EI1857

Bringing Social Justice Context into Civil Engineering Courses for First and Third Year Students

A. M. Aramati Casper, Ph.D.[1]; Rebecca A. Atadero, Ph.D., M.ASCE[2]; A. Rahman Abdallah, Ph.D., M.ASCE[3]; and Tom Siller, Ph.D., M.ASCE[4]

[1]Research Scientist II, Department of Civil and Environmental Engineering, Department of Biology, and Graduate Degree Program in Ecology, Campus Delivery 1372, Colorado State University, Fort Collins, Colorado 80523 (corresponding author). Aramati.Casper@colostate.edu
[2]Associate Professor, Department of Civil and Environmental Engineering, Campus Delivery 1372, Colorado State University, Fort Collins, Colorado 80523. Rebecca.Atadero@colostate.edu
[3]Civil Engineer, EXP U.S. Services, 201 Alhambra Circle, Coral Gables, Florida, 33134. rahman.abdallah@exp.com
[4]Associate Professor, Department of Civil and Environmental Engineering, Campus Delivery 1372, Colorado State University, Fort Collins, Colorado 80523. Thomas.Siller@colostate.edu

Abstract

Civil engineering education must be updated to keep pace with the profession and move past a culture of disengagement where technical work is considered separate from societal impact. Civil engineering students need to engage with diversity, equity, inclusion and justice (DEIJ) so they can understand the differential impacts of engineering on individuals from different groups within society. We aim to encourage the transformation of civil engineering education to produce engineers that will be prepared to meaningfully engage with society and advance justice in their future professional roles by providing examples of pedagogical change and analyzing student responses. In this study we implemented new course assignments in an introductory civil engineering course and a civil engineering materials course. In the introductory assignment students were taught to draw systems models and asked to consider social and technical factors contributing to the Hurricane Katrina disaster. In the materials course students completed pre-class readings about a regional highway reconstruction project, including articles about neighborhood opposition to the project, and participated in an in-class discussion. We analyzed student submissions using qualitative content analysis. Students in both courses (33% introductory, 60% materials) described learning about the impact engineering designs had on the community. In the materials class students were asked specifically about the impact of race and wealth on infrastructure decision-making. Student responses showed a wide range in how students understood the history of the situation and dynamics of power and privilege. Errors and limitations in student responses point to specific ways the instructors can improve student learning. Our results demonstrate that the integration of activities about societal impact is possible in technical engineering courses, emphasize the importance of integrating social context and related DEIJ content into technical courses, and provide insights into what students perceived they learned from the activities.

Practical Applications:

This article provides two examples of how engineering educators can incorporate the social context of engineering into their required technical courses. One example uses Hurricane Katrina to help students learn about system models that include social systems as integral parts and the other example uses a regional highway reconstruction project as a way to consider the Envision sustainability rating system. Analysis of student responses to these activities showed that students learned about the impact of social context on engineering work, and this information seemed novel to many students. Students were willing to engage with questions specifically about race and socioeconomic status, but their responses showed that they need more historical background to understand how unjust conditions came to exist. Ultimately, changes to individual courses such as those described here will have limited impact on students, civil engineering departments and majors need to reconsider curriculum more holistically.

Introduction

ASCE's Future World Vision describes how external pressures, such as climate change and resource scarcity, globalization and computing, and income inequality and social unrest, are changing the demands, possibilities, and constraints acting on civil engineering design spaces and the ways in which civil engineering work is done (American Society of Civil Engineers, 2019). Civil engineers of the present and future need to design and manage individual projects and infrastructure systems while working *with* communities and engaging in policy, outreach, and planning. In ASCE's strategic plan for 2023-2028, two of the strategic objectives, innovate and advocate, highlight the role civil engineers must play in society (ASCE, 2023). Innovate describes the need for civil engineers to lead in moving infrastructure into the future, adapting infrastructure for a changing climate, and incorporating sustainability and equity into design. Advocate describes the ways civil engineers must become involved in policy to address societal challenges. This shift toward policy and societal leadership is demanded by the conditions of society, but is also essential for preserving work for U.S. civil engineers, as traditional technical design work becomes more automated and commoditized leading to outsourcing (Arciszewski & Harrison, 2010).

As the field of civil engineering changes, traditional civil engineering curricula become obsolete. These changes demand that civil engineering educators update their pedagogical practices and course content to produce graduates who are prepared for modern and future demands. In this paper we describe new activities in two civil engineering courses, a first-year introductory course and a third-year materials course, and the response of students to these assignments. These activities were intended to help students understand the societal implications of engineering work. The activities included some emphasis on racial disparities and drew on two key areas of changing needs and growing demands in civil engineering: sustainability and community resilience. In this paper we report on student responses to activities in 2018 and 2019. The societal context around race, and diversity, equity, inclusion and justice more generally, has continued to evolve since the assignments were first implemented and these data were collected, but we believe these results are still informative for faculty seeking to incorporate these topics in their courses as the urgency to incorporate these assignments has only increased.

Societal context and social justice in civil engineering

Sustainability and resilience have become fundamental features of civil engineering work. Both are included in the ASCE code of ethics (American Society of Civil Engineers, 2022) as part of one of the fundamental principles: create safe, resilient, and sustainable infrastructure. And, both demand that our students are prepared to deeply engage with the societal implications of their work, which often requires systems level thinking. Despite this, the social implications of engineering and systems level thinking are largely still omitted from undergraduate engineering education or compartmentalized into specific courses away from technical content (Josa & Aguado, 2021; Russell & Stouffer, 2005).

Sustainability is often conceptualized in terms of three pillars or interwoven components: environmental, economic, and social (Wiek et al., 2011). The social pillar of sustainability requires civil engineers to understand the people they serve and to effectively advocate for technological change (Wiek et al., 2011). For example, the Intergovernmental Panel on Climate Change found that much of the technology needed to cut carbon emissions and control climate change is already available; but, this technology has not been adopted on the scale needed due to a lack of political will (Kahn, 2022). Within civil engineering, the resilience pillar can be framed in terms of building hardened infrastructure that is able to resist some of the worst impacts of climate change. But, resilient infrastructure is only one component of building resilient communities. Social infrastructure, “the networks of spaces, facilities, institutions, and groups that create affordances for social connection” (Latham & Layton, 2019, p. 3), must also be able to withstand and quickly recover from disruptions (National Institute for Standards and Technology, 2016). Effective civil engineering must integrate interactions between the natural world, the built environment, and social institutions to meaningfully advance sustainability and community resilience and live up to the societal obligations of civil engineering. Even as some examples of infrastructure failing society age, such as Hurricane Katrina (Sills et al., 2008), the “Big Dig” (Bearfield & Dubnick, 2009), and the Flint Michigan drinking water crisis (Pauli, 2020), we encounter new examples such as another drinking water crisis in Jackson, Mississippi (Grigg, 2023) and infrastructure failures in Puerto Rico during Hurricane Maria (Mejia Manrique et al., 2021). Positively, the U.S. Infrastructure Investment and Jobs Act combined with executive orders from the Biden administration, provides significant equity focused infrastructure investment opportunities (HDR, 2023) that may help shape the careers of civil engineering students and recent grads depending of course on future elections and administrations.

The ethical imperative of engineers to improve the quality of life for all is a call to social justice, a call that also can be thought of as creating fairness within society. Defining what is fair is a normative question that will have different answers from different people in different contexts. This is part of why a more narrow definition of social justice can be hard to specify. Leydens and Lucena (2018) defined engineering for social justice as “engineering practices that strive to enhance human capabilities (ends) through an equitable distribution of opportunities and resources while reducing imposed risks and harms (means) among agentic citizens of a specific community or communities” (p.15). Further, “social justice is not so much a thing to be achieved, as it is a continuing process and an ongoing struggle” (Riley, 2008, p. 1). We need to engage civil engineering students with questions of justice throughout their schooling, so they are prepared to engage with these topics as professionals. When we teach using only problems with right answers, as is common, we give the impression that right and wrong, just and unjust, can be expressed in a simple decision. We neglect the fact that many questions have no right answers and ignore the way that a series of instrumentally ethical decisions can lead to unjust outcomes. We also ignore the ongoing nature of social justice work. We must shift our framing to teach the societal impacts of civil engineering work and how the work of civil engineering can advance justice or thwart it.

There is a growing recognition among engineering educators of the need to engage our students in lessons about the societal implications of engineering and social justice (e.g., Rottmann & Reeve, 2020), but many, if not most, engineering educators never experienced this type of learning. Faculty who lack formal education in ethics and social impact may feel uncomfortable going beyond the traditional technical content of courses (Polmear et.al 2018). Further, many faculty have not worked in professional practice and may not have personal experiences with ethics and societal impact that they can share with students (Polmear et al., 2018) (Polmear et.al 2018). Thus, faculty may not know how to begin incorporating lessons about societal impact and social justice. Furthermore, faculty may feel this type of content is dangerous, or be in settings where there may be constraints on what they teach, given the deep political polarization in the United States and the recent wave of state level legislation banning different kinds of DEI activities at public institutions (Lieb, 2023). Also, Morgan (2020) found that students express skepticism about the ability of faculty to integrate political topics into their courses. Guidance is needed to help faculty overcome these barriers to incorporating societal impact and social justice content into their courses.

Purpose/Objective

The purpose of this paper is to encourage the transformation of civil engineering education by promoting the development of engineers that are prepared to engage with society and advance justice in their future professional roles. This goal requires broadening the beliefs that underly civil engineering courses (and eventually degree programs) about what knowledge and practices constitute the practice of engineering (Cech & Sherick, 2015). Our intended audience is civil engineering faculty who teach <u>required</u> undergraduate courses. We specifically focus on required courses because every civil engineering graduate should be exposed to these concepts. In this paper, one of the assignments we describe is about Hurricane Katrina, the other is about a regionally significant freeway expansion/reconstruction project. We describe the assignments, their fit into required courses, and students' responses to the activity in pursuit of the following big-picture objectives: (1) demonstrate how social issues can be integrated into civil engineering curricula in a way that is relevant to course content, and (2) provide examples of and discuss analyses of student responses to help inform future construction of similar activities and to reduce instructor uncertainty about assignment implementation, encouraging more instructors to try these types of assignments. We address the first objective by describing how we integrated the content into the courses and address the second objective through our analysis of student work.

Theoretical Framework

Engineering in the United States is largely, although implicitly, framed within a Culture of Disengagement. The Culture of Disengagement has three underlying ideological pillars: depoliticization, the technical/social dualism, and meritocracy (Cech, 2014). Depoliticization is the belief that engineering is unbiased, and therefore can and should be removed from social and political contexts, as these may bias an otherwise "pure" field and practice (Cech, 2014; Cech & Sherick, 2015; Niles et al., 2020). The term "depoliticization" refers to the removal of the entire social context from engineering, not simply avoiding more narrowly political factors (e.g., elected officials). The technical/social dualism creates a false dichotomy between technical and social factors and devalues social values and competencies in favor of technical skills and knowledge (Cech, 2014). And, meritocracy upholds current social structures as both fair and just (Cech, 2014).

Together, these ideological pillars uphold the façade of separating engineering and other STEM fields from social contexts. The pillars of depoliticization and technical/social dualism support the moral justification of separating any social or political context from the practice of engineering (Cech & Sherick, 2015), defining social welfare as beyond the responsibility of engineers, turning this into someone else's (less important) problem (Cech, 2014; Niles et al., 2020). In contrast, US and global society has never been more technologically dependent, and therefore it is vital for engineering to be framed as it actually exists – embedded within social, cultural, and technical systems and as a practice with real social justice ramifications (Cech & Sherick, 2015). The pillar of meritocracy enforces the assimilation of those with minoritized identities into the Culture of Disengagement in engineering, as bringing up concerns regarding marginalization belong in the social realm, which meritocracy frames as not relevant in engineering (Seron et al., 2018). Thus, even when women engineering student recognize that they are being marginalized they still tend to uphold the cultural practices that propagate these systems of oppression (Seron et al., 2018).

An engineer's undergraduate education is when they are professionally socialized – when they learn to be and think like engineers (Cech & Sherick, 2015). In their synthesis of literature, Cech (2014) provide the engineering culture of Germany and France as examples of engineers who are more socially engaged than in the United States, naming German engineers as more engaged with public debates about the long-term societal impact of technology and French engineers as more involved with bureaucratic life. While Cech (2014) noted that while these practices still have room for growth, they provide models for change. Downey and Lucena (2004), who Cech (2014) drew from, provided a deeper analysis of the differences in engineering culture and practices in different countries and how these differences have emerged as engineers interact with a range of national and engineering cultural norms, including what has historically been considered "progress" and "valuable" in different countries.

In contrast, in the U.S. Cech (2014) found that undergraduate engineering students graduated less engaged with the social contexts of engineering than when they started, demonstrating that engineering education had socialized students with the concept that "thinking like an engineer" involved creating an "unbiased" space distanced from social context. In parallel, in a large national study Hughes and Kothari found that students in STEM who are socially engaged may be more likely to leave STEM (2021), and in a smaller interview study Rulifson and Bielefeldt (2017) found that students who were motivated by social responsibility were more likely to leave engineering (Hughes & Kothari, 2021).

To address the Culture of Disengagement, Niles, Roudbari, and Contreras (2020) built forward on Cech's (2014) three pillars and argued that the pillars need to be addressed from a social justice perspective that critically engages with systemic inequities for effective change. And, because it is difficult for engineering students to resist cultural ideologies that are considered to be part of engineering (Seron et al., 2018), changes in how engineering is conceptualized and countering the Culture of Disengagement must occur as students are being socialized as engineers and developing their engineering identities. Thus, integrating social context and related DEIJ content into technical courses is likely a key leverage point to change the culture of engineering.

Countering the Culture of Disengagement with our Interventions

To help counter the Culture of Disengagement we developed one targeted assignment for an introductory civil engineering course and one for an upper-level materials course. Our work is embedded within a small but growing movement towards integrating societal issues into engineering courses (Atadero et al., 2018; Casper et al., 2021; Hartman et al., 2019; Ihsen & Gebauer, 2009; Koretsky et al., 2018; LaFave et al., 2015; Leicht-Scholten et al., 2009; Peixoto et al., 2018; Riley, 2003, 2008; Riley et al., 2009). While LaFave et al. (2015) successfully integrated cultural competency work into a senior-level engineering course based pre-post self- and peer assessments of intercultural competency measures, Rottmann and Reeve (2020) struggled with backlash from students in their ethics intervention in a workshop with primarily upper-level students. To avoid backlash problems Rottmann and Reeve (2020) recommended including critical analyses to avoid moral relativism and to focus on building and implementing respectful dialogue skills. Relatedly, Morgan et al. (2021) found that of all STEM disciplines in their study, engineering students were the least engaged in sociopolitical discussion and consciousness-raising activities, the latter of which were measured by a range of activism behaviors, such as engaging in donations for a social or political cause, and attending a public event (e.g., protest, rally, march, prayer, candlelight vigil). Morgan et al. (2020) found the lack of political involvement could be attributed in part to the time engineering students spend on coursework, but also the fact that engineering classrooms emphasize technical content. These reasons indicate that incorporating societal impact and social justice into *required* engineering coursework may be a way to support consciousness raising within tight schedules. Thus, there is still much need for research on how to effectively integrate social context and DEIJ topics into the engineering curriculum.

In this study, we build upon our previous work in which we integrated diversity of knowledge into a technical undergraduate course (Casper et al., 2021). In that study our new curriculum helped students value teamwork in engineering and a wide range of knowledge and backgrounds. However, students were rarely able to connect what they learned with the importance of DEIJ in engineering. In our current study we focus more closely on the equity and justice aspects of DEIJ. We did not expect our stand-alone activities to completely change students' perspectives; but we hypothesized that these activities could provide us with valuable information about implementing larger changes in the future and that they could act as "gateway" activities to integrating social issues and other DEIJ content into these classes. Therefore, as we analyzed student responses to these assignments, we sought to address the following research questions to help us achieve our second objective:

1. What types of things did students perceive they learned about in these activities, and how does this perceived learning relate to the DEIJ topics in the activities and their relevance to course content?

2. How do students respond to questions or activities that directly engage with topics such as race and engineering practices?
3. What do students' responses to prompts about what they liked and would change about the activity tell us about students' receptiveness to these types of prompts?

Methods

Researcher Identities

This study was performed by an interdisciplinary team, including a STEM education research scientist, two associate professors in civil engineering, and a civil engineering post-doctoral scholar. At the time we performed the study all but the post-doctoral scholar had over 10 years of experience in STEM education research. The associate professors had 12 and 34 years of experience teaching undergraduate civil engineering courses, and the research scientist had 8 years of experience teaching STEM courses; the three authors with extensive teaching experience were involved in activity design and implementation, including teaching the activities. The STEM education researcher was involved in teaching the activities in both classes. All four authors were involved in data analysis and interpretation. Relevant to our positionality in teaching and in our analyses, the STEM education researcher and associate professors of civil engineering are white, and the post-doctoral scholar is from the Middle East and came to the United States to pursue a doctorate degree. None of us are from the communities discussed in either assignment, which likely influences how we discuss the situations. In particular, our perspectives of the situations are limited to external reading, rather than personal knowledge of the situations. However, we posit that approaching engineering situations from an external perspective is common in engineering and that even when engineers are outsiders designing for a community they need to learn to respect and work with the community rather than making assumptions about the community (Bearfield & Dubnick, 2009; Cech, 2014). We worked to address our outsider status by drawing from a wide range of sources to learn about the situations, including materials that included first-hand accounts from local community members. The three authors involved in developing and teaching the assignments all had prior experience researching and teaching about diversity, equity, inclusion, and social justice (DEIJ) topics as embedded in STEM courses.

Course contexts

This research was performed in two courses in a civil and environmental engineering department at an R1 land grant university in the western US. Below is specific information for each course.

Introduction: Civil/Environmental Engineering is a required 3 credit course. The course is offered in the fall semester and is taken by students in their first semester in the civil and environmental engineering majors. The course met weekly for two 50 minute lecture sessions taught by the course instructor, and a two hour lab session taught by a graduate teaching assistant. Enrollment is typically 75-100 students. The intervention described in this paper was implemented in the lecture section. This course was taught in a single section with civil and environmental engineering students combined for many years. Starting in the Fall 2018 semester, as environmental engineering enrollments were increasing, the course was split into two sections, one section for civil engineering majors and one section for environmental engineering majors. Our intervention and data collection in this course took place in Fall 2019 in only the civil engineering section of the course.

This course is students' introduction to the profession of civil engineering. It was designed to be a welcoming environment where civil engineering concepts are explored, and students become excited about a future career in civil engineering. It was taught using interactive pedagogy, including open discussions, contemporary engineering case studies, and a team-based design project. This format provided a flexible environment where new ideas could easily be explored and is not constrained by rigid content requirements found in upper-division courses. This course focused on what civil engineers do and how they interact with society rather than technical content. A major theme was the phrase "civil engineering is a people serving profession." This made the course an ideal location to re-politicize engineering, as suggested by Cech and Sherick (2015). They suggest adopting less technical content to make room for re-politicization. A major resource used in the course were modern sustainability rating systems. These systems provided natural connections to social aspects of the civil engineering profession.

In previous versions of this course, assignments had a traditional focus on the role of civil engineers in designing infrastructure to resist extreme loads. By using current examples, such as Hurricane Katrina, concerns with equity and inclusion were easily incorporated into the course.

Evaluation of Civil Engineering Materials is a three credit course required of all civil engineering majors. The course is offered every fall semester, and most students take the course during their third year of undergraduate study. The course met weekly for two 50-minute lecture sessions taught by the course instructor. Students were divided into smaller three-hour lab sessions taught by a graduate teaching assistant. Enrollment is typically 80-100 students. The intervention described in this paper was implemented in the lecture section.

This course provided an in-depth analysis of properties and characteristics of different materials with implications for design. Lectures involved discussions of materials and design. In the lab students tested materials and analyzed the resulting data in weekly lab reports. The current course instructor has been gradually adding sustainability content to the course for the past decade. Early efforts focused primarily on environmental sustainability including topics such as the material specific credits in LEED and the fundamental steps in a Lifecycle Assessment (LCA). Later, lifecycle cost analysis and a discussion of material durability were added as examples of the economic pillar of sustainability. The theme of sustainability was also used to introduce the social sustainability assignment that is the topic of this paper.

Interventions

Introductory course intervention

In this paper we focus on analyzing responses to one intervention at the end of the semester, however students engage with multiple activities that relate to countering the culture of disengagement in engineering. Early during the semester, the dean of the college made a presentation to the class. This served both as a time for the students to get to know the dean and for the dean to set the stage for the college's goal for an inclusive environment. Part of the presentation focused on the NASA effort to land humans on the moon. The presentation included slides from NASA highlighting the predominance of white males in charge. We followed up this presentation with an assignment where students were directed to read several papers that discuss the 'Hidden Figures,' mainly people of color and women, who were active participants during the NASA effort but who's contributions went unacknowledged until recently (Shetterly, 2017). After reading three articles, students were prompted to answer questions to engage with the material. A second intervention mid-semester involved having a theatre group attend the class and engage in a role-playing experience that demonstrated the impacts that team member biases can have on student team projects. To do this, after the actors performed the scene, an open discussion was held to discuss the team dynamics. This was followed by inviting students to volunteer to fill the empty chair on the stage and intervene in the situation, helping them to develop skills in dealing with biased team dynamics. After a few students engaged, the facilitators discussed the interventions and how they worked. The following class session also involved a class-wide debrief where students discussed the importance of inclusive behavior in the engineering profession. These early interventions helped to set the stage for later class discussions and the Hurricane Katrina activity at the end of the semester, which is discussed in detail in this paper.

The Hurricane Katrina assignment was implemented in the 13th week of the semester, right before fall break. This assignment was designed to introduce students to the use of system modeling as a tool to map out the complex interactions of a system and have them grapple with how complex social and cultural factors influenced how different people experienced Hurricane Katrina. System modeling involves creating a diagram or "system map" that includes elements or characteristics and lines that show relationships between these elements.

The impact of Hurricane Katrina on the infrastructure in New Orleans was not uniformly felt across socioeconomic or racial segments of the population. Students were tasked with learning about how the quality of infrastructure is unevenly distributed, with lower income neighborhoods, typically including higher percentages of people with minoritized racial and ethnic identities, having much lower quality infrastructure and services. For this assignment students read a short description of the socially situated nature of STEM (see Supplementary Materials 1) and a case study describing the complex social, ecological, and infrastructure interactions that occurred during Hurricane Katrina (contact author for materials). Both of these materials were developed by the first author. In class, students were led through small group and whole class discussions of the case study and through the process of developing system models that described a particular aspect of the case study. When the students were working in groups the instructor circulated the classroom to answer questions and help facilitate student discussions and drew out overarching themes during the whole class discussions. At the end of class students each completed a short reflection; question prompts relevant to this study are provided in the respective table headers (See Supplementary Materials 2 for reflection worksheet). Each response was a few words to a few sentences in length or involved drawing a diagram. These assignments were graded on completion.

Materials course intervention

During the semester when the data for this paper were collected, the materials course had limited interaction with the social context of engineering prior to the social sustainability assignment. The course proceeded in a very traditional format spending a few weeks on each of the major civil engineering materials. Near the end of the semester, in the week before the social sustainability assignment, the course focused on the meaning of sustainability, lifecycle assessment, and sustainability rating systems, setting the stage to emphasize social considerations as one of the pillars of sustainability. In semesters since, the introduction to sustainability has been moved to week three of the semester helping to facilitate sustainability and social impact considerations being distributed more throughout the semester.

The social sustainability assignment (Authors, 2020) was implemented in the 14th week of the semester in the lecture, directly after the fall break. This assignment was designed to introduce students to the Envision criteria for evaluating the sustainability of a project (Institute for Sustainable Infrastructure, 2018) and to have them grapple with the social and cultural factors influencing a nearby interstate highway renovation and expansion project. The overall framework of the Envision rating system was introduced in lecture. The Envision rating system was designed to help stakeholders and engineers create more sustainable, resilient, and equitable projects (Institute for Sustainable Infrastructure, 2018) In the assignment students were asked to review two specific Envision criteria, or credits,: QL1.1 *Improve Community Quality of Life* and *QL3.1 Advance Equity and Social Justice*.

Interstate infrastructure in the United States was initially built targeting communities that were predominantly made up of people with minoritized racial and ethnic identities for areas of construction (Archer, 2020). Not only were these communities harmed by the initial impact of land requisition and having an interstate built through them, these communities continue to sustain harm through ongoing noise and environmental pollution, difficulties in safe access across the communities, and interstate renovations (Karas, 2015).

The assignment was designed to allow for a jigsaw style class discussion (Aronson, 2022). Students were assigned to one of four reading groups using the course management system and assigned pre-class readings (See Authors, 2020 for readings). These groups were simply used to distribute different readings to different students; these large groups were not used for any group work.

As part of their pre-class homework, all students were asked to read a one-page description of the socially situated nature of STEM (a slightly revised version of one used in the introductory course assignment in Supplementary Materials 1) and to review the interstate construction project page on the State Department of Transportation website. Then, each group of students read one or two media sources about the project (See Authors, 2020 for a full list of the media sources provided). Some groups had articles that were critical of the project and explained community resistance. Other groups read articles that were more favorable. As part of this pre-class work, after reading their articles students were asked to respond to reflection questions that prepared them for the in-class discussion.

During class, students started in groups of four for small group discussion with others who had read the same set of articles. After 15 minutes groups were rearranged into new small groups of four to allow students to discuss the project with those who had read a different set of articles for 15 minutes. Finally, we ended the lecture period with 15 minutes of debrief as a whole class. The instructor and the STEM research scientist circulated the classroom while students were working in the smaller discussion groups. The STEM research scientist was invited to assist in class that day because the instructor wasn't sure how the activity would go and wanted some “back-up” in the room. Toward the end of class, the instructor tried to synthesize student statements during the whole class discussion. After class, students responded to questions about the assignment. Question prompts used in this study are provided in the respective table headers. Student responses to these prompts were a few words to several sentences in length and the pre-class and post-class assignments were graded on completion.

Data collection

Data for both courses consisted of student responses to assignment prompts. In the introductory course students turned in their written work at the end of class. In the materials course students completed pre-and post-class assignments using the course learning management system.

In the introductory course data were collected in the Fall 2019 semester. In this semester there were 74 students enrolled and 62 were present for the in-class activity. Of these students, 25 consented to have their work analyzed. Of these consenting students, 20 were first year students and five were second year students. Twenty-three of the students were civil engineering majors, one was an engineering science major, and one was an engineering option major. The mean age of the students was 18. Thirty-six percent of students were Students of Color and 64% were white. Fifty-two percent were men, 48% were women, and 0% had gender diverse identities (e.g., transgender, non-binary). Eight percent were heterosexual, 16% had lesbian, gay, bisexual, and related sexual orientations, and 4% preferred not to respond to this question. Racial identity data were collected using the recently recommended categories from Pew research (Cohn, 2017) and gender and sexual, romantic, and related identity information were collected using the survey questions developed by Casper et al., (2022). Age and engineering major were collected as open-ended responses.

In the materials course data were collected in the Fall 2018 semester. In this semester there were 103 students enrolled and 92 completed the pre-class, in-class and post-class activities. Students in this course are generally in their third year of their engineering studies. Of these students, 77 consented to have their work analyzed. Of these students 75 were civil engineering majors, one was a mechanical engineering major, and one was an engineering science major, as reported by the university. Using institutionally collected data, which collects gender as a binary, 29% were women and 71% were men. We did not have access to any other demographic data for these students. Students in the materials course may or may not have taken the introductory course within the department, as students transferring into the major are usually assigned an additional engineering technical elective rather than taking the introductory course. Further, the junior level students we collected data from in 2018 likely had less exposure to societal impact in the 2016 version of the introductory course than later students, as the introductory course was undergoing a shift in instructors at that time.

Data Analysis

We used Qualitative Content Analysis (QCA) to analyze all data. QCA includes synthesizing data into themes and quantifying the frequency of these themes across responses (Mayring, 2015). Thus, while QCA is generally considered a qualitative analysis method (Elo & Kyngäs, 2008; Graneheim & Lundman, 2004), Mayring (2015) argues that it is a mixed-method research method, because its last step involves quantifying the qualitative results. QCA is appropriate for our data because it allowed us to compare commonalities and differences across the data that are both frequent and uncommon, and allows researchers and readers to understand the frequency of the different themes (Elo & Kyngäs, 2008; Graneheim et al., 2017; Graneheim & Lundman, 2004). It is also particularly appropriate for our dataset, as it allowed us to use the same analysis method to analyze both student written responses and student system models (a type of concept map) (Ekinci & Şen, 2020). While frequency does not inherently demonstrate value, in education studies where an entire class makes up the population involved in an intervention these frequencies can be helpful in interpreting how different students responded to the material.

QCA involves three steps: preparation, organization, and reporting (Elo & Kyngäs, 2008). We followed Elo and Kyngas' (2008) directions for QCA for each of these steps. We started our analyses by analyzing all the written student responses. In our preparation step we defined each student's response to a specific prompt as our unit for analysis. In our organization phase the first three authors first read through the preliminary QCA coding of the introductory course data that was done by the first author and presented as preliminary results as a conference poster (Casper et al., 2019). Then, they read through all the student responses for a specific prompt and discussed potential codes. These potential codes included the codes initially developed by the first author in the earlier preliminary coding, as well as any other additional codes that the researchers thought fit the data. Then, two of these authors individually coded all the responses for one prompt. Next, the three authors involved in coding met to discuss the codes until they reached consensus for each student response, as per Stemler (2004). Then, we distilled codes into the themes. When we coded the prompts asked in both courses we compared the responses, codes, and themes across courses to determine which codes and themes were applicable to both courses. However, we did not limit our codes and themes to ones that were applicable to both classes for the questions that were asked in both classes. In our reporting phase we created tables of themes, definitions of themes, example quotes, and calculated the percentage of students whose responses fit within each theme. Because we analyzed the data by student response to a specific prompt, we kept our themes grouped by prompt in our analysis. All student quotes are provided verbatim, including grammatical errors, unless otherwise indicated.

After we completed our analyses of written responses, we analyzed the system models created by students in the introductory course. Similar to our analyses above, two researchers independently read through the student responses and looked at the system models. These two researchers also independently read through the themes related to the parallel prompt in the materials course and determined which codes and themes were applicable, and what new codes and themes needed to be developed. The two researchers then met to discuss the coding of the system models and discussed their coding until they reached consensus. Because we were unable to group students by if they had consented to participate in the research project or not, we were only able to analyze four system models, representing seven students' work. While this clearly does not represent the ideas of all the students in the class, it does provide insight into how some students engaged with the content.

We used multiple strategies to address trustworthiness in our research, following Lincoln and Guba (1985). According to them, trustworthiness includes credibility, transferability dependability, and conformability. In addition to Lincoln and Guba's (1985) overarching guidelines, we also followed the specific guidance provided by Graneheim and Lundman (2004) for QCA. We addressed credibility through prolonged engagement both with the data and the courses, and negative case analysis by continually looking for negative cases in our analysis. Because we were evaluating activities students participated in within a specific class, we were able to invite all of them to participate in the study and make sure that all students had participated in the experience we were studying. Also, students responded to the question prompts as assignments that were given while students were participating in the activity, so there was no time lag between their experiences and their responses. We also followed Graneheim and Lundman's (2004) recommendation of focusing our meaning units on a response to a specific prompt to further help with credibility. We used thick description both in our analysis process and description of findings to establish transferability. We developed dependability through involving multiple researchers in the coding process, including researchers who were also involved in implementing the activities we were studying. We established confirmability through reflexivity (multiple researchers with multiple perspectives, providing researcher positionality information), and keeping an audit trail.

Findings and Discussion

Our findings: a) demonstrate that integration of this type of activity is possible and important in technical engineering courses (objective 1), and b) provide insights into what students perceived they learned from the activities and how the students reacted to the activities (objective 2). Combined, these findings help provide guidance for future revisions of the assignments we describe here, and, more importantly, for others who are working to engage with the social context of engineering (including DEIJ content) into their own courses. The two courses and the intervention in each were different; our goal in discussing and comparing and contrasting these different activities in different contexts is to help instructors understand how DEIJ-related activities can be brought into differing course contexts using different strategies.

Student Perceptions of their Learning

It is valuable to measure student's perceptions of their learning because these perceptions provide information about student satisfaction with the quality of their teaching and can provide insights into how students perceive they are meeting their learning goals (Kuhn & Rundle-Thiele, 2009). Thus, while asking students about what they learned measures something different than tools that measure student learning, perceived learning is still a valuable measure. Furthermore, in higher education, there is evidence that students' perceptions of learning can also accurately capture their actual learning (Kuhn & Rundle-Thiele, 2009). We argue that student perceptions of what they've learned is useful when engaging with topics such as the social context engineering because measurements of these concepts will always be more subjective than measuring things such as skills to perform a calculation, and students' beliefs about their skills, abilities, and knowledge influence their ability to use these skills, abilities, and knowledge (Bandura, 1997).

A focal learning goal for courses was for students to be able to describe the importance of social context and society in engineering practices using the specific examples within each assignment we analyzed. In this way, students directly engaged with social context and countered the culture of disengagement in engineering. The activities also had other course learning goals specific to content goals in each course, such as being able to construct a systems model diagram in the introductory course and being able to apply criteria from the Envision sustainability rating system in the materials course. In our narrative we focused on student responses related to societal context and DEIJ topics, but all themes identified in our analyses of student perceived learning are described in Tables 1 and 2.

Social impact was the most common theme for student perceived learning in both courses, with 60% of materials students and 33% of introductory students writing about this topic. This commonality, despite the differences in activities and courses, may indicate that it was particularly notable to students when compared to their other courses. In their responses, students discussed social impact in a range of ways, although students' responses generally just focused on community and society being relevant to engineering. For example, students discussed engagement with the community in the materials class, *"There is a lot of community consideration than I ever thought there was during the development of a* *project this size,"* and the way social-engineering interactions could lead to different outcomes in a disaster, *" I learned that the lower income areas suffered the worse because of the poorer quality in infrastructure and levees which could have prevented much flooding and damage."*

Additionally, in each course there were a few students (8% in materials, 1 student in introductory) who explicitly wrote about DEIJ topics, delving explicitly into issues such as racism, instead of just discussing the social impact of engineering. The introductory course student wrote, "*social impacts and systemic oppression play a much larger role in engineering than I first thought."* The materials course students who wrote about DEIJ topics almost all specifically discussed bias, such as *"one thing I learned during this assignment that I never knew before was about how the highway system was planned in the 50's. This opened my eyes to some of the previous bias I had and I now have a new and altered view point on the subject."* While there were many differences between the courses, it is possible that the upper-level students had more outside experience and knowledge which they were able to bring into the explicit discussions about topics such as racism and bias, leading to more students discussing DEIJ topics and discussing them more specifically. The differences in the activities and small group in-class discussions may have also led to these types of differences, although both activities explicitly engaged with bias and discrimination that was interrelated with each situation discussed in the respective activities.

There were also themes that described responses less explicitly related to the social impact of engineering. In the introductory course 29% of students wrote that they learned about the complexity of systems, often having responses that implied the importance of social content without explicitly naming social systems, such as, *"engineering projects go beyond the math and science. Every project has an impact we should be aware of."* In contrast, only 6% of the materials students wrote about systems being complex, such as: *"these consequences can vary greatly depending on the specific results of the project that are being analyzed. For example, the environmental effects of a project could be beneficial while as the resulting social factors are negative."* The way students discussed complexity is also demonstrated by the quote in Table 1 from an introductory course student, where the student talks about how everything is interconnected and there are things that are important beyond money and land. Related to system complexity, in the materials course 37% students wrote that they learned about conflict related to engineering projects, such as *"I learned that it is hard to get the support of all the people and no matter what someone will be unhappy with the project no matter how much it is needed,"* whereas none of the introductory students wrote about this (see Table 2 for additional quotes from the materials course). These differences may be at least partially due to the differences in activities, since the introductory course activity focused on the inter-relatedness of systems explicitly in their engagement with the aftermath of Hurricane Katrina, and the materials course activity focused on the different perspectives that different stakeholder groups had about a highway reconstruction project. Thus, in each course students focused on system complexity in different ways. While we were unable to engage students in both types of activities in a single course (one that focuses at the system level, and one that focuses on stakeholder perspectives), the different ways students engaged with the social impact and complexity in their responses indicates that completing activities that engage at different levels of focus may help students develop a more complex perspective to think about the inter-relatedness of systems.

Spanning the topics discussed above, overall, 85% of students in the materials course and 61% of students in the introductory course wrote that they learned something about the engineering-society relationship. These numbers indicate that the activities were reasonably successful at teaching many students about the relationship between social topics and engineering. The different types of responses that students provided demonstrate that students perceived that they were learning about topics that counter the culture of disengagement in engineering. This assignment differed from those students were accustomed to completing in their engineering courses because it helped students explicitly contextualize engineering in a large social context and conceptualize social context and impact as an actual part of engineering, instead of focusing on calculations or technical components.

In addition to discussing that they learned about social topics, students also frequently wrote that their concept of the practice of engineering broadened. This was the second most common theme for materials (52%), and less common in the introductory course, with only 17% of students writing about it. While teaching students about what engineers do was not a direct target of either activity, it is related to our goal of helping students conceptualize the social components of engineering as part of the practice of engineering. The difference in the frequency of this theme between the two courses may have been related to older students thinking more about becoming practicing engineers. The materials course assignment may also have emphasized the connection with engineering practice. Alternatively, since Cech (2014) found that engineering students are less socially engaged when they graduate than they were when they entered college, the students in the introductory course may have thought that benefiting humanity and working for a community did not seem so different from what engineers do, but for the upper-level students this seemed different from everything students had learned.

Not surprisingly, many students also wrote that they learned about topics related to other learning objectives we had for the activities, such as system models in the introductory course (25%), and transportation systems (23%) and Envision (20%) in the materials course. This range of responses that integrated traditional engineering course content and social systems and DEIJ-related content indicate that these types of assignments have promise for achieving both types of learning goals. Therefore, instructors do not need to give up technical content to integrate social justice content, as these types of activities demonstrate that both types of learning objectives can be met in the same activity.

Social Context-specific Prompts

In each course students responded to a prompt that explicitly engaged with the social context of engineering, countering the culture of disengagement in STEM. In the materials course they answered a question that related to the role of race in the situation. In the introductory course students learned to draw system models to depict the different interactions involved in the disaster that occurred after Hurricane Katrina.

In the materials course the prompt was *What do you think would have been done differently in this project if it was located in an affluent predominately white neighborhood?* Our goal in asking this question was to elicit responses that demonstrated how students perceived the social context of the situation and the structural racism that is embedded within the socio-cultural context of engineering practices in the United States. Student responses were mixed (Table 3), but about half (53%) discussed how social justice issues have some kind of role with this type of project, as demonstrated by Themes A and B, which are discussed below. While we cannot know how much a student's response to this prompt related to their pre-existing knowledge and beliefs versus what they learned through the assignment, students' responses indicated that nearly all students were willing to engage with a prompt that specifically targeted racism. Similar to the prompt about what students learned, these responses indicate that we were somewhat successful in our goals with the assignment.

The first four themes (labeled with letters A-D) in Table 3 are mutually exclusive and describe how the student's response related to the discussion of race and socioeconomics in the prompt. These themes demonstrated a spectrum of engagement with racial justice and other DEIJ topics, which are described below, from those most engaged with to those antagonistic towards these topics.

Of these themes, Theme A*, Social Economic, and/or Racial Power Structures*, was the most common (41%) and demonstrated the highest level of engagement with discussing racial, social, and/or economic factors involved in the engineering project they discussed. While student responses coded under this theme did not need to directly engage with race, responses could not exclude race as an important factor in the situation, such as:

> *I feel like since the government is majority white people, they probably would have considered the impact in the communities a little more. Odds are that the government may correlate more poverty with minority groups and not consider these people 100% equal which is absolutely not true. I believe if this was in a predominately white neighborhood than the communities voice would be heard more since they would not be a minority.*

While these responses still often demonstrated nascent conceptualizations of the role of race and DEIJ as part of the social context of engineering, they demonstrated an engagement with and acknowledgement of the importance of these topics in the situation, and therefore likely indicate a willingness to learn and engage more.

An additional 12% of students had responses related to Theme B, *Mixed Racial Inequities and Idealized Response,* which combined an acknowledgement of these factors as influencing the situation with ideas related to race not being relevant:

> *Hard to say because you never know what wealthy angry people can do if they have friends in high places. However, I would like to think that no special privileges or considerations were given to the "affluent predominately white neighborhoods" of [another area of the city] when [a public transit infrastructure project] was going on.*

Some of the responses in this category particularly demonstrated both the complexity of the situation, and the challenges students had in grappling with the situation. These challenges may have arisen from trying to conceptually navigate multiple incompatible frameworks for thinking about the social context of engineering. One student's lengthy response exemplified this complexity and the student's attempt to navigate multiple ways to conceptualize the interactions between race, class, and power:

> *I believe today's society works on who you know, what power you have, and how much money you can pay. I also believe that although many people come into this power through family or are just handed these things in life, many other people earn it from nothing. I do agree there are injustices against people of ethnicity, but I do not believe this is one of them. If this project was to go through an affluent white neighborhood, I believe those people would take the steps they could to get out of it. I don't know if they would work, and I'm sure some of those people would only have their power because they had had it handed to them, but the people who have had to work for almost everything they've ever gotten would talk to the people they knew to see if there was anything they could do to help. I also believe if this project is what is best for the economy and did minimal damage to the environment, the affluent neighborhood wouldn't fight it. The amount of traffic on [Interstate] is ridiculous and if this highway can alleviate the time those cars are running, who knows what long term environmental impacts it could have. It could possibly help the environment if we hurt it a little upfront using the low emission construction equipment. I believe the low income families are worried about losing their homes which is understandable but they are in that situation because of choices they've made. Everyone gets screwed over in life, and yes race is a problem in our society, but I don't believe race is a factor in this scenario. The money and influence is a factor but that can be based off of your merit and intelligence, not always what you've been handed. So, I believe this project would have gotten more feedback upfront about what was to happen and more studies would have been conducted if it was in an affluent neighborhood to see how it could benefit the economy and environment before feedback was provided as the whether or not it should happen.*

In this response, the student includes concepts of meritocracy as well as privilege, acknowledges racism but claims this situation is not one where race/ethnicity is relevant, and then blames low-income families for their situation. In the end, the student concludes that the affluent community would have had more power, but also claims that those in an affluent neighborhood would care more for environmental consequences, without providing any evidence to support this claim. These types of conflicting ideas may indicate that a student is trying to make sense of multiple ways to conceptualize the system; this attempt at sense-making may help them be receptive to new information. Even with these conflicting thoughts, the student is clearly countering the culture of disengagement in their answer.

Twenty-four percent of students wrote responses that fit into theme C*, Idealized Response that Race Should Not Matter.* In some responses students acknowledge that racism could be a problem, but it is not in this situation. Interestingly, one student specifically argues:

> *While i can see how this could be made into a race issue, I don't see it that way in this case. This section of [Interstate] was preexisting, meaning unless they intentionally originally built it was racial segregation in mind, it wasn't purposely trying to demolish a lower class, predominately black neighborhood. There is simply no other route which allows for the realistic reconstruction of that 10-mile stretch. …. I could be wrong, but what I can say is, if there was deliberate collusion against the black minority, it wasn't from the engineers, or at least the vast majority of them.*

This student's point is particularly interesting, since the highway was explicitly built to do the things the student doesn't think could have motivated the original location. The students' point that argues the collusion wasn't from the engineers also clearly exemplifies the pillar of technical/social dualism in the culture of disengagement – making the social component someone else's responsibility, but not the responsibility of the engineers.

Students' responses in this theme generally represented post-racial or "colorblind" conceptions, such as "*nothing. I don't really see how the race of a neighborhood is important to the improvement of transportation,"* which are problematic because they perpetuate racism by simply avoiding engaging with race and claiming it is not relevant (Crenshaw et al., 2019). Notably, some of the students with idealized responses talked about how they *wanted* race not to matter, *"I hope nothing would have been done different."* These students may be more open to further discussion about how race is relevant than students who were more declarative that race is not relevant. This may be particularly true for students like the one quoted who is incredulous that the highway could have been built to specifically target a racialized community if they learned more about the history of the interstate system.

Eighteen percent of students wrote responses that fit into theme D, *Better in an Affluent White Neighborhood*. These students discussed both structural and social factors in their reasoning. Some students wrote about how the affluent white community would have better infrastructure,

> *All of the repairs to the school and home improvement actions would have been reduced or eliminated. The destruction of businesses and homes would have also been limited since they would have been worth more and the owners would have had more input due to money. I don't believe the fact that the community being white would have any impact on the outcome rather the incomes of the community would be more likely considered.*

Others thought that the residents would have supported the project, *"in my experience that type of community would be more in favor of this type of project."* These responses indicate a range of conceptions about the situation, many of which were rooted in either a lack of engagement with the complexity of the social situation, or ideas that people in a white affluent neighborhood are morally superior, and thus would make sacrifices for the greater good. Students with these conceptions may have a range of openness to materials that engage more deeply with racism and DEIJ issues related to the project. Students with these conceptions may not necessarily change their ideas with curriculum that focuses on countering the culture of disengagement, because their ideas are focused on their perceptions of the community where the project is being built, rather than separating society from engineering.

In addition to the mutually exclusive categories, which described perceptions in relationship to the role of race and racism in the situation, 20% of students had answers that focused on economic class rather than race. Some of these students felt the need to explicitly point out that affluence, and not race, is what is important in the situation, such as:

> *This case would also be extremely rare, because affluent neighborhoods are typically not next to highways, because highways decrease the property value of homes significantly. I also don't see why race had to be included in this discussion, because we are people not defined by color.*

This category was not exclusive because many of these students had responses that overlapped with Theme C, the idealized responses about race category. Their responses indicate the need to explicitly engage with interactions between race and socio-economics when teaching to dispel the myth that race is irrelevant. Similar to theme D, activities that counter the culture of disengagement in engineering will not necessarily address these types of responses, since students with these types of responses are engaging with social and political concerns related to engineering.

Only 5% of students wrote about being upset about the question; that we were discussing race in relationship to this activity. These students, such as the one quoted in table 3, actively pushed back, writing about the question being offensive. We did not conduct a formal research observation during the class discussion, but we do note that while students were willing to voice this view in their written responses, these responses were not brought up in the whole-class discussion. Thus, negative written responses do not inherently indicate that students will be disruptive in class discussions. And, while these response data are from the first year that we implemented this assignment, this lack of disruption has held true across 3 years of implementing iterations of this activity. This experience may be reassuring to civil engineering instructors who are still learning how to facilitate difficult conversations. It can also be a sign of self-censorship on the part of students. Students may be afraid of the social consequences of sharing their views in front of their peers (Adedoyin, 2022). We are glad that students were willing to share their views in writing where the course instructor could see their response, but an area for further development is how to help students voice disagreements in productive and respectful ways that can lead to learning. Furthermore, unlike the experiences of Rottman and Reeve (2020), because these negative responses were only expressed in student written work, and not in the in-person classroom discussions, we did not have the need to directly engage with these responses in the classroom. Since we wanted students to engage with the materials without concern about the correct answer, student responses were graded based on completion and in a format that did not easily allow for feedback. Therefore, we were not able to engage with the students who were negative about the assignment in their written work.

Along with the categories above, 5% of students discussed in their rationale that the highway was pre-existing, *"The need was to revamp an already built highway and the goal seems to be achieved but not for a certain neighborhood."* While the highway was indeed pre-existing in 2010 and the structural concerns of the bridge needed to be addressed, these students wrote from the perspective that people in the neighborhood needed to deal with the nearby interstate. However, this situation is more complex, as the highway (along with much of the interstate system in the United States) was specifically built through these neighborhoods when it was constructed (Archer, 2020; Karas, 2015). Thus, the instructor needed to provide more background information that made this history explicit.

In the introductory course students worked to develop system models that explicitly connected the complex components of the disaster surrounding Hurricane Katrina. Because the students developed the models in an in-class activity they are, due to time constraints, relatively simple system models. And, some students did not actually create interconnected system models. To align our work with the scope of this paper, in our analysis we looked only one key aspect: how students engaged with content in relationship to the themes related to race and class we discussed for the materials class. The themes from the materials class that we used were: i) social, economic, and/or racial power structures (parallels themes A-D in the materials class) and ii) if they focus on economic class rather than race. Additionally, we determined if there were differences in how the material relating to points i and ii were represented in their brainstorm writing versus their drawn model.

Unlike the students in the materials class, all of the first-year students whose models we were able to analyze had models that were classified as Theme A, Social, Economic, and or Racial power structures. All the students also wrote about race or racism in some way, either in their brainstorm or in their models. However, we thought it was interesting that only two of the four groups included race/racism in some way in their actual model. Figure 1a is an example of a model that does not include racism in the model, even though in their brainstorm one of the students listed "*redlining,*" as a factor, which is specifically based on race and racism. Figure 1b is an example of a model that does include racism. And, this inclusion was further supported by the student's written text, which included *"Transportation prevented evacuation of impacted areas, which were primarily lower class minorities, 80% women"* and *"not placing minorities in communities that were in danger of natural disasters in the first place, providing more resources for infrastructure in these areas."* Therefore, these students not only explicitly named minority communities, referencing those with minoritized racial/ethnic identities, in their model, they expanded upon this statement in their text.

We argue that the differences in if race/racism appeared explicitly in a model, or if the model only discussed poverty as a factor, may indicate what students think is most important when selecting information from their brainstorms. We base this argument on how students initially brainstormed ideas, and then worked together to pull salient points from their brainstorms into a system model. This may also indicate differences in what the students working together valued. One of the students who worked on model 1a wrote that they learned *"social impacts and systemic oppression play a much larger role in engineering than I first thought,"* whereas that student's partner's reflection focused on the teamwork elements of the project, and that they learned *"how to work off others ideas in brainstorming."* We cannot know if the first student would have included race in the model if they had a different partner. However, these differences in reflections indicate how even students who worked together engaged with the activity very differently including how they engaged with the culture of disengagement in their group work.

Liked and would Change

While what students liked or would change about an activity doesn't inherently tell us how it helped them learn, it does help us consider how to more effectively engage with students in the future. It also can provide assurances to instructors who may be concerned about engaging with the social context of engineering in their classes, and their concerns about the ramifications of countering the culture of disengagement in their courses.

Liked

The differences between the two activities and courses, including the level of students, may have led to fewer commonalities in what students liked (Tables 4 and 5). In the introductory course students most commonly wrote about liking learning or about how the activity made them think (36%). In the materials course, more than half of the students wrote about how they liked working on a real project (56%); they also often wrote about how they liked learning about a local project that was directly relevant to their lives. This may indicate the importance of a) integrating local place-based learning into course activities, and helping students think more broadly about the things that impact them, and b) engaging with these types of activities at multiple levels of the curriculum as students learning pathways are different but complimentary at different stages of their academic career.

The inter-relationship between engineering and society was the third most common thing students liked in the materials course (30%), but one of the least common themes in the introductory course (16%; see tables 4 and 5 for example quotes). This difference is particularly interesting, in that twice as many students wrote about learning about this social relationship in the introductory course. This difference could be representative of a range of reasons, including that talking about the social component of engineering was something the introductory course instructor did more throughout the course, so it may have seemed more novel in the materials course. The difference may also have some relationship to the level of the students and their career trajectory. As some students noted in the materials course, they found it refreshing to do something beyond calculations.

It is notable that in response to what they liked, only one student wrote that they did not like the activity for the Hurricane Katrina activity (and later noted they did not like the system model part, they did not write about not liking the social aspect). None of the students in the materials course responded to this prompt by saying they did not like the activity, even if they were critical of the social components of the activity in other responses.

Suggested Changes

Similar to the "what students liked" prompt, what students would change does not inherently provide guidelines of what *should* be changed, as students are not experts in content design and delivery. However, it does provide insight into students' perceptions of an activity. Across both activities, students commonly noted fairly minor structural changes to the activity, such as needing more time for the activity or doing the activity earlier in the semester (36% of students in the introductory course and 15% of those in materials); providing more guidance, background information, and/or examples (61% of materials course; 32% of introductory course); and allowing students more freedom in the topics they focused on or otherwise broadening the scope of the activity (27% of materials students and 4% of introductory students; see Tables 6 and 7 for example quotes). These suggestions all addressed challenges that are common to implementing any kind of new activity in a course. It is also noteworthy that 24% of the introductory students and 12% of the materials students had no suggestions.

The few students who were critical of the activities provide additional insights in how to address student resistance to this type of activity. The only student who suggested not doing the introductory course activity was critical of the system model, not the DEIJ content, and did not actually create a system model in their work; we agree with this student that the diagram they created is limited in its ability to help understand a system. Thus, future implementation of this activity would benefit from more framing around the use of system models to help guide students in effectively creating a system model. This response also indicates the importance of not assuming that negative responses are due to the DEIJ content of an activity. In the materials course there were 5 students (7%) who were critical of the DEIJ content when discussing what they would change. Additionally, the one student whose response did not fit into the themes in the table acknowledged that some students were critical but that they thought that the DEIJ content was important:

> *I think that bringing up anything even remotely related to politics can be a sore spot for people. I know that the "how would things change if this project was occurring in a predominately white neighborhood" question made several people angry. That being said, I personally think it is important to recognize the differences.*

As discussed in the DEIJ-specific prompt section, these types of responses exemplify the importance of this type of activity, rather than a reason not to do it.

In addition to the very few students who were against the activity, 10% of the students in the materials course wrote about wanting the activity to be more engineering-centric, with responses that exemplify the perspective that engineering is depolitical. These types of responses indicate a need for a clearer connection between politics, social context, and engineering, to help demonstrate that what they wanted – better connections to Envision – was actually embodied in the assignment, and the social-political aspects of engineering are parts of- both engineering and the Envision criteria.

Limitations

Our research provides useful information about integrating content about the social context of engineering into technical engineering courses, thus countering the culture of disengagement in engineering. Before we discuss the implications for instructors, we want to acknowledge the limitations of the study that indicate the need for future related research. We collected data on two individual activities, each taught during one class session in each specific course. Both were taught at one university with its own socio-cultural context influenced by its geo-political location. The data we analyze in this paper were collected in 2018 and 2019, before COVID-19 and before the racial reckonings of the summer of 2020 prompted by the murders of George Floyd, Breonna Taylor, and Ahmaud Arbery. Societal awareness of systemic or structural racism is undoubtedly higher than it was before 2020, and current students will likely have a different (perhaps more sophisticated) understanding of some topics today. However, the ongoing attack on teaching DEIJ topics and history that is not whitewashed, including in higher education (Curran, 2023), indicates both the vital nature of this kind of work and that some students may be more antagonistic to this type of teaching and that they may come in with an even more simplified understanding of racism, including systemic racism. While few students in our study outrightly argued against the DEIJ content, we realize that students may not want to be perceived as racist, misogynistic, or homophobic in front of their peers. Thus, we may not be capturing the full range of student beliefs. Unfortunately, it is very difficult to measure beliefs that an individual perceives as potentially socially undesirable; future studies could engage with specific strategies to measure socially undesirable beliefs and attitudes to address this limitation.

We did not directly measure student learning, measure student prior knowledge, nor did we attempt to measure any long- term effects. A limitation related to student learning is that we did not engage with students who had responses that argued against the existence of racism or who argued that social topics did not belong in engineering. Future interventions (and studies) should build in strategies for engaging more deeply in dialogue to help support student learning, both for those with limited and/or problematic perspectives and to help prevent these perspectives from harming other students, particularly those with minoritized identities.

Student response rates to our survey were well within the norms for similar research, yet the lower response rate in the introductory course means that there are types of student responses we may not have captured – Baruch and Holtom's (2008) meta-analysis revealed a mean response rate of 49%, with a standard deviation of 24% for education research. We had a response rate of 83% of materials students and 40% of introductory students. Lastly, our demographic information is limited by university data collection practices and the types of demographic data we had access to for the materials course. Additionally, to protect the privacy of students, we did not disaggregate data by identity. Future studies with larger sample sizes, which allow for disaggregation of identity with fewer privacy concerns, as well as more intensive data collection practices could address these limitations.

Implications

We implemented new assignments about the importance of societal context in civil engineering in the context of two very different types of civil engineering courses. The findings from our research questions about what students perceived learning (RQ1), how students responded to content or questions focused on race (RQ2), and what students liked and would change (RQ3) provide specific insights for instructors planning to implement these types of assignments in their own courses. Our study also points to larger considerations to change curricula and departments to re-politicize and re-engage civil engineering education.

Specific guidance for instructors

Our results are encouraging for instructors who are unsure about countering the culture of disengagement in their courses through directly discussing the social context of engineering. Based on our findings we recommend that instructors a) explicitly discuss the culture of disengagement in engineering, b) engage with the topics throughout their course, and c) provide more time and scaffolding for the activities than they would for a similar activity that does not involve integrating social context. In addition, we suggest having an additional instructor in the room when implementing novel, social-context related curricula for instructors who want to try something new but aren't quite sure how students will respond. Instructors who are working on implementing new activities can work in pairs or small groups, helping each other out, which is in line with Williams and Conyers' (2016) recommendations that instructors have a supportive peer group when engaging with race pedagogically.

For the highest likelihood of success we recommend that instructors engage deeply with the social context of engineering, including explicitly talking about the culture of disengagement prevalent in STEM and engineering, race and racism, and historical factors that have led to current situations. Not surprisingly, we found that students' abilities to discuss issues of race and socio-economic status in relationship to infrastructure projects ranged widely. We were pleased that most students were willing to engage in the topic and that the class was able to have productive conversations. Based on student responses, we think our activities could have been even more effective through more explicitly discussing the culture of disengagement that exists within engineering and explaining why this culture is problematic. The responses also indicate that students needed help to grapple better with the impacts of socio-economic class and race/ethnicity and how these impacts are interrelated and yet distinct, something we did not engage with in either class. For example, if, in the materials course, we had discussed how the U.S. interstate system was explicitly designed to go through and disrupt communities of people with minoritized racial/ethnic identities and focused more on historical practices such as redlining, students may have been less likely to decide that the situation was not related to racism. In contrast, the activity for the introductory students explicitly discussed the racial and historical dynamics of the situation in more detail, and all of these students engaged with the racial dynamics of the situation in some way.

The range of ways that students engaged with the content in these activities also demonstrated how it is vital that content relating to the social context of engineering, including DEIJ content specifically, occurs throughout a course, rather than just as a one-off activity. While there were many differences between the two courses we analyzed, the students in the introductory class had more exposure to the social context of engineering throughout their course. This repeated exposure may have been one factor that helped students engage with the activity we analyzed. Creating space for new content can be challenging because existing courses are already full of content. Our activities demonstrated that these types of content can be integrated into a course through teaching content differently, rather than replacing existing content. Additionally, these topics are vital. There may some other topics that can be compressed or that are traditionally part of a course but not as important to modern practice.

From a logistical standpoint, our students' responses from both courses also indicate that it is important to allot more time than you anticipate needing for these types of activities. Students may need more guidance in both pre-class and in-class activities than you expect, especially if they are used to having assignments that are focused on performing the correct calculation and an assignment requiring reading and reflection is comparatively new to them.

Broader Implications

In a larger sense, our results point to the need for a cultural change that refutes the culture of disengagement throughout the engineering curriculum. The students who wanted the activities to change to be more "engineering aligned" demonstrated this disengagement gap. Students need to conceptualize social context and DEIJ as **part of** engineering, not **apart from** engineering. We are harming students by teaching that social context and DEIJ are not part of engineering by making them less prepared to engage effectively as engineers. Many of the students in our study wrote about learning about the social context of engineering and expanding their perspective of what engineers do; these responses also demonstrated the manifestation of the Culture of Disengagement in the rest of their education, particularly in the materials course, where students were well into their engineering program; yet, these students found fairly basic assignments integrating the social context of engineering as novel. For students who want to have a social impact in their professional work, this lack of engagement may be giving them reason to doubt their desire to be engineers.

Interdisciplinary collaborations can help facilitate change, because engineering faculty have been enculturated to separate engineering from social context and DEIJ. However, DEIJ content needs to be part of the degree curriculum and be part of what is done across engineering departments. Our discussion of implementing activities in two different courses demonstrated the applicability of these strategies for multiple course contexts. Because social context and DEIJ topics aren't a one-off activity, instructors can make integrating social context and DEIJ into content a thread throughout both the semester and the entire curriculum of a degree. Currently, the burden of creating change falls disproportionately on instructors with marginalized identities, who already pay an "identity tax" on their student evaluations (Chávez & Mitchell, 2020; Fan et al., 2019; Kreitzer & Sweet-Cushman, 2022); making this the responsibility of all is an equity issue from the perspective of teaching students better as well as regarding the work instructors do.

Data Availability Statement

All data, models, or code generated or used during the study are proprietary or confidential in nature and may only be provided with restrictions. Due to IRB regulations, access to the data would require additional IRB review from both the authors' and requester's institutions.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant Number 1726268.

Disclaimer

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Supplemental Materials

A short description of the socially situated nature of STEM that students read as preparation for their assignments and Worksheet students completed as part of the Hurricane Katrina assignment are available online in the ASCE Library (www.ascelibrary.org).

References

Adedoyin, O. (2022, March 7). Do students self-censor? Here's what the data tell us. *The Chronicle of Higher Education*.

American Society of Civil Engineers. (2019). *Future World Vision: Infrastructure Reimagined* (p. 20). American Society of Civil Engineers.

American Society of Civil Engineers. (2022). *Code of Ethics*. ASCE. https://www.asce.org/career-growth/ethics/code-of-ethics

Archer, D. N. (2020). "White Men's Roads Through Black Men's Homes": Advancing Racial Equity Through Highway Reconstruction. *Vanderbilt Law Reviews*, *73*, 72.

Arciszewski, T., & Harrison, C. (2010). Successful Civil Engineering Education. *Journal of Professional Issues in Engineering Education and Practice*, *136*(1), 1–8. https://doi.org/10.1061/(ASCE)EI.1943-5541.12

Aronson, E. (2022). *The Jigsaw Classroom*. The Jigsaw Classroom. https://www.jigsaw.org/

ASCE. (2023). *American Society of Civil Engineers Strategic Plan*. ASCE. https://www.asce.org/-/media/files/asce-strategic-plan.pdf

Atadero, R. A., Paguyo, C. H., Rambo-Hernandez, K. E., & Henderson, H. L. (2018). Building inclusive engineering identities: Implications for changing engineering culture. *European Journal of Engineering Education*, *43*(3), 378–398. https://doi.org/10.1080/03043797.2017.1396287

Authors. (2020).

Bandura, A. (1997). *Self-efficacy: The exercise of control*. W.H. Freeman.

Baruch, Y., & Holtom, B. C. (2008). Survey response rate levels and trends in organizational research. *Human Relations*, *61*(8), 1139–1160. https://doi.org/10.1177/0018726708094863

Bearfield, D. A., & Dubnick, M. J. (2009). All mega-projects are local? Citizen participation lessons from the big dig. *Journal of Public Budgeting, Accounting & Financial Management*, *21*(3), 392–425. https://doi.org/10.1108/JPBAFM-21-03-2009-B003

Casper, A. M. A., Atadero, R. A., & Fuselier, L. C. (2022). Revealing the queer-spectrum in STEM through robust demographic data collection in undergraduate engineering and computer science courses at four institutions. *PLoS ONE*, *17*(3), e0264267. https://doi.org/10.1371/journal.pone.0264267

Casper, A. M. A., Atadero, R. A., Hedayati-Mehdiabadi, A., & Baker, D. W. (2021). Linking Engineering Students' Professional Identity Development to Diversity and Working Inclusively in Technical Courses. *Journal of Civil Engineering Education*, *147*(4), 04021012. https://doi.org/10.1061/(ASCE)EI.2643-9115.0000052

Casper, A. M. A., Atadero, R. A., & Siller, T. (2019, December 8). *Teaching the socially-situated nature of climate change science in technical STEM courses: A Hurricane Katrina case study*. American Geophysical Union Conference, San Francisco, CA.

Cech, E. A. (2014). Culture of Disengagement in Engineering Education? *Science, Technology, & Human Values*, *39*(1), 42–72. https://doi.org/10.1177/0162243913504305

Cech, E. A., & Sherick, H. M. (2015). Depoliticization and the Structure of Engineering Education. In S. H. Christensen, C. Didier, A. Jamison, M. Meganck, C. Mitcham, & B. Newberry (Eds.), *International Perspectives on Engineering Education* (Vol. 20, pp. 203–216). Springer International Publishing. https://doi.org/10.1007/978-3-319-16169-3_10

Chávez, K., & Mitchell, K. M. W. (2020). Exploring Bias in Student Evaluations: Gender, Race, and Ethnicity. *PS: Political Science & Politics*, *53*(2), 270–274. https://doi.org/10.1017/S1049096519001744

Cohn, D. (2017). *Seeking better data on Hispanics, Census Bureau may change how it asks about race*. Pew Research Center. http://pewrsr.ch/2oYVUMV

Crenshaw, K., Harris, L. C., HoSang, D., & Lipsitz, G. (Eds.). (2019). *Seeing race again: Countering colorblindness across the disciplines*. University of California Press.

Curran, F. C. (2023, March 28). Proposed legislation threatenes viewpoint diversity in higher education. *The Brookings Institution - Brown Center Chalkboard*.

Downey, G. L., & Lucena, J. C. (2004). Knowledge and professional identity in engineering: Code-switching and the metrics of progress. *History and Technology*, *20*(4), 393–420. https://doi.org/10.1080/0734151042000304358

Ekinci, S., & Şen, A. İ. (2020). Investigating grade-12 students' cognitive structures about the atomic structure: A content analysis of student concept maps. *International Journal of Science Education*, *42*(6), 977–996. https://doi.org/10.1080/09500693.2020.1744045

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, *62*(1), 107–115. https://doi.org/10.1111/j.1365-2648.2007.04569.x

Fan, Y., Shepherd, L. J., Slavich, E., Waters, D., Stone, M., Abel, R., & Johnston, E. L. (2019). Gender and cultural bias in student evaluations: Why representation matters. *PLOS ONE*, *14*(2), e0209749. https://doi.org/10.1371/journal.pone.0209749

Graneheim, U. H., Lindgren, B.-M., & Lundman, B. (2017). Methodological challenges in qualitative content analysis: A discussion paper. *Nurse Education Today*, *56*, 29–34. https://doi.org/10.1016/j.nedt.2017.06.002

Graneheim, U. H., & Lundman, B. (2004). Qualitative content analysis in nursing research: Concepts, procedures and measures to achieve trustworthiness. *Nurse Education Today*, *24*(2), 105–112. https://doi.org/10.1016/j.nedt.2003.10.001

Grigg, N. S. (2023). Root-Cause Analysis of Water System Failures in Jackson, Mississippi, and Flint, Michigan, Using the Institutional Analysis and Development Framework. *Journal of Performance of Constructed Facilities*, *37*(2), 04022081. https://doi.org/10.1061/JPCFEV.CFENG-4352

Hartman, H., Forin, T., Sukumaran, B., Farrell, S., Bhavsar, P., Jahan, K., Dusseau, R., Bruckerhoff, T., Cole, P., Lezotte, S., Zeppilli, D., & Macey, D. (2019). Strategies for Improving Diversity and Inclusion in an Engineering Department. *Journal of Professional Issues in Engineering Education and Practice*, *145*(2), 04018016. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000404

HDR. (2023). *Infrastructure Investment and Jobs Act Policy Brief #5: Equity and Environmental Justice*. HDR. https://www.hdrinc.com/sites/default/files/inline-files/hdr-advisory-services-iija-brief-equity-env-justice.pdf

Hughes, B. E., & Kothari, S. (2021). Don’t Be Too Political: Depoliticization, Sexual Orientation, and Undergraduate STEM Major Persistence. *Journal of Homosexuality*, 1–28. https://doi.org/10.1080/00918369.2021.1996101

Ihsen, S., & Gebauer, S. (2009). Diversity issues in the engineering curriculum. *European Journal of Engineering Education*, *34*(5), 419–424. https://doi.org/10.1080/03043790903137551

Institute for Sustainable Infrastructure. (2018). *Envision: Sustainable Infrastrcture Framework Guidance Manual* (p. 189). Institute of Sustainable Infrastructure.

Josa, I., & Aguado, A. (2021). Social sciences and humanities in the education of civil engineers: Current status and proposal of guidelines. *Journal of Cleaner Production*, *311*, 127489. https://doi.org/10.1016/j.jclepro.2021.127489

Kahn, B. (2022, April 4). The IPCC says we already have the tech tools to stop climate change. *Protocol*. https://www.protocol.com/climate/ipcc-renewable-technology-wind-solar

Karas, D. (2015). Highway to inequity: The disparate impact of the interstate highway system on poor and minority communities in American cities. *New Visions for Public Affairs*, *7*(April), 9–21.

Koretsky, M. D., Montfort, D., Nolen, S. B., Bothwell, M., Davis, S. C., & Sweeney, J. D. (2018). TOWARDS A STRONGER COVALENT BOND: PEDAGOGICAL CHANGE FOR INCLUSIVITY AND EQUITY. *Chemical Engineering Education*, *52*(2), 11.

Kreitzer, R. J., & Sweet-Cushman, J. (2022). Evaluating Student Evaluations of Teaching: A Review of Measurement and Equity Bias in SETs and Recommendations for Ethical Reform. *Journal of Academic Ethics*, *20*(1), 73–84. https://doi.org/10.1007/s10805-021-09400-w

Kuhn, K.-A. L., & Rundle-Thiele, S. R. (2009). Curriculum Alignment: Exploring Student Perception of Learning Achievement Measures. *International Journal of Teaching and Learning in Higher Education*, *21*(3), 351–361.

LaFave, J. M., Kang, H.-S., & Kaiser, J. D. (2015). Cultivating Intercultural Competencies for Civil Engineering Students in the Era of Globalization: Case Study. *Journal of Professional Issues in Engineering Education and Practice*, *141*(3), 05014008. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000234

Latham, A., & Layton, J. (2019). Social infrastructure and the public life of cities: Studying urban sociality and public spaces. *Geography Compass*, *13*(7), e12444. https://doi.org/10.1111/gec3.12444

Leicht-Scholten, C., Weheliye, A.-J., & Wolffram, A. (2009). Institutionalisation of gender and diversity management in engineering education. *European Journal of Engineering Education*, *34*(5), 447–454. https://doi.org/10.1080/03043790903137700

Leydens, J. A., & Lucena, J. C. (2018). *Engineering justice: Transforming engineering education and practice*. John Wiley & Sons ; IEEE Press.

Lieb, D. A. (2023, April 17). GOP states targeting diversity, equity efforts in higher ed. *The Associated Press*. https://apnews.com/article/diversity-equity-inclusion-legislation-7bd8d4d52aaaa9902dde59a257874686

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage Publications.

Mayring, P. (2015). Qualitative Content Analysis: Theoretical Background and Procedures. In A. Bikner-Ahsbahs, C. Knipping, & N. Presmeg (Eds.), *Approaches to Qualitative Research in Mathematics Education* (pp. 365–380). Springer Netherlands. https://doi.org/10.1007/978-94-017-9181-6_13

Mejia Manrique, S. A., Harmsen, E. W., Khanbilvardi, R. M., & González, J. E. (2021). Flood Impacts on Critical Infrastructure in a Coastal Floodplain in Western Puerto Rico during Hurricane María. *Hydrology*, *8*(3), 104. https://doi.org/10.3390/hydrology8030104

Morgan, D. L., Davis, K. B., & López, N. (2020). Engineering political fluency: Identifying tensions in the political identity development of engineering majors. *Journal of Engineering Education*, *109*(1), 107–124. https://doi.org/10.1002/jee.20300

Morgan, D. L., Zilvinskis, J., & Dugan, B. (2021). Opening the Activism and Postsecondary Education Black Box: Relating High-Impact Practices and Student Identity With Activist Behaviors. *Journal of Political Science Education*, *17*(1), 55–78. https://doi.org/10.1080/15512169.2019.1612248

National Institute for Standards and Technology. (2016). *Community Resilience Planning Guide for Buildings and Infrastructure Systems* (NIST Special Publication 1190, Volume I; p. 114). U.S. Department of Commerce. http://dx.doi.org/10.6028/NIST.SP.1190v1

Niles, S., Roudbari, S., & Contreras, S. (2020). Integrating Social Justice and Political Engagement into Engineering. *International Journal of Engineering, Social Justice, and Peace*, *7*(1), 57–69. https://doi.org/10.24908/ijesjp.v7i1.13568

Pauli, B. J. (2020). The Flint water crisis. *WIREs Water*, *7*(3). https://doi.org/10.1002/wat2.1420

Peixoto, A., Gonzalez, C. S. G., Strachan, R., Plaza, P., de los Angeles Martinez, M., Blazquez, M., & Castro, M. (2018). Diversity and inclusion in engineering education: Looking through the gender question. *2018 IEEE Global Engineering Education Conference (EDUCON)*, 2071–2075. https://doi.org/10.1109/EDUCON.2018.8363494

Polmear, M., Bielefeldt, A., Knight, D., Swan, C., & Canney, N. (2018). Faculty Perceptions of Challenges to Educating Engineering and Computing Students About Ethics and Societal Impacts. *2018 ASEE Annual Conference & Exposition Proceedings*, 30510. https://doi.org/10.18260/1-2--30510

Riley, D. (2003). Employing liberative pedagogies in engineering education. *Journal of Women and Minorities in Science and Engineering*, *9*(2), 137–158. https://doi.org/10.1615/JWomenMinorScienEng.v9.i2.20

Riley, D. (2008). Engineering and Social Justice. *Synthesis Lectures on Engineers, Technology and Society*, *3*(1), 1–152. https://doi.org/10.2200/S00117ED1V01Y200805ETS007

Riley, D., Pawley, A. L., Tucker, J., & Catalano, G. D. (2009). Feminisms in Engineering Education: Transformative Possibilities. *National Women's Studies Association Journal*, *21*(2), 21–40.

Rottmann, C., & Reeve, D. (2020). Equity as Rebar: Bridging the Micro/Macro Divide in Engineering Ethics Education. *Canadian Journal of Science, Mathematics and Technology Education*, *20*(1), 146–165. https://doi.org/10.1007/s42330-019-00073-7

Rulifson, G., & Bielefeldt, A. (2017). Motivations to Leave Engineering: Through a Lens of Social Responsibility. *Engineering Studies*, *9*(3), 222–248. https://doi.org/10.1080/19378629.2017.1397159

Russell, J. S., & Stouffer, W. B. (2005). Survey of the National Civil Engineering Curriculum. *Journal of Professional Issues in Engineering Education and Practice*, *131*(2), 118–128. https://doi.org/10.1061/(ASCE)1052-3928(2005)131:2(118)

Seron, C., Silbey, S., Cech, E., & Rubineau, B. (2018). “I am Not a Feminist, but. . .”: Hegemony of a Meritocratic Ideology and the Limits of Critique Among Women in Engineering. *Work and Occupations*, *45*(2), 131–167. https://doi.org/10.1177/0730888418759774

Shetterly, M. L. (2017). *Hidden figures: The American Dream and the untold story of the black women mathematicians who helped win the space race* (First William Morrow paperback edition). William Morrow, an imprint of HarperCollins Publishers.

Sills, G. L., Vroman, N. D., Wahl, R. E., & Schwanz, N. T. (2008). Overview of New Orleans Levee Failures: Lessons Learned and Their Impact on National Levee Design and Assessment. *Journal of Geotechnical and Geoenvironmental Engineering*, *134*(5), 556–565. https://doi.org/10.1061/(ASCE)1090-0241(2008)134:5(556)

Stemler, S. E. (2004). *A Comparison of Consensus, Consistency, and Measurement Approaches to Estimating Interrater Reliability*. *9*(4). https://doi.org/10.7275/96JP-XZ07

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, *6*(2), 203–218. https://doi.org/10.1007/s11625-011-0132-6

Williams, S. A. S., & Conyers, A. (2016). Race Pedagogy: Faculty Preparation Matters. *Administrative Theory & Praxis*, *38*(4), 234–250. https://doi.org/10.1080/10841806.2016.1239396

Appendix A: An Introduction to the Social-Situated Nature of STEM

An understanding of social issues may seem far removed from the technical skills needed to design a bridge, describe molecular movement, or study ecosystem function. A physical object like a bridge may be thought of narrowly, as something made of materials and designed for a goal, such as holding a specific load while minimizing costs. But, bridges also make connections between people.

Practices in STEM fields are rooted in values and assumptions, which may be explicitly stated but often are not. For example, many bridges prioritize vehicle traffic over pedestrian or bicycle traffic, and bridge location influences who and what is impacted during construction and how easily different people can travel. The situated nature of bridges and roads becomes a life-and-death context in situations such as the evacuation of New Orleans for Hurricane Katrina, where the assumptions made during infrastructure development interacted with a climate-change driven hurricane and many other factors to prevent the effective evacuation of people without access to cars and who lived in particular areas.

The people who designed the infrastructure of New Orleans did not set out to consciously limit who could leave. However, in all aspects of our lives, including how we think about and do STEM-related activities, we are influenced by our life experiences and our assumptions about a situation influence the factors we consider, and if we are not being intentionally inclusive, we may be inadvertently exclusive. It is not possible for the knowledge we possess to exist outside of our experiences; therefore, our knowledge is situated within our experiences, and cannot be neutral or decontextualized. While we can work to move beyond our own limited perspective by specifically seeking different perspectives and thinking about the needs of those who are different from ourselves, we still cannot be neutral. While neutrality is often claimed in STEM fields, this claimed neutrality erases the context in which knowledge is created and used (Harding, 1992; Tuana, 1996). What is usually considered "neutral" in STEM fields is situated in Western ways of thinking and doing science (Wilson, 2008). Questions surrounding benefit – how will something help, who needs to be able to use it – as well as questions about potential harm – who will be harmed or excluded, what is the larger environmental and social impact, and who decides what tradeoffs are most important – may be considered from only one or few perspectives.

Due to the culturally embedded nature of everything, including STEM, STEM activities manifest existing biases that benefit those in power (Tuana, 1996). Gender, race, ethnicity, abilities, social class, age, language and other factors play an important role in how people have access to resources (Finch et al., 2010; Laska & Morrow, 2006). The biases and power dynamics that influence ecological system function and people's access to resources are already being exacerbated by climate change, which will only increase as we move through the 21st century (Rockstrom et al., 2009). One way this manifests is in the increasing frequency of 'natural disasters' combined with limitations in accessing needed resources for survival (Rockstrom et al., 2009). It is vital that we consider the situated nature of science and engineering as we work to address both the root causes of climate change, as well as the ways we address existing social, environmental, and infrastructure challenges and plan for the future. To move toward equitable STEM practices and confront climate change we must not only reflect upon how our identities influence our own perspectives and decision-making, but also create space for collaborative work that includes all the voices of those involved, rather than working from a controlling, top-down strategy (Reid et al., 2009; Tengö et al., 2014). Addressing inequities in our existing physical and social structures will not happen if outsiders drop in to fix only the problems they identify; rather, this collaborative work must shift existing power structures to create space and power for all involved (Straubhaar, 2015; Tengö et al., 2014).

References

Finch, C., Emrich, C. T., & Cutter, S. L. (2010). Disaster disparities and differential recovery in New Orleans. *Population and Environment*, *31*(4), 179–202. https://doi.org/10.1007/s11111-009-0099-8

Harding, S. (1992). Rethinking standpoint epistemology: What is "strong objectivity?" *The Centennial Review*, *36*(3), 437–470.

Laska, S., & Morrow, B. H. (2006). Social vulnerabilities and Hurricane Katrina: An unnatural disaster in New Orleans. *Martine Technology Society Journal*, *40*(4), 16–26.

Reid, R. S., Nkedianye, D., Said, M.Y., Kaelo, D., Neselle, M., Makui, O., Onetu, L., Kiruswa, S., Kamuaro, N. O., Kristjanson, P., Ogutu, J., BurnSilver, S. B., Goldman, M. J., Boone, R. B., Galvin, K. A., Dickson, N. M., & Clark, W. C. (2009). Evolution of models to support community and policy action with science: Balancing pastoral livelihoods and wildlife conservation in savannas of East Africa. *PNAS*, 6. https://doi.org/10.1073/pnas.0900313106

Rockstrom, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sorlin, S., Snyder, P. K., Costanza, R., Svedin, U., … Foley, J. A. (2009). A safe operating space for humanity. *Nature*, *461*(24), 472–475.

Straubhaar, R. (2015). The stark reality of the 'White Saviour' complex and the need for critical consciousness: A document analysis of the early journals of a Freirean educator.

Compare: A Journal of Comparative and International Education, *45*(3), 381–400. https://doi.org/10.1080/03057925.2013.876306

Tengö, M., Brondizio, E. S., Elmqvist, T., Malmer, P., & Spierenburg, M. (2014). Connecting Diverse Knowledge Systems for Enhanced Ecosystem Governance: The Multiple Evidence Base Approach. *AMBIO*, *43*(5), 579–591. https://doi.org/10.1007/s13280-014-0501-3

Tuana, N. (1996). Revaluing science: Starting from the practicies of women. In J. Nelson (Ed.), *Feminism, Science, and the Philosophy of Science* (pp. 17–35). Springer.

Wilson, S. (2008). *Research is Ceremony: Indigenous research methods*. Fernwood Pub.

Appendix B: Hurricane Katrina Case Study Follow-up Questions

1) Will what you learned from this activity affect the way you work in teams for future engineering projects? Please Explain why or why not.

2) What did you learn from this activity?

3) What did you like about this activity?

4) What would you suggest to improve this activity?

Supplementary Materials 1: An Introduction to the Social-Situated Nature of STEM

An understanding of social issues may seem far removed from the technical skills needed to design a bridge, describe molecular movement, or study ecosystem function. A physical object like a bridge may be thought of narrowly, as something made of materials and designed for a goal, such as holding a specific load while minimizing costs. But, bridges also make connections between people.

Practices in STEM fields are rooted in values and assumptions, which may be explicitly stated but often are not. For example, many bridges prioritize vehicle traffic over pedestrian or bicycle traffic, and bridge location influences who and what is impacted during construction and how easily different people can travel. The situated nature of bridges and roads becomes a life-and-death context in situations such as the evacuation of New Orleans for Hurricane Katrina, where the assumptions made during infrastructure development interacted with a climate-change driven hurricane and many other factors to prevent the effective evacuation of people without access to cars and who lived in particular areas.

The people who designed the infrastructure of New Orleans did not set out to consciously limit who could leave. However, in all aspects of our lives, including how we think about and do STEM-related activities, we are influenced by our life experiences and our assumptions about a situation influence the factors we consider, and if we are not being intentionally inclusive, we may be inadvertently exclusive. It is not possible for the knowledge we possess to exist outside of our experiences; therefore, our knowledge is situated within our experiences, and cannot be neutral or decontextualized. While we can work to move beyond our own limited perspective by specifically seeking different perspectives and thinking about the needs of those who are different from ourselves, we still cannot be neutral. While neutrality is often claimed in STEM fields, this claimed neutrality erases the context in which knowledge is created and used (Harding, 1992; Tuana, 1996). What is usually considered "neutral" in STEM fields is situated in Western ways of thinking and doing science (Wilson, 2008). Questions surrounding benefit – how will something help, who needs to be able to use it – as well as questions about potential harm – who will be harmed or excluded, what is the larger environmental and social impact, and who decides what tradeoffs are most important – may be considered from only one or few perspectives.

Due to the culturally embedded nature of everything, including STEM, STEM activities manifest existing biases that benefit those in power (Tuana, 1996). Gender, race, ethnicity, abilities, social class, age, language and other factors play an important role in how people have access to resources (Finch et al., 2010; Laska & Morrow, 2006). The biases and power dynamics that influence ecological system function and people's access to resources are already being exacerbated by climate change, which will only increase as we move through the 21st century (Rockstrom et al., 2009). One way this manifests is in the increasing frequency of 'natural disasters' combined with limitations in accessing needed resources for survival (Rockstrom et al., 2009). It is vital that we consider the situated nature of science and engineering as we work to address both the root causes of climate change, as well as the ways we address existing social, environmental, and infrastructure challenges and plan for the future. To move toward equitable STEM practices and confront climate change we must not only reflect upon how our identities influence our own perspectives and decision-making, but also create space for collaborative work that includes all the voices of those involved, rather than working from a controlling, top-down strategy (Reid et al., 2009; Tengö et al., 2014). Addressing inequities in our existing physical and social structures will not happen if outsiders drop in to fix only the problems they identify; rather, this collaborative work must shift existing power structures to create space and power for all involved (Straubhaar, 2015; Tengö et al., 2014).

References

Finch, C., Emrich, C. T., & Cutter, S. L. (2010). Disaster disparities and differential recovery in New Orleans. *Population and Environment*, *31*(4), 179–202. https://doi.org/10.1007/s11111-009-0099-8

Harding, S. (1992). Rethinking standpoint epistemology: What is "strong objectivity?" *The Centennial Review*, *36*(3), 437–470.

Laska, S., & Morrow, B. H. (2006). Social vulnerabilities and Hurricane Katrina: An unnatural disaster in New Orleans. *Martine Technology Society Journal*, *40*(4), 16–26.

Reid, R. S., Nkedianye, D., Said, M.Y., Kaelo, D., Neselle, M., Makui, O., Onetu, L., Kiruswa, S., Kamuaro, N. O., Kristjanson, P., Ogutu, J., BurnSilver, S. B., Goldman, M. J., Boone, R. B., Galvin, K. A., Dickson, N. M., & Clark, W. C. (2009). Evolution of models to support community and policy action with science: Balancing pastoral livelihoods and wildlife conservation in savannas of East Africa. *PNAS*, 6. https://doi.org/10.1073/pnas.0900313106

Rockstrom, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sorlin, S., Snyder, P. K., Costanza, R., Svedin, U., … Foley, J. A. (2009). A safe operating space for humanity. *Nature*, *461*(24), 472–475.

Straubhaar, R. (2015). The stark reality of the 'White Saviour' complex and the need for critical consciousness: A document analysis of the early journals of a Freirean educator.

Compare: A Journal of Comparative and International Education, *45*(3), 381–400. https://doi.org/10.1080/03057925.2013.876306

Tengö, M., Brondizio, E. S., Elmqvist, T., Malmer, P., & Spierenburg, M. (2014). Connecting Diverse Knowledge Systems for Enhanced Ecosystem Governance: The Multiple Evidence Base Approach. *AMBIO*, *43*(5), 579–591. https://doi.org/10.1007/s13280-014-0501-3

Tuana, N. (1996). Revaluing science: Starting from the practicies of women. In J. Nelson (Ed.), *Feminism, Science, and the Philosophy of Science* (pp. 17–35). Springer.

Wilson, S. (2008). *Research is Ceremony: Indigenous research methods*. Fernwood Pub.

Supplementary Materials 2: Hurricane Katrina Case Study Follow-up Questions

1) Will what you learned from this activity affect the way you work in teams for future engineering projects? Please Explain why or why not.

2) What did you learn from this activity?

3) What did you like about this activity?

4) What would you suggest to improve this activity?