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Perspectives of Seven Minoritized Students in a First-Year Course Redesign toward Sociotechnical Engineering Education

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Abstract

The social/technical dualism in the engineering curriculum leaves students ill-prepared to tackle real-world technical problems in their social, economic, and political contexts (Cech, 2013; Faulkner, 2007; Trevelan, 2010, 2014). Increasingly, students have expressed the desire for their technical courses to show the interplay between social and technical considerations (Leydens & Lucena, 2017), but they have few opportunities to develop these sociotechnical ways of thinking (i.e., values, attitudes, and skills that integrate the social and technical). Instead, students are left to infer engineering as technically neutral through the instructional decisions that make up an engineering curriculum (Cech, 2013; Trevelan, 2014).

In this study, we focus on how students understand the role of sociotechnical thinking in engineering. Particularly, this study centers seven minoritized students in an introductory engineering computation class who are pursuing an engineering degree. The study takes place at a medium private university in New England. These seven students are from a group of roughly seventy students split between two of the five sections for the course. These two sections were recently revised to include more sociotechnical readings, discussions, and homework facilitated with learning assistants. We are interested in understanding the self-described sense of belonging that these students feel as they relate it to learning about engineering as a sociotechnical field.

While the dualism between engineering's technical and social dimensions has been studied in ASEE LEES papers, articles in Engineering Studies, broader engineering education research, and Science, Technology, and Science publications (e.g., Cech, 2013; Faulkner, 2007; Leydens & Lucena, 2017; Riley, 2017; Wisnioski, 2012), there is a need to connect this vast literature with the similarly extensive research on students' sense of belonging and engineering identity development, specifically for those students who have historically been excluded from engineering. Specifically, we draw on W.E.B. DuBois's notion of a 'double consciousness' from the *Souls of Black Folks* (1903) as a lens through which to understand how these seven students take on the political, economic, and social dimensions presented to them through a first-year engineering curricular redesign around engineering *as* sociotechnical.

We note the small-n design of this study (Slaton & Pawley, 2018). The seven interviewed students are gender and racial minorities in engineering. However, we note that they do not represent all minoritized students in engineering, and to respect and elevate their experiences, we take a narrative approach. This study is intended to center the perspectives and experiences of these seven students as they navigate an engineering learning environment. We do not intend for the findings to be generalizable or exhaustive but informative as we think about scaling up the sociotechnical curricular redesign in engineering at this university and more broadly.

Introduction

> "Basically, like, I think that you really need as engineers to, like, consider perspectives that are not our own, to really like, understand that the world is a place full of diverse people and diverse circumstances, and situations, right. And like, it'll one, make you better as an engineer, right? […] And two, it'll make you a better human being" [Luca, first year engineering student, see Table 1].

Historically, engineering has advocated for diversity in engineering under the promise that broadening STEM participation would lead to more innovation and domestic economic growth. These neoliberal and assimilationist justifications for diversity in engineering are rooted in deficit narratives of minoritized individuals (Lucena & Smith, 2016; Lee, Knight, & Cardella, 2020). In a similar vein, STEM education discourses tout social mobility gains as a key benefit of outreach programs that target students from minoritized backgrounds, with STEM positioned as primarily a path for upward economic mobility (Lucena, 2005; Vakil & Ayers, 2019). These deficit-model discourses portray engineering as an unchanging, neutral discipline that requires individual students to assimilate into rather than as a discipline that changes and evolves to reflect the society in which it sits. Indeed, we see engineering discourse perpetuate the exclusionary and harmful ideologies upon which it was built (Noble, 1979; Riley, 2019; Slaton, 2015).

In this paper, we contend that the engineering curriculum and its implicit value system need revision if we are to broaden participation meaningfully and in a non-assimilationist manner. To this, we ask, how can we, as engineering educators, make meaningful changes to curriculum that will instill a sense of belonging for minoritized students in engineering, which places value on who they are as people? As Luca, a self-identifying queer engineering student, states in the quote above, engineering education that brings in different perspectives and values helps people become better engineers and better humans.

In this study, we focus on students' sense of belonging as it relates to their sociotechnical impressions of engineering. These students participated in a recently revised introductory engineering computation course that strives to position engineering as a sociotechnical endeavor. Through a series of interviews, we seek to understand students' self-described senses of belonging as they learn about engineering as a sociotechnical field.

Who was engineering for?

To situate the impressions and experiences of the seven students from minoritized identities, we look first to who, historically, has belonged in engineering. Matt Wisnioski, in his historical analysis of the engineering profession through the Cold War era, details the engineers' progression from "systems builders to servants to the system" (2012, p. 15). In the early 1960s, the engineers were "dark-suited, short-sleeved, nondescript, white men with black-rimmed glasses. College-educated residents of suburbia; they lived in artificial environments and worked in vast teams with narrow responsibilities" (Wisnioski, 2012, p. 16). Additionally, this was the time of the Cold War era, in which hands-on, practical education was less valued in the engineering curriculum, which instead was made up of heavy science and theory-focused courses (Seely, 1999; Noble, 1979).

During this time, increases in federal funding for science and engineering research changed the trajectory and size of engineering departments across the U.S. As a result of this rise in funding, engineering departments sought to develop engineering scientists, thus valuing the rigor, objectivity, and prestige of science over practical and materials testing-type research (Seely, 1999; Noble, 1979) as well as ways of knowing in the humanities and liberal arts (Solovey,

2020). From these shifts towards the *scientification* of knowledge, engineering took on notions of objectivity and neutrality that elevated its knowledge and those who produced this knowledge (Noble, 1979).

Broadening Participation in Engineering

As the engineering curriculum took on notions of objectivity, there were also efforts to increase the diversity of who became an engineer. These efforts were primarily measured by counts of minority representation. The metrics cited across many broadening participation reform efforts consisted of enrollment numbers and graduation numbers across gender and demographic data. One IEEE article from 1974 discussed three programs in engineering education on the basis of "alleviating the shortage of minority representatives in the engineering profession" (Hartford, 1974, p. 50). These numbers of representation have been tracked since these broadening participation efforts first began (Holloman, Lee, London, et al., 2018). Despite an incredibly financial and human effort that has gone into improving representation in engineering, there remains a lack of significant gains in numbers of minority representation in engineering.

Even with decades of efforts to address the racial and gender gaps, there remains a significant gap in who studies engineering. Only 4.3% and 11.4% of engineering degrees were awarded to Black/African American and Hispanic/Latinx students, respectively, in 2018 (ASEE, 2019). Notably, the number of Black/African American engineering graduates had been in decline from 2008 to 2016. The small upward trend from 4.1% in 2017 to 4.2% in 2018 is an improvement in that it reverses the previous trend. These graduation rates have been quite stark when broken down by gender. In 2016, Black women made up only 1% of engineering degrees awarded (7% and 2.3% for Hispanic and Latina women) (ASEE, 2017). These numbers are a result of both lower initial recruitments to engineering and lower retention once in engineering programs. While, on average, nearly 59% of students who enter undergraduate engineering programs graduate with an engineering degree within six years, only 45% of Hispanic/Latinx students and 36% of Black/African American students do so (ASEE, 2017). Thus, while these students were interested in engineering when they entered college, they may not have developed a professional engineering identity as readily as their white male peers (Meyers, Ohland, Pawley, Silliman, & Smith, 2012).

Scholars have pointed to the split identity students from minoritized backgrounds can feel when they enter an educational environment that homogenizes their lived experiences with the dominant group. Malazita and Resetar (2019) discuss their sociotechnical computer science course designed to address minoritized students' experiences of split identity. In a similar vein, Amy Slaton points out that the countless resources spent on increasing access for historically excluded students in engineering are at odds with engineering ideologies that depict the field as meritocratic, neutral, and objective (Slaton, 2015). These perspectives can be difficult to parse for students (and faculty) who have lived experiences that counter the alleged neutrality of engineering. Science, Technology, and Society (STS) scholar Ruha Benjamin highlights the many ways engineering applications have perpetuated and reinforced racist outcomes because they sit on allegedly neutral decisions made by engineers with narrow lived experiences or without a critical understanding of history and power relations (2019).

Double Consciousness and the Role(s) of Education

Contemporary theories around identity development and sense of belonging are not dissimilar from those articulated by W.E.B. Du Bois in *Souls of Black Folks* in 1903. Du Bois was a sociologist, historian, and Black liberation activist whose arguments around self and education resonate deeply today. We draw on his notions of *double-consciousness* in education, which he describes in the *Souls of Black Folks*:

> *"A peculiar sensation, this double-consciousness, this sense of always looking at one's self through the eyes of others, of measuring one's soul by the tape of a world that looks on in amused contempt and pity. One ever feels his twoness,-an American, a* [Black person]*; two souls, two thoughts, two unreconciled strivings; two warring ideals in one dark body, whose dogged strength alone keeps it from being torn asunder"* (1903, p. 6).

For context, Du Bois wrote *The Souls of Black Folks* "in the midst of… overpowering segregationist discourse" (Kendi, 2016, p. 291). According to Kendi, with this book, Du Bois made Americans "listen to the strivings in the souls of black folk"—celebrating and centering the lived experiences of Black folk in this time (2016, p. 291).

One of the essays in *Souls of Black Folks* was a case against "Mr. Booker T. Washington and Others," critiquing Washington's emphasis on uplift suasion through industrial education for Black folks (Du Bois, 1903, p. 33). Du Bois' response to Washington's model of education for Black people is one that resonates with models of education today:

> *I insist that the object of all true education is not to make* [people] *carpenters, it is to make carpenters* [people]*; there are two means of making the carpenter a* [person]*, each equally important: the first is to give the group and community in which* [they] *works, liberally trained teachers and leaders to teach* [them] *and his family what life means; the second is to give* [them] *sufficient intelligence and technical skill to make* [them] *an efficient workman*" (Du Bois, 1903, p. 200; edited to be gender-inclusive).

In an engineering context, these critiques of developing people into engineers versus engineers into people still resonate. Booker T. Washington pushed industrial education and "uplift suasion," while W.E.B. Du Bois critiqued these efforts as assimilationist and only 'elevating' Black people economically under a system that still only serves the dominant majority (Kendi, 2016, p. 267). These arguments on the role of education from the early 20th century have their own historical context that differs from current education reform initiatives, but many of the core tenets that make up the arguments are still prominent ideologies that influence engineering and STEM education broadly. For instance, Costanza-Chock in *Design Justice* extends Du Bois' critique to the education of coding. In her book, she poses a similar question for coders:

> *"Following Du Bois, we might ask of the recent emphasis on learning to code: Is the ultimate object to make people good coders, or to make coders good people?"* (Costanza-Chock, 2020, p. 29).

The question of educating one to do a profession versus educating one in their humanity reveals different economic paradigms. When education turns people into carpenters or coders, value is

placed on their professional or economic contribution to society rather than their humanity. This assimilationist model of education operates under a neoliberal paradigm, in which people are reduced to their economic metrics. Consequently, the problem of social inequality is understood as economic inequality in which the solution becomes education that can promise higher salaries. Sengupta-Irving and Vossoughi call this "the politics of respectability in STEM, in which persons devalued in society will be valued when they reflect what the market values (e.g., STEM skills), as a way to end racialized poverty by gaining power within capitalism" (Sengupta-Irving & Vossoughi quoted in Vakil & Ayers, 2019, p. 452).

In the introduction to this special issue of *Race Ethnicity and Education,* Vakil and Ayers problematize how institutions have positioned STEM as the "key in mitigating decades of structural inequality" (2019, p. 450). In parallel to Du Bois' critiques of industrial education for upward suasion, Vossoughi and Vakil (2018) pose a critique of STEM, asking, "STEM Towards what ends?" These authors challenge STEM educators to make the unspoken political and economic goals of expanding STEM education explicit (Vossoughi & Vakil, 2018), which Sengupta-Irving and Vossoughi also point out as making known "the inextricable link between STEM learning, national economic gain, and global ascendancy" (2019, p. 480). However, this positioning of STEM for upward suasion and economic productivity is assimilationist and reduces people into their would-be profession.

Much of the DEI effort in engineering education has sought to increase the number of minoritized populations in engineering without necessarily bringing change to the STEM curriculum and implicit value systems it purports. Broadly speaking, STEM education ignores histories of science as well as the "myriad ways in which scientific knowledge and forms of racialized power have co-constructed one another historically and in the present" (Vakil & Ayers, 2019, p. 454). Without this sociotechnical analysis, students are left without the tools to bring their own subjectivity and lived experiences into their developing STEM identity. To date, "being a 'STEM person'" has consisted of a narrow definition of identity (Vakil & Ayers, 2018, p. 455). To combat this rigidity, Vakil and Ayers invite STEM educators to:

> "Imagine the possibilities that open when being a 'STEM person' (as a programmer, student, teacher, scientist, engineer, technician, or professor) invites a world view and set of cultural, ecological, and societal storylines that are synergistic with the kinds of values, morals, and ethics associated with participation in historical resistance and freedom struggles. One can be a scientist or engineer and a community activist without irony or pause. Or a political engineer, for instance, whose curiosity and pursuit of technical knowledge and understanding is always guided by a motivation to imagine and design new technologies that resists oppression and empowers marginalized groups in society" (2018, p. 454-455).

To invite such synergistic identity development of students, particularly for minoritized students, educators can bring different ways of knowing in STEM to contextualize the dominant representations of 'settler' science and engineering (Bang & Medin, 2014; Haraway, 1991; Star 1999; Kimmerer, 2013). In addition to curricular changes, we must center the experiences of minoritized students such that they feel embraced and valued by engineering culture rather than tokenized and vulnerable (Vakil & Ayers, 2018). Ultimately, re-envisioning an engineering curriculum that seeks to cultivate engineers *as* people is not one that "just bring[s] learners into existing engineering practices, structures, and ways of knowing" (McGowan & Bell, 2020, p.

981). Instead, we work to engage students in learning experiences that introduce them to and extend their knowledge of different epistemologies in STEM so that they can become *people* who are political engineers or science activists if they so choose. In this study, we choose to center the experiences of minoritized students as they engage in an introductory engineering computation course with sociotechnical curricula.

Research Methods

The scope of this research is to focus on the experiences and sociotechnical thinking of seven students who enrolled in the two sections of the "Introduction to Computing for Engineering" course with the sociotechnical curricular additions. We relied on tenets of phenomenology (Moustakas, 1994) to understand students' sense of belonging and sociotechnical understandings of engineering. This approach allows for greater breadth with the phenomena—*belonging* in engineering and engineering as *sociotechnical*—that center the students' varied lived experiences. Overall, this study investigates these seven students' self-described sense of belonging and engineering identity as it pertains to the engineering curriculum—whether it is comprised of integrated social and technical knowledge or decontextualized technical content.

Research Setting and Participants

The study is situated in a first-year engineering computation course at a medium-sized private university in New England. The course is taken by the majority of students majoring in an engineering discipline and is split up into five sections with five distinct faculty instructors. Our participants for this study included seven self-identified racial and gender minorities pursuing an engineering undergraduate degree.

Course: 'Introduction to Computing for Engineering'

The course that the students were enrolled in was part of a pilot project targeting two of the five sections of the course. In the piloted two sections, we introduced sociotechnical curricular modules across a 15-week semester. Previously, this course included solely technical content in which students learned the basics of a coding language, such as Python, and some core principles of data science. In the 'sociotechnical' sections, we introduced three types of curricular revisions. The first and most common was a weekly 'Computing in the World" discussion, in which students read articles that discussed social, political, and economic dimensions of an engineering or technological development. The second addition was a weeklong case study around public transportation ridership. The third aspect of the curricular redesign was an additional requirement to the final proposal and project that includes social, political, and economic discussions of the problem and solution area that students chose to explore.

Through these changes, we worked to emphasize how human decisions are often rendered invisible in engineering work, with the intention that students would engage with the subjectivity and alleged neutrality embedded in engineering. Additionally, in highlighting decisions in engineering, we sought to highlight decisions in the engineering curriculum that opened a historical window into the sociopolitical shaping of engineering education. We take heed of Vossoughi and Vakil's charge to bring "historicized approaches to STEM education that invite students to interrogate the genealogy of STEM concepts and their uses and that define STEM fields as shaped by sociopolitical contexts and values" (2018, p. 135).

Data Collection and Analysis

Data was collected via semi-structured interviews. The interviewers were two undergraduate researchers who had formerly worked as Learning Assistants (LA) in the course. As learning assistants, these undergraduate researchers were familiar with the setup of the course, the goals of the sociotechnical discussions, and how the students generally responded to the discussions. However, we did not want them to interview the students they acted as LAs for, so they interviewed first-year students from the opposite section. The interview was the first time the undergraduate researcher and engineering computation student had met. The interviews were conducted with students who had completed either of the two sociotechnical computation sections in introductory engineering computation. A total of seven students were interviewed from a sample of seventy students enrolled in the two sections. Each of the interviews was conducted over Zoom during the summer following the semester of the course. The interviews were audio and video recorded using Zoom software. IRB approval was obtained for this study.

We note here that each of the students who self-selected to be interviewed is of gender and/or racial minority in engineering. While self-selection bias is prevalent and a limitation of this study, we note the significance of this overrepresentation of minoritized students electing to be interviewed on a project around sociotechnical and justice-oriented engineering education.

Table 1. Interviewed student pseudonyms and self-described identities

Pseudonym	**Student Self-Descriptors**
Michelle	Student of color, woman, engineering, second year
Alex	Student of color, man, engineering, first year
Ava	Student of color, woman, engineering, first year
Charlotte	White, woman, engineering, first year
Luca	Student of color, non-binary, engineering, first year
Karis	Student of color, woman, engineering, first year
Elijah	Student of color, man, engineering, first year

The analysis of the interviews was based on broad categories around student conceptions of engineering and their sense of belonging. We were interested in how seeing engineering as sociotechnical might influence their sense of belonging in engineering. Drawing from the literature on engineering cultures, engineering as sociotechnical, and sense of belonging, the first author used an iterative inductive coding strategy to generate five themes—engineering as sociotechnical, inclusion & exclusion in engineering, engineers as people, sociotechnical engineering & sense of belonging, and sociotechnical topics across the curriculum. We do not contend that these themes are distinct categories. We use them to organize the students' experiences around broader categories of belonging with a curriculum that posits engineering as sociotechnical.

Findings

Engineering as Sociotechnical

These seven students reflected on their experiences with the revised aspects of the introductory computation course in various ways. Michelle, a female-identifying student of color who recently transferred into the school of engineering, pointed to the role sociotechnical discussions played in her learning python. She notes that the "discussions […] at the beginning of every class, frame the class in a different way than if the professor just taught coding all the time… When you put the discussion in front of [the coding], I can see a bigger goal that my coding can contribute towards, instead of just this is the coding problem I have to solve" [Michelle]. For Michelle, the discussions of the social dimensions of computation motivated and helped her see how coding might play a role in society based on the 'Computing in the World' discussions.

Ava, a first-year woman of color, notes that the discussions "did open [her] eyes to thinking about engineering more broadly in the sense of people that are actually going to use those products that engineers make." A different student, Charlotte, talked about her realizations about bias: "bias can be so hidden but is often there" [Charlotte]. Charlotte is a white student who identifies as female. She notes how she "didn't really realize before how science isn't as objective as we think about it" and is "really conscious of that and what [she does] now" [Charlotte].

For Elijah, a male-identifying student of color, the sociotechnical discussions were welcome because he had "always thought of engineering as sociotechnical, but felt like the [past] courses [he] was taking didn't." He specifies further by saying that he "really liked discussing how these things [referencing computation] affect people […] because going into the real world and taking that knowledge but not knowing how it affects people is always going to produce harm." Elijah emphasizes that "we all have certain biases, or like, just ignorant of certain things. […] STEM is not enough to actually help people in the best ways possible." In his interview, Elijah reflects on his observations of what the engineering curriculum has been missing and how its lack of societal discussions will produce harm.

Elijah also touches on engineering as "a problem-solving field that aims to help different communities." He offers a critique of this help by saying, "I feel like we never talk about how we can help different communities and how different communities are affected by our solutions." Continuing on, he states that he "just really hates the idea that one solution fixes everything the same way. Because that's how tons of people like don't get the support that they need, or like are harmfully affected, like racial bias in like A.I. or medicine, or like, design not being like accessible to people or like disabled people." Ultimately, he wraps up this thought by saying that he "thinks if we learn more about equity, especially early on in engineering, there would just be a lot better products in the world that'd be able to help more kinds of people." Students discussed how engineering can help improve the "quality of life" of different people, but not solely by "improving your technological quality of life" but instead by thinking about how "engineering can help with inequalities" and the "social aspects of society."

These students exhibit a range of responses, in which each of them reflects on a different learning experience they had based on the same sociotechnical discussions in the introductory computation class. Students come from different places in their thinking about engineering as sociotechnical and engineering's relationship with inequity.

Inclusion & Exclusion of Engineering

For some students, these reflections on engineering evolved into reflections on the engineering curriculum, who it attracts, and who perseveres. Luca's notions of who pursues engineering is based on who is discouraged:

> "A lot of people are, like, often discouraged to do engineering. And that's just because, you know, they believe it to be like, math, science, like more math, and get scared of that. But I kind of wish people would see it as like a, like a study where you're learning like different things. Not only like, math and science is more than that. It's more like about you know, like you, you're learning something, and you're applying it to real world like situations." [Luca].

For Luca, the emphasis on math and science is clear for a path into engineering, but they note that this social expectation acts as a deterrent for many others. Alex, a male-identifying student of color, emphasizes more meritocratic ideologies when asked, 'Who can and should go into engineering:"

> "I mean, I would say anyone, um, you know, I didn't really, I didn't come from a really good high school. I probably came from, like, one of the worst in the country. But, you know, here I am trying my hardest, like, with engineering, and I feel like, it's just like, anyone can do it, you just have to have like, the dedication and like, the, the commitment to do it. Yeah, it's, it's never like skill-wise, or it's never like, what, you know, it's more like, Are you willing to put in the energy and the work? And it's a process, but, you know, you eventually get there." [Alex]

Both of these students hold up engineering (with an emphasis on math and science) as rigorous and daunting. In the second quote, the student brings in meritocracy, where hard work and energy are the ingredients to success. The counterexample, however, is that unsuccessful endeavors can be construed as the lack of hard work and energy rather than systemic inequities that make hard work and energy negligible.

Engineers as People

Themes around what *engineering* is and isn't were prominent in the student interviews. In addition to the reflections on who persists in engineering broadly, the students discussed their development as humans in relation to what is involved in learning engineering. Many of these students note how their definitions of engineering expanded to include more social dimensions, which include discussions of developing as an engineer *and* as a human. Specifically, one student noted the importance of learning to be engineers as well as "actual humans and people" [Michelle].

Michelle points out the deficits of her math and science courses as they relate to what they value:

> "There is a way to incorporate more beauty and facets of being human into math and science classes, instead of the way that it's taught right now." She doesn't "know what it

would look like. [But if she were to] "see it, [she] 'd know it, where it feels like [she's] being valued as a person and what [she does] here matters."

In these reflections, Michelle has picked up on the values embedded in her math and science curricula. Values that she states exclude her development as a person.

In the context of engineering, another student holds up diverse human experiences as the way to become a better engineer:

> "Basically, like, I think that you've really need as engineers to, like, consider perspectives that are not our own, to really like, understand that the world is a place full of diverse people and diverse circumstances, and situations, right. And like, it'll one, make you better as an engineer, right? […] It'll make you a better human being. And so I think that if there's like one value, that's really, like, important, it's just sort of understanding that not everybody is the same, and you can't design one product to fit everybody... As we've seen many times" [Luca].

On a related note, Charlotte holds up the diverse perspectives of her classmates as a valuable and novel aspect of this STEM course.

> "I've never had a STEM class where we have discussions like this. And people brought in totally different perspectives. And I think people… it made people want to care more also hearing what others have to say" [Charlotte].

A different student, Ava, relates the inclusion of people in the engineering work to the development of engineers *as* humans who care:

> "So a lot of times, you're just creating stuff, just to create it, but you never really see the people that it will affect the people that it won't affect. So it honestly made me I think. It put me in a better position to be a better engineer, because it opened my eyes to multiple things. So I would definitely I feel like, the best engineers would take a class like that, because it allows them to be more than just engineers, but actual humans and people that cared about like, helping a specific group of people" [Ava].

Luca broadens this notion of care from engineers to people more broadly, "I genuinely think that anything that gets people to care more about the wellbeing of other people will make the world a better place" [Luca]. Across the interviews, care was a prominent theme in their discussions of being a better human being and an engineer.

Sociotechnical Engineering & Sense of Belonging

Many of these students spoke of their development as engineers as benefitting from learning from diverse perspectives in the readings and of their classmates. Additionally, students reflected on the content of the sociotechnical curricula in relation to their learning and confidence.

> "I feel like if there were more socio and political and economic aspects into engineering, it might give me more confidence as to like me coming up with different ideas and perspectives, but I feel like I would still feel this, feeling bad, in terms of the technical skills, I'm not competent. like honestly, right now, how much of my thermo class do I remember? Nada. So, like if you just like gave me a reactor and told me like here's a problem on it, I want you to solve it, I still don't know what to do with it." [Michelle]

This student notes that her sense of confidence from bringing different ideas and perspectives into an engineering problem might give her more agency in the classroom. A different student brings up her minority identity to frame her interest in engaging with the sociotechnical content.

> "Because I'm a minority, there are some topics that I'm more passionate about and more, like, amped up to discuss with people, especially since [it's a] largely, like, white population at the school. So I just felt like, I had to, like I had a responsibility to start talking about certain stuff. And I think when it comes to just times that I would be more quiet, it would mainly be more times when I just didn't know enough about it, or I was just thinking about it more so rather than having something to say." [Karis]

On the topic of racial bias in medical technology, which was one of the weekly topics, this student states:

> "I felt like I had to speak up and say something ... I don't like calling it a responsibility, because it's not my responsibility as a P.O.C., [1] to like, educate other people. But I feel like when it comes to those intimate discussions with like, three or so people that I just I feel like I could say something, and I want to speak up." [Karis]

This student went on to focus on racial bias in medical technology in her final class project. However, a different student with shared racial and gender identities shared that in some of the discussions explicitly about racial bias, she felt vulnerable and tokenized:

> "I guess this is just like an experience, just go into like a predominantly white school, but like, when you're talking about, like, housing inequalities, or like, due to race or due to like, you know, racism, and then like, you're the only like, African American person, or person of color in your group, it gets kind of weird, because then it feels like the discussion is on your shoulders. So like, while I did appreciate those topics that specifically talked about one race being affected over the other, I felt like it kind of put me in a vulnerable or uncomfortable position having to be like the spokesperson, or like the token Black person to talk about it." [Ava].[2]

A different student with a shared racial identity discussed that he felt that the discussions did not evoke feelings of tokenization.

> "I'm a first-generation person of color. And I felt like, you know, a lot of things, a lot of these things were kind of, like, comforting for me. You know, coming into, like, you know, a school where the majority is like, not me, you know, a lot of people don't look like me. So, it was pretty cool to see like, you know, people, like the professors like, understand my situation. What I face and how, I guess, they're trying to inform other people on ways to like, not make me feel like I'm being you know, singled out" [Alex].

The variety of experiences represented in these quotes is critical as we understand the ways students with different lived experiences and identities take up different curricula. Creating learning environments built on respect and peer learning is a critical prerequisite to encouraging and valuing students' diverse voices. These interviews are from seven students from a sample of seventy students. While these seven are from minoritized backgrounds and have traditionally not

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[1] POC in this context refers to People of Color

[2] Ava's experience of feeling tokenized was a concern for minoritized students across the entire project. To combat this possibility, we designed the sociotechnical curriculum to pair with an' Equity Learning Assistant' model such that the power dynamics in the small group discussions would not be such that minoritized students felt further minoritized. In addition, we worked to ensure that students of color and women were not the only ones in their groups. Ava disclosed these feelings during the project to the ELA in her class and we were able to follow up with her to better support her experience and learning in this course. However, we note and emphasize that even if the majority of other minoritized students did not voice experiences of tokenization, one student's experience is enough to completely change the project such that we are creating and sustaining a psychologically safe learning environment.

been served by engineering, there are a plethora of different experiences that are not included in this study.

Ultimately, the variety of learning experiences that students note is a goal of this sociotechnical revision. We note, however that the feelings of tokenization are not a goal of this revision, and we actively center minoritized student experiences to reduce these potential harms and rectify the curriculum and classroom structure if they do happen. We note that students take away different learning experiences based on their lived experiences and their interests. Part of the sociotechnical revisions was to move away from a homogenizing learning experience in which all students acquired a set level of competency in coding. Instead, students take away introductory coding skills with a variety of ideas and interests in how those skills may be used with real data with attention to the social, economic, and political decisions that go into their collection, analysis, and application. Elijah describes the learning variance in this way:

> "I think when it comes to topics based on equity, different groups of people take away different things. So, I think that people of color, it's more about because you know how, like, certain things harm you already, because that's just your experience, whereas white people may not know those things. So in the classroom, they might be learning these things, whereas P.O.C. are like discussing these things, and like, trying to like think of solutions already. So I think that's a different experience for both groups. But I think it's rewarding for both of them." [Elijah].

Sociotechnical topics across the curriculum

Towards the end of many of the interviews, students reflected on the impact this course had on their learning in other engineering courses. Luca notes that the sociotechnical revision is "a good direction to take engineering into." They go on to explain their reasoning:

> "Because I've taken other engineering courses, here and elsewhere. I'm like, oh yeah, that was like a really good course… And then if you start to think about it, then you're like, okay, that course had nothing about the real world… like, I had a lot of fun, I enjoyed a lot of like, just, I'm thinking like, I did the CAD one. And so it was like, a lot of CAD, a lot of, like, not a lot of social impact. And sometimes, I guess, there doesn't need to be, but also a part of you feels like, maybe that's just like, the ingrained sort of like, your classes have never had that sort of, like, bent to them, or like, the sort of social justice things incorporated. So maybe like, they can all use more like, social aspects, and I just don't know it, you know, I feel like this is very important."

Luca reflects that bringing in the social dimensions of technical learning helped them realize that there is a lack of this sociopolitical contextualization in other engineering courses.

Charlotte, seemingly, was in a different place in thinking about the social dimensions of engineering. She notes that the sociotechnical emphasis helped her find meaning in her engineering education. In her interview, she states that she had known she wanted to use engineering in a meaningful way but was worried about making it through the technical dimensions:

> "I just hope that this is, it seems like this is starting with us too but maybe in other classes, I feel like if this sort of discussion at the beginning of class, were just incorporated into projects was in other engineering classes. I think something that I was scared about coming into engineering was that it would just be all this technical stuff that

> isn't interesting in the moment. But I'm like, I have to get through it to be able to do something with it. If that's taught with the classes, then I feel like I'm actually learning something for a reason and not just doing it to get over with it to be able to do something." [Charlotte]

In this reflection, Charlotte reveals that she had the expectation that she would have to persevere through the heavy technical content that she contrasts with "learning something for a reason." Bringing in more sociotechnical discussions might change the way she sees herself going through the engineering curriculum.

Lastly, Luca offered comments on the design of the course we revised. One of the learning goals of the sociotechnical curricula was to highlight the human decisions that go into engineering work, to help students realize that engineering is non-neutral and made by people with different positionalities. Thus, when Luca reflected on the instructor and curriculum design decisions that made up the sociotechnical curriculum, we, as researchers and instructors, were flattered and humbled to be noticed (and hopefully, in the future, critiqued) for our curricular decisions.

> "I think that this class did that, was very, like […] I think I said courageous in one of them, but I think it was very courageous to sort of take that step towards bringing, like social issues into the engineering classroom. Because it's, like, it's so true. Like, nobody ever teaches you that, like, the things that you make as an engineer or the ideas that you will, like, put into the world like, will actually affect like real people, you know, and, and it's like they do, like they always do. So I think that that's important.. and something that a lot of like STEM courses don't really get at."

Discussion and Conclusion

In 1903, Du Bois challenged Washington's emphasis on the industrial education model as a sole pathway for Black people. In this education model purporting uplift suasion, Du Bois lamented that Black people are reduced to their potential economic productivity without room for humanity or creativity. These notions of economic productivity and social mobility are echoed by contemporary discourses of STEM education that promise similar economic gains and national innovation from diversity initiatives (Vakil & Ayers, 2019). Proponents of industrial education in the 1900s and engineering education through the Cold War era are rooted in rhyming sociopolitical ideologies. Learning environments in STEM education are no different. The STEM curriculum has long held a value-neutral façade, but each learning environment is a negotiation that explicitly and implicitly imbues ethical meaning (Hess & McAvoy, 2014).

In this study, we provided a brief overview of contemporary justifications of diversity, equity, and inclusion initiatives in STEM education. We linked these efforts with the curriculum revision efforts to convey engineering as sociotechnical, in which we center the varied experiences of minoritized engineering students. This work is influenced by Du Bois' critique that education should turn not just turn people into carpenters but carpenters into people.

Over a 15-week semester, students participated in weekly sociotechnical discussions, one weeklong midterm project, and a sociopolitical requirement in the final project. Some students felt empowered and comforted by these discussions. One student, in particular, noted that she felt

like she wanted to speak up because of an interest in the topic of racism in medical technology. Another student described feelings of comfort because in a school of predominately white students and faculty, he was glad to feel like the "professors understand my situation." A different student voiced a critique of STEM: it "is not enough to actually help people." There is a need to bring sociotechnical understandings into STEM to work against inherent biases and structural inequities.

On the topic of who is in engineering, a different student noted that *anyone* can go into engineering, but to succeed, you need hard work and energy. These notions of hard work as the ingredient to success is a tenet of meritocracy. Meritocratic ideologies are well-documented in engineering (Cech, 2013; Slaton, 2015) and legitimize the inequities between success and unsuccess as a feature of merit (Sandel, 2020). Ultimately, meritocratic ideologies legitimize those who become engineers as hard workers and those who leave engineering as those who did not work hard enough, which leaves out systemic and structural inequities that influence one's positionality (Cech, 2014; Slaton, 2015; Riley, 2019; Hampton, Reeping, Ozkan, 2021). These underlying ideologies of engineering are important to address with students in engineering courses; otherwise, these underlying ideologies can be reproduced and reinforced by traditional cultures in engineering.

Many of the seven students centered in this study discussed the importance of engineers developing as people, caring for their classmates, and the diversity of perspectives, as well as caring and learning about the people for which they would be designing engineering products. Students also noted how the inclusion of sociotechnical discussions helped them question their other STEM curricula and reflect on what the inclusion of these discussions could mean for their own learning, engineering identity development, and the impact on society. Interestingly, these students did not necessarily link designing engineering products to economic productivity but to helping people who had not previously been helped.

While the readings, discussion prompts, and projects were the same for each student, they came away with different learning experiences and reflections. The basis of this study is to emphasize that no two students had the same experiences in the class, especially those with minoritized backgrounds. We position this study to highlight the different learning experiences they had based on the same curriculum revisions. In this reimagined engineering computation course, we have tried to "center minoritized students' subjective experiences [to] learn what it takes to create places of refuge and joy that refuse a loss of self" (Sengupta-Irving & Vossoughi, 2019, p. 497). However, we did have a student describe her experience of feeling tokenized in the discussion of racial bias in technology. While many education models have emphasized a 'majority-fits-all' approach, evidenced by rewarding scalable instruction and assessment practices, we, as authors and co-designers of this project, strive to center our minoritized students' varied experiences in basing our curricular decisions. We also note that even though we only were made aware of the one student voicing these feelings of tokenization, there are likely other students who felt similarly and were not able to bring these experiences to our attention.

Unfortunately, tokenization and feelings of representing one's entire race, ethnicity, gender, or sexuality (among other minoritized identities) are not new in higher education. Berhane, Secules, and Onuma describe the experiences of five Black men in engineering with attention to their individual racial and engineering identity formation. They note how engineering identity can be "assumed to be representative of the totality of students" with "little consideration given to students' lived realities of having multiple salient identities" (Berhane et al., 2020, p. 112). In this study, Ava reflects on her feelings of tokenization and feeling like she's representing all Black people, while Karis and Elijah, two other Black students, expressed feelings of empowerment and comfort from the discussions on racism and technology.

Implications

This study works to center the subjective and varied experiences of minoritized students in an introductory engineering course with sociotechnical revisions. With mounting pressure in academia for projects to scale or researchers to produce 'generalizable' best practices, less attention and, thus, value is paid to individual student experiences. With this project, we also have intentions to scale up from the two sections to five sections, but we are intentionally scaling this growth slowly and deliberately, to ensure that we can continue to center students' individual experiences. Ultimately, in this study, we have strived to center individual student voices that continue to be underrepresented, underserved, and historically have been excluded from studying engineering. We maintain that these minoritized student experiences are critical to attend to with any curricular revision, but especially one that highlights the subjectivity of the social, political, and economic decisions that go into allegedly neutral engineering work.

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