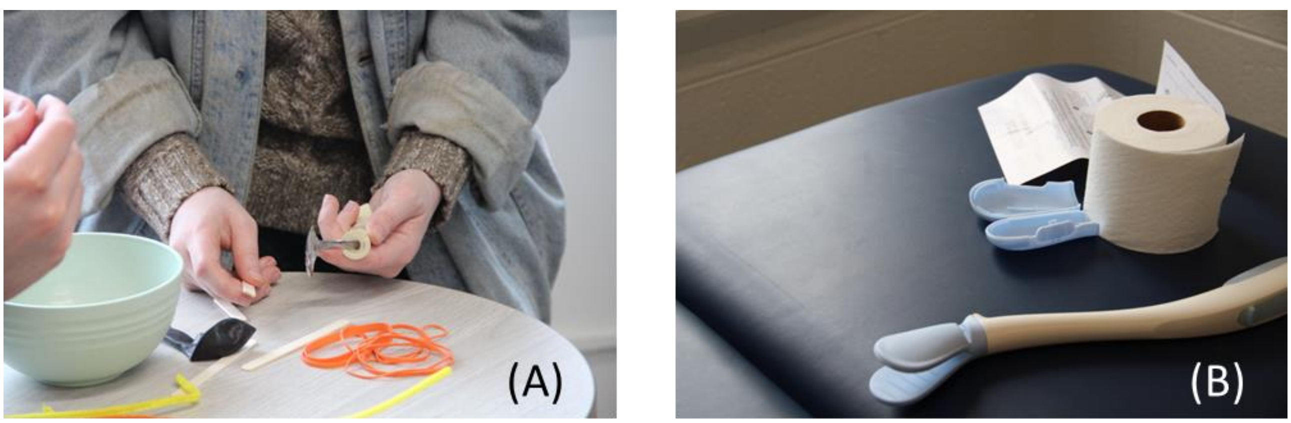

Figure 1: Example products redesigned for occupational therapy patients with reduced dexterity and mobility: a swivel spoon (A) intended to passively stabilize a tremor hand during eating and a long-handled toilet aid (B) intended to grasp and release toilet paper with a long-arm during bathroom usage.

The second session began with a 20-minute debrief on the OT activity, including topics of household product exclusion and engineering and health care collaboration. Subsequently, the students were introduced to the University of Cambridge Exclusion Calculator [19], [20]. The use of an exclusion calculator to evaluate design choices and provide more inclusive solutions was discussed in class. Students evaluated their own designs from the prior course session and a common household appliance, a KitchenAid Stand Mixer, for inclusion.

2.4 Assessments

2.4.1 Homework

The formative assessment for the course was a weekly evolving inclusive design manual. The goal of the document was to create a standalone reference for students entering the workforce as early career engineers. Each week, the students added an additional page to their manual based upon the module for the prior week. Students were encouraged to include design frameworks, examples of positive and negative designs, and external resources. Every other week the students received feedback from a peer. On alternate weeks, the students received feedback from the instructor. Students were expected to iterate on prior week's submissions based upon the feedback received. An excerpt from a representative handbook is provided in Figure 2.

2.4.2 Design Projects

Students completed a semester long project in groups of two. The project was broken into two summative evaluations focused on the same user group and problem. In Project 1, the students were required to identify a user group and understand how it is currently served by the engineering design process. Students were expected to execute steps one and two of the human centered design process, empathize and frame, to understand the needs of their users and craft a problem statement. To facilitate the empathize steps, students were exposed to empathy maps, interview methodologies, and card sorting. They were provided with the Field Guide for Human Centered Design to supplement the methodologies [12]. Students were restricted from presenting design solutions or any brainstorming during Project 1 presentations to ensure ample time was dedicated to understanding their user and stakeholder experiences. The impact of this is discussed in Section 3.

In Project 2, students worked to design a solution to the problem defined in Project 1 with their partner, focusing on steps 3-5 of the design process: ideate, prototype, and feedback. They were required to solicit two rounds of feedback from their target user group and potential stakeholders. Two class periods were dedicated to Project 2 workdays. The first class period an ideation session with other students was facilitated by the instructor. Later in the semester, a prototype feedback session was conducted. Students were encouraged to revisit their problem statement and approach throughout the design process if they were not meeting their core user need. Students presented their prototypes and user feedback in the last two weeks of the class.

2.4.3 Inclusive Topic Projects

The instructors acknowledge how their lived experiences influenced the design of the course and the topics included. To include student voices in the topics discussed, students were tasked to prepare a class period, including prep materials and in class activities, on a topic of their choosing relating to inclusive design but not presented in the semester as their third project. Submitted topics included: inclusion in the beauty industry, accessibility in sports, size inclusivity in the built environment, and distracted driving. Select topics were presented on the last day of the course by the instructor and will be integrated in future offerings.

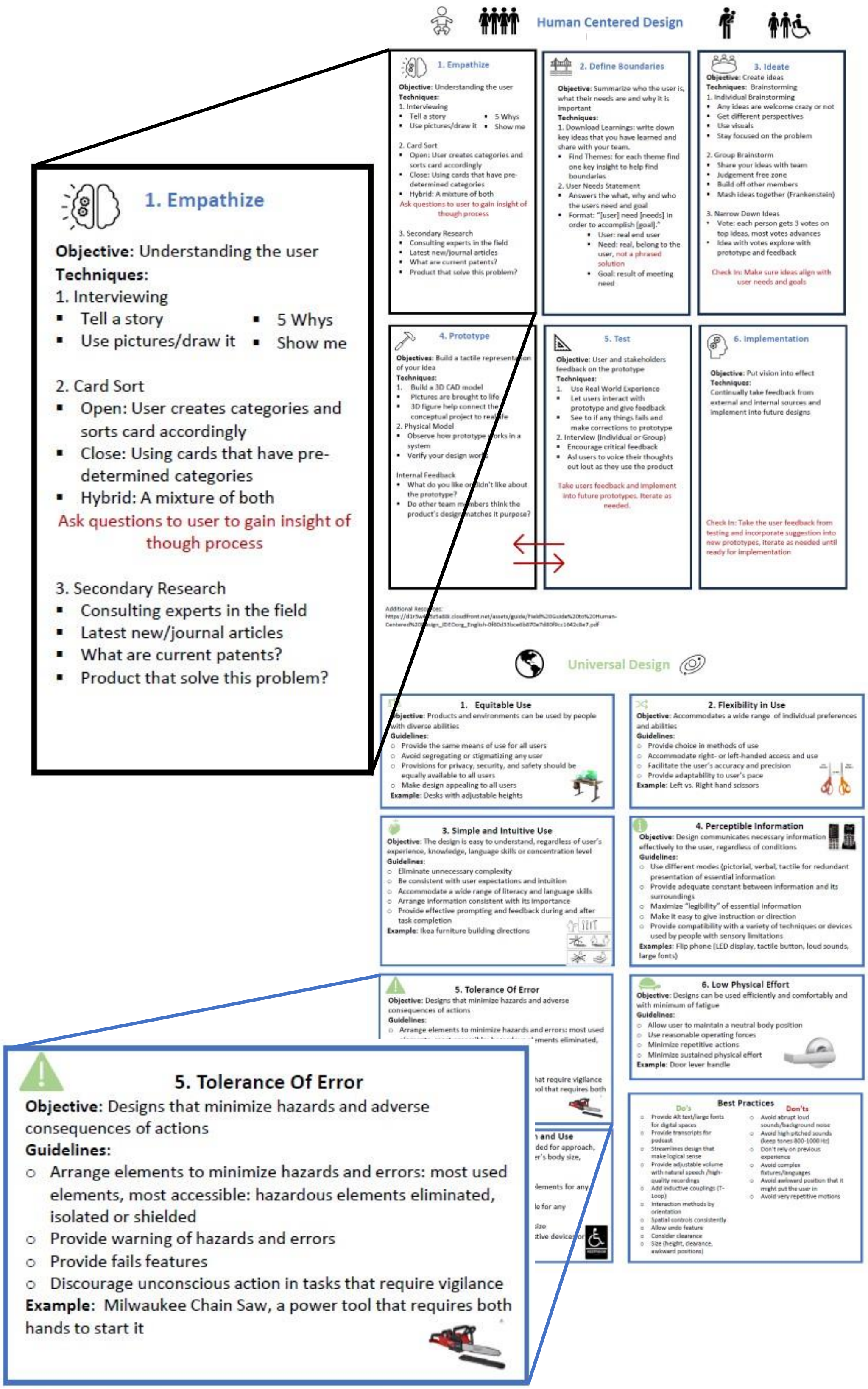

Figure 2: Representative sample of two pages from a student's design handbook on human centered design (top) and universal design (bottom). Insets of select parts are provided for visual clarity.

3 Impact

3.1 Student Growth

Students reported limited exposure to the empathy and user experience steps of the human centered design process prior to the course. In a Project 1 individual reflection, a student reported:

> *For project 1, going through the interview process was incredibly eye-opening to the perspectives and opinions I would have likely missed without it. It was incredible how quickly my preconceived notions of the problems with the study were reinforced and disproven in certain interviews.*

This sentiment of surprise that a student's original assumptions and understanding of a given problem were faulty was commonplace in the project reflections and course discussions. It was demonstrated that these impacts were beyond the scope of the course described herein as a student reported in an individual Project 2 reflection the following:

> *As this project and the semester has gone on, I have been working part-time as a die cast component engineer at [company]. I was working on creating a hydraulic lift cart that would be used to assist in removing large stamping dies in areas that can't be serviced by a forklift. This class and the design process we were walking through at the time prompted me to go and talk through ideas with the machine operators that would be interacting with it. Empathizing with them allowed me to refocus on the true problem at hand and it brought up a lot of key pain points that I wasn't aware of. … This was an extremely valuable moment for me as an engineer and the inclusive design frameworks are now a very easy model for me to follow as I continue to work on projects in the future.*

The instructional team observed most students evolved into a greater attention to and appreciation of user and stakeholder voices. Many students additionally took care to consider the diversity of their user group. Students reported their prior design course experiences lacked the user-centric emphasis provided in this class and that this content was a missing piece for design effectiveness.

In one class activity early in the semester, students were tasked with navigating well known campus landmarks while wearing visual impairment glasses. The students commented they had not realized the effects of building shadows on navigation and the importance of audible indicators at crosswalks. A student observed the fire alarm was at the same height and location expected for a light switch, causing a potentially hazardous situation. Often throughout the semester, students referenced this activity and its impact on their perception of design choices and processes. Navigating campus in ways that are different than a student's typical experience provided an immersive experience that anchored the need for broader user perspectives. In the final class discussions, students reported having a greater appreciation for the impact of engineering design choices on populations and noticing exclusionary designs in many aspects of their day-to-day life.

3.2 Instructional Team Reflection

As described in Section 2.1, the instructional team was made up of a mechanical engineering faculty member and an instructional designer trained in secondary education. The makeup of this team is of note as the faculty member was encouraged to use pedagogical strategies in this course beyond the active, problem-based approach she has previously used. This often-created friction within the instructional team as discussion heavy and fluid class session planning was outside of the comfort zone of the faculty member. In hindsight, this growth of the faculty member was critical for an effective execution of the course as it is presented herein. The instructional team hypothesizes that a traditional lecture-style or problem-based learning approach would not be as impactful for this course material. Furthermore, the dual background of the instructional team created more robust activities. The team served as a sounding board and a bias check when considering topics to include and ways to present course material. This type of course is compatible with team teaching to improve the topics' overall reach.

The class size of 26 students was at times too large to achieve full group discussion. The negative impact of this was reduced because the faculty member had prior course experience with 25 of the students, therefore building student rapport was significantly easier. The need for a trusting foundation of the faculty-student relationship should not be understated. The instructional team recommends significant effort be placed on building the community amongst students early in the semester.

3.3 Limitations

Future implementations of this course as presented herein may be limited to senior level electives. The topics and projects require a level of maturity and design acumen that may be limited prior to upper-level student standing. Additionally, the nature of the course is less technical, making it more suited for an elective. Although discussed herein as a mechanical engineering course, the topics and examples could be adapted to other engineering disciplines.

The built environment for this course was a traditional lecture-style classroom with individual desks. This limited group activities and free movement within the classroom. Future instructors are encouraged to consider the built environment and its limitations for collaboration. Notably, this environment provided a frequent example of exclusion in design as the desks lacked size inclusivity, the room was not accessible, the desks were right- or left-handed, and the temperature was often uncomfortable. Although not recommended, this did provide for first-hand experience for the students.

The report herein is intended to be a practice paper. There was significant care taken for the instructional design described. However, there was no intentional research data collection, quantitative or qualitative. Although there is an anecdotal impact of the course presented, the generalization beyond the course described herein may be limited.

4 Relevance to Social Justice and Design

The instructional team chose to design this course to fill a need within the engineering curriculum that demonstrated the impact of design choices and systems on individuals and groups often left out of the engineering process. The course objectives were twofold: (1) provide students with the tools to design for a wider audience, thereby creating better designers in general, and (2) expose students to the existing oppressive systems within the engineering space and the importance of mitigating designer biases. Objective 1 was achieved by anchoring the course in the human centered design and universal design frameworks. Objective 2 was achieved through diverse perspectives in the guest speaker and prep materials chosen, frequent immersive activities on exclusion in design, and many opportunities for student-led course discussions.

The topics presented in this course, as detailed in Table 1, were centered in mechanical engineering design due to the nature of the elective. However, there was an intentional emphasis to discuss relevant social issues in the context of engineering. Module 9 was focused on algorithmic bias. The responsibility to ethically and equitably designing human-machine interactions [21], facial recognition software [8], [22], and evaluation software [23] were explored. Many majority students' expressions during the class sessions were those of awe, as they had limited prior exposure to these disparities. A large group discussion on mitigation techniques, such as acknowledging unconscious bias, providing algorithmic audits, and incorporating transparency into designs, was presented. In future modules and project discussions, students were found referencing back to role of algorithmic and designer bias as opportunities for improved inclusion. Note that, before Module 9, the students had not openly connected the relationship between exclusive design choices and systemic oppression.

Module 10 focused on medical device design and health disparities. The design of pulse oximeters, known to overestimate the oxygenation level of individuals with darker skin [6], was heavily discussed. Additionally, the risk calculators for breast cancer [23] and heart failure [24], which have known race-corrections that lead to reduced perception of risk for people of color, were explored. By Module 10, students were quick to identify that engineering design teams should reflect the community they are designing for, and if they cannot, should be interfacing with that community in a meaningful way in the design process. This approach of community-based engineering democratizes problem-solving in such a way that can create less harmful and more effective solutions.

This course provided an opportunity for engineering faculty and students to move beyond the traditional engineering pedagogical approach focused on mathematics and theory heavy delivery into a discussion-heavy, dynamic, project-based course that explored social implications of design. The non-traditional aspects of this course made the instructor uncomfortable at times. She was often concerned about the impact and rigor of the elective course. However, the students' final reflections and course discussions demonstrated the value of this type of instruction. Students reported a new awareness of exclusionary systems and designs. They reported the value of a diverse team for creating effective products. And they drew direct connections between the engineering design process and the social impact of a solution, working to dismantle their previously held beliefs that engineering is "objectively" insulated from social justice issues.

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