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Student Perceptions of Learning about Diversity and its Place in Engineering Classrooms in the United States*

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Engineering students must be prepared to function as professionals in increasingly diverse societies. However, addressing diversity is primarily relegated to efforts focused on underrepresented groups, rather than being meaningfully integrated into engineering education curricula. The purpose of this study is to advance understanding of how students in the United States (U.S.) perceive the relationship between learning about diversity and engineering classrooms. Given the strong focus on technical skills in U.S. engineering and the role that student attitudes and resistance play in educational reform, educators may need to carefully integrate such topics. We used an exploratory, qualitative research design to investigate engineering students' perceptions of and task values for engaging with learning tasks associated with diversity-focused education. We interviewed 41 students, both undergraduate and graduate, from a university in the U.S. using Eccles' expectancy value model to inform data collection and analysis. When discussing diversity-focused education in engineering, students: (1) focused on issues of culture related to diversity and engineering; (2) recognized challenges associated with learning and teaching; and (3) varied in the nature of and degree to which they perceived value for such content. If educators are strategic, there are opportunities to more effectively incorporate topics and address issues related to diversity in engineering courses. In addition to clearly demonstrating the value of diversity, educators will also need to address uncertainty regarding the structure of such a task as it may increase the likelihood of disengagement.

Keywords: diversity; inclusion; motivation; instruction

1. Introduction

> "The question is not whether we want diversity or whether we should accommodate diversity, for diversity is clearly our present and our future. Rather, it is time to move beyond old questions and to ask instead how we can build diversity into the center of higher education, where it can serve a powerful facilitator of institutional mission and societal purpose." Daryl G. Smith [1, p. 3]

In *Diversity's Promise for Higher Education*, Smith argues that if excellence is to be achieved in a diverse society, diversity must not be an afterthought [1]. Our research is inspired by the desire to support the educational reform necessary to make diversity a central tenant in engineering, where, to date, it has largely existed on the margins of engineering curricula. Although ABET [2], the accreditation board for engineering and technology programs throughout the U.S., calls for the development of skills that are arguably related to and impacted by diversity (typically referred to as professional skills) – e.g., an ability to function on teams, communicate effectively, and consider global, economic, environmental, and societal contexts – the development of such skills is seldom emphasized in the curriculum [3]. Moreover, when these professional skills are addressed, instruction seldom includes *diversity-focused education*, i.e., course content that explicitly includes or addresses elements of human difference related to power, oppression, equity, social justice, inclusion, etc. In the U.S., the topic of diversity is conventionally relegated to conversations about broadening participation (e.g., [4]), improving climate and culture (e.g., [5]), implicit bias, or simply treating each other respectfully. Though such conversations and associated efforts are critical, we argue that the current approach to advancing diversity is limited, positioning it as separate from both engineering education and engineering practice.

Achieving Smith's "excellence in a diverse society" requires diversity becoming an integral part of the professional formation of engineers. To date, several initiatives have aimed to have such an impact. For example, the Ohio State University established a program to train engineering students that identify as male to become better allies for their female colleagues [6]. University of San Diego's Shiley-Marcos School of Engineering has been making a concerted effort to connect the engineering curriculum to social justice, peace, humanitarian advancement, and sustainable practices [7, 8]. And Riley demonstrated the possibility of integrating topics such as critical justice thinking and social engagement into traditional thermodynamics curricula [9]. If such initiatives are to become status quo, additional research is needed

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to illuminate the potential of diversity-focused education in the engineering curriculum. And while scholars in engineering education interested in diversity-focused education are emerging, research on the topic, at least within engineering, remains limited.

We argue that an important starting point for building research-based literature on diversity-focused education is developing an understanding of how students perceive the relationship between learning about diversity and engineering classrooms. The student perspective is important because student attitudes and resistance are often barriers to education reform [10–15]. Research has shown that students may resist learning approaches that are unfamiliar or unexpected, e.g., the introduction of problem-based learning [16]. Diversity is one such topic that may be unexpected: students may not anticipate grappling with issues related to race, gender, sexuality, class, disability, etc. in an engineering classroom. Better understanding the student perspective can stimulate ideas for effectively incorporating diversity-focused education into engineering.

1.1 Purpose

The purpose of this exploratory study is to advance understanding of how students perceive the relationship between learning about diversity and engineering classrooms in the United States. We address this purpose by answering the following research question: *How do students pursuing an engineering degree in the U.S. envision diversity-focused education being incorporated in the engineering curriculum?* To answer our questions, we used Eccles' Expectancy X Value theory (EVT) [17, 18] as a theoretical lens. We selected this theory because it considers both the personal and social factors that contribute to conceptualizing and willingly engaging in specific tasks or activities.

Due to the exploratory nature of this study, we ask the reader to temporarily suspend their personal perspective on what *diversity* means (or should mean) before proceeding. While an individual reader may subscribe to a particular connotation, the purpose of the study required that we think about this term as broadly as possible. We chose an exploratory approach because, though interested in further incorporating diversity-focused education into engineering classrooms, none of the authors had much experience doing so at the onset of this project and our search for well-developed views on how to engage engineering students with such topics was unsuccessful. Therefore, we began this study under the premise that diversity referred to the virtually limitless combinations and intersections of human difference, and we relied on the participants to decide which differences were relevant.

2. Theoretical Foundation

Eccles' Expectancy x Value Theory (EVT) is a useful lens for the examination of student perceptions of diversity-focused education in engineering because it was intentionally designed to consider the psychological, social, and cultural factors contributing to choices to engage in specific tasks or activities [17]. EVT has proven useful within engineering education, as a growing body of literature draws on this theory to examine engagement in specific learning activities across a variety of aspects of teaching and learning at the college level (e.g., [19–21]).

According to EVT, expectancies of success and subjective task values directly impact choices to engage in tasks and the subsequent performance in those tasks. Herein, the task is *learning about diversity in the engineering curriculum*. Expectancy of success is an individual's belief in how well they will complete an upcoming task or activity [18, 22], and subjective task values address the relative importance of the task to the individual. Importantly, expectancies of success and subjective task values are situated towards the outcomes end of the EVT model. (For a current version of Eccles' EVT model see [17].) The full model shows that expectancies of success and subjective task values are shaped by a variety of factors including personal characteristics, the cultural milieu, the beliefs and behaviors of socializers, previous achievement-related experiences and previous achievement-related experience as well how all of these are perceived, experienced, and processed by the individual. Importantly, the model recognizes the overall situation within a given context, i.e., expectancies of success and task values are not inherent properties of an individual but rather they are shaped by the social context in which the individual is functioning [23].

For this study, we focus on subjective task values associated with learning about diversity in the engineering curriculum and its relationships with the cultural milieu of engineering broadly and engineering learning environments more specifically (see Fig. 1). Subjective task values describe the relative importance of the task to the individual and include four categories: the personal importance of the task (*attainment value*); interest in the task (*interest value*); the usefulness of the task (*utility value*); and the things one must give up to engage in the task (*cost value*) [24]. In the context of this study, an attainment value towards learning about diversity in the engineering curriculum would include a desire to do so because it is consistent with

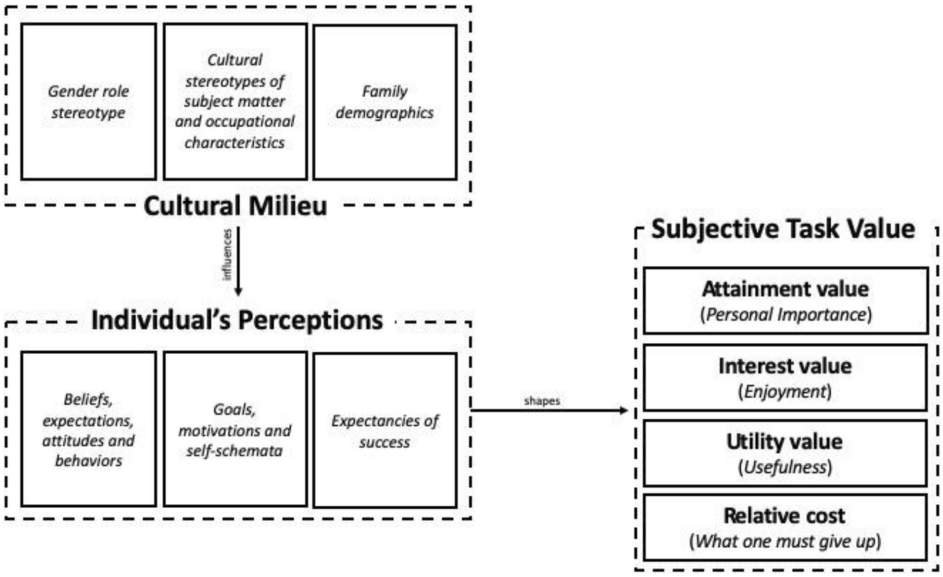

Fig. 1. Condensed Version of Eccles' Expectancy x Value Theory.

the type of person one envisions themselves to be; an interest value would indicate finding enjoyment in learning about diversity in the engineering curriculum; seeing learning about diversity as useful to potential future work in diverse environments is an example of a utility value; and thinking that learning about diversity in the engineering curriculum would take away from technical content would be a cost value. Whereas higher is better for attainment, interest, and utility values, a lower cost value associated with a task is desirable. Eccles defines cultural milieu to include gender and other social role systems and stereotypes of activities and the nature of abilities [23]. As described in the following sections, both of these aspects are present in the professional development of engineers.

2.1 Culture of Engineering and Emphasis on the Technical

In the U.S., engineering is by-and-large seen as a purely technical discipline, and such perceptions have important consequences for individuals' beliefs about the nature and value of engineering work. Scholars have shown how, following World War II, engineering disciplines began to focus more directly on mathematical approaches to problem solving [25, 26]. Such approaches led to a narrow and technically-focused curriculum that rarely incorporated global or societal concerns. For example, Riley [27] notes the ways in which common engineering jokes and memes reflect deeper cultural norms associated with technocracy, individualism, objectivity, and other themes that position engineering as primarily concerned with science and math and thus unconcerned with – and uninterested in – the humanistic elements of professional practice. These themes can shape student beliefs about what is and is not engineering, even as scholars and researchers have explicated the interconnectedness of social and technical systems inherent in engineering work (e.g., [28]). More recently, public messaging has given considerable attention to convincing younger children that "mathematics and science are easy or fun and that engineering is challenging, exciting, hands-on, and rewarding" [28, p.4]. Though intended to generate interest, such messaging also serves to reinforce beliefs that the field is principally concerned with solving math and science problems. As a result, popular notions of the discipline emphasize technical skills, despite engineering being a social, interactive activity that requires an ability to work within and across diverse groups [30]. These popular notions can directly influence students' perceptions of what engineering education and careers will be like and sustain the expectation that they focus on technical content.

At the same time, such persistent messaging around math and science as the core of engineering has in turn led to a perceived lack of value for social or professional skills – sometimes even referred to as *soft* skills [31, 32]. This messaging is problematic because the delineation between technical and professional skills confines people's (e.g., students, teachers) perceptions about the relevance and appropriateness of certain topics for engineering. Consequently, non-technical skills are seldom seen as integral to engineering education, even when the desire for such skills is expressed by industry, government, and society. For example, integrating topics such as communication, teamwork, and leadership into engineering education has been

historically challenging [33, 34]. Such research shows that though these skills are understood as critical for practice, many teachers and students still question the significance of such topics and consistently view them as secondary to other engineering skills as it relates to curricular priorities.

2.2 Culture of Engineering Learning Environments

In addition to the culture of engineering broadly, the culture of engineering learning environments is also expected to influence how students perceive diversity-focused education. Engineering culture by and large provides rules and boundaries for what counts as engineering, and most engineering learning environments are products of those values and norms – though some educators are able to subvert the dominate paradigm (e.g., [9, 35]). Consequently, the pedagogical choices of engineering instructors may also present barriers for diversity-focused education. Though notable progress has been made, current dominant paradigms of teaching and learning in engineering are centered on lectures [36] and solving closed-form problems [37]. We acknowledge that instructors might have reasons for doing so as some simplifications are necessary in order to make conceptual learning more efficient. Nonetheless, teaching in these ways tends to offer a decontextualized view of the world, making diversity-focused issues not readily apparent and, worse, signaling that such issues are not the concern of engineers.

Because diversity-focused education in other disciplines is primarily student-centered and experiential (e.g., [38]), it is reasonable to presume that these contextual factors will present challenges. For example, there may be an incompatibility between how students believe they can learn about diversity and how they expect most engineering instructors to deliver content. Because diversity-focused education is currently atypical in engineering, it may be necessary (and desired) for the community of engineering educators to leverage more creative and novel pedagogical approaches. It is the goal of the present research to better understand the ways in which broader engineering culture might manifest in specific learning environments related to diversity. We argue that doing so is an important first step in informing engineering faculty regarding how to address such issues in their pedagogical practices.

2.3 Summary

In summary, Eccles argues that an understanding of cultural milieu is a precursor to both expectancies of success and subjective task values. As a result, it is vital that we consider scholarship related to engineering culture and how it might affect attitudes or beliefs about diversity. The capacity for incorporating non-technical (or social) content into the curriculum may be impacted by popular notions of engineers principally requiring skills in mathematics and science [39]. Engineers tend to maintain boundaries around technical and social aspects of engineering, placing relatively less value on the social. Accordingly, diversity-focused education is likely to be seen as social, presenting challenges to integrating such content into engineering courses. Further, such content may generate questions about the relevance and utility of such knowledge in relation to "legitimate" engineering needs.

3. Research Design

To elicit the engineering student perspective of diversity-focused education, we implemented an exploratory qualitative research design [40]. We interviewed a stratified sample of undergraduate and graduate students in engineering, probing their beliefs about diversity and where learning about diversity fits within, or alongside, the engineering curriculum. Our analysis focused on identifying the extent to which the structure and culture of engineering learning environments were salient during these discussions and the associated subjective task values. Given our underlying goal of understanding student choices and perceptions, EVT guided both the development of research protocols as well analytic approaches. However, the exploratory nature of our study meant we also remained open to emergent categories of observation [41].

3.1 Research Team Positionality

We acknowledge that the individual characteristics and interests of the researchers and participants may have impacted the results of our study. In particular, seven different researchers – who collectively may be considered diverse on the basis of race, gender, and age – led the interviews; and three different researchers were involved in data analysis. Though no attempts were made to match our social identities with those of participants, it is possible that both similarities and differences impacted the research process. For instance, it is also possible that the lived-experiences of the researchers may have impacted data analysis. To reduce contextual impact on the interview (e.g., social desirability bias), we took caution to avoid interview questions and language that might stigmatize participants, discourage authentic responses, or make either the interviewer or interviewee uncomfortable. To reduce researcher bias during data analysis, we iteratively returned to the data to ensure participants' words were being accurately represented.

3.2 Participant Recruitment

We recruited participants from a subset of respondents to a questionnaire (also about diversity in engineering) who indicated interest in being interviewed. This questionnaire was distributed as part of a larger research project. We used *purposive* sampling [40] to recruit students over two phases, aiming to solicit a broad range of perspectives. During the first phase, we recruited undergraduate students from an engineering-themed, living-learning community (LLC) with which the lead author is affiliated. During the second phase, we recruited graduate students from engineering departments across the college. By recruiting students at various academic levels and with differing experience with engineering, we ensured that the perspectives held by participants would be wide ranging. Undergraduate students, who were primarily in their first year, could provide the perspective of those who had limited exposure to engineering; whereas graduate students could provide the perspective of those who presumably already earned at least one degree in engineering.

To incentivize participation, we offered each respondent a $20 Amazon gift card. We invited each student that expressed interest and interviewed everyone whose schedule permitted meeting with us during the timeframe for data collection (i.e., Spring 2016). Combined, these efforts resulted in 41 participants (19 undergraduates and 22 graduates) described in Table 1. To maintain participant anonymity, participant demographics are not broken down any further, particularly as it relates to academic level and discipline.

3.3 Data Collection

We collected data using semi-structured interviews. We developed a common interview protocol, asking follow-up questions based on participant's responses. To achieve the flexibility needed for exploratory conversations related to diversity and diversity-focused education while maintaining some consistency across members of the research team, we developed a common interview protocol and trained interviewers in semi-structured interview approaches. Interview questions explored participants' perceptions of engineering and diversity as well as any relations they perceived between the two. We also explored participants' prior experiences in both learning about and promoting diversity. Further, knowing our sample would likely include participants currently or previously engaged in diversity-focused activities already, we also tailored the interview protocol to inquire about ongoing diversity efforts at the research site. Example questions from the interview protocol were:

- How would you describe engineering?
- What are the first words or phrases that come to mind when you think about "diversity" in engineering?
- Do you think learning about diversity has a place in engineering? Please explain.
- Why would diversity be of interest to the field of engineering?
- The college is implementing [ongoing diversity efforts]: Do you think this is a good or bad idea?
  - What topics or issues would you expect to be covered?
  - What topics or issues would you hope were not covered?
- How interested are you in learning about diversity?
- How important is it for you as an engineer to learn about diversity?
- How useful would it be for you as an engineer to learn about diversity?
- What advice would you give an instructor who wanted to cover issues related to "diversity" in a classroom full of your peers?

Interviews lasted 30–75 minutes with an average of about 40 minutes. A team of seven researchers (including the first three authors) conducted the interviews, often in pairs and rotating who led. To maintain procedural consistency, interviewers were briefed in terms of interviewing techniques (e.g., probing questions, waiting for responses, attending to participant body language, etc.) and one of the authors were involved in each interview.

Table 1. Participant demographics

Race/Ethnicity	Women	Men	Total
Hispanic/Latino	0	3	3
Native American	1	0	1
Asian/Pacific Islander	5	3	8
Black/African American	2	0	2
White	12	11	23
More than one	2	2	4
Total	22	19	41

3.4 Data Analysis

Due to the exploratory nature of our study, data analysis leveraged existing EVT constructs when applicable while remaining open to emergent categories. We achieved this balance via an iterative process of both inductive and deductive coding. Developing the codebook entailed the research team working recursively through findings and existing codes to operationalize relevant constructs and identify themes within our findings. For example, as participants described the kinds of people that tend to become engineers, they referred to

stereotypes or occupational characteristics (e.g., ''Engineers are anti-social'' or ''They are the kinds of people who fix things and solve problems''). These discussions were iteratively compared to theoretical definitions of EVT constructs as well as prior research using the framework (e.g., [17, 20, 24]). As we iterated through our analysis, we narrowed our focus on the constructs that most appropriately aligned with student responses, and developed our own working definitions for each construct.

Our analysis resulted in the codebook shown in Table 2. Participants articulated beliefs along three primary dimensions. *Engineering Culture* captures student beliefs about engineering, the topic of diversity, and their perceived relationship. *Learning Environments* considers student beliefs about how diversity-focused education could or should take place within an engineering curriculum, emphasizing both the content and pedagogical aspects of such learning. Finally, *Subjective Task Value* describes the different ways in which diversity-focused learning might be important for engineering at both a disciplinary and individual level.

3.5 Validity and Trustworthiness

To enhance the trustworthiness of our study [42], we engaged in practices to promote credibility [43] while making and handling the data [44]. Specifically, we designed the data collection instruments with the EVT framework in mind. Also, the second author, who led data analysis, held regular meetings with the first and third authors as a means of researcher triangulation [40] to ensure that the codebook was conceptually sound. For example, the third author's expertise with EVT in engineering education informed our use of expectancy and value constructs while the first author's expertise in diversity in engineering informed our understanding of the cultural milieu. Following codebook development and preliminary coding, the lead author sorted and reviewed coded segments to ensure the internal consistency and conceptual boundaries set by each code. He also reviewed segments across codes to make sure each code was conceptually distinct. Throughout data collection and analysis, the research team discussed inconsistencies and discrepancies until reaching consensus.

4. Results

The purpose of this exploratory study is to advance understanding of U.S. engineering students' conceptions of and expectations related to diversity-focused education. Specifically, we address the following research question: *How do students pursuing an engineering degree in the U.S. envision diversity-focused education being incorporated in the engineering curriculum?* Fig. 2 provides an overview of our three themes. First, how students perceive diversity-focused education in the context of engineering is impacted by both their conception of engineering as well as their conception of diversity–and at the intersection of diversity and engineering, students viewed both constructs as separate yet connected. Second, the expectations students have regarding teaching and learning in engineering results in a high anticipated-level of difficulty as it relates to learning about diversity. And lastly, though students were able to identify multiple reason for diversity being valuable to engineering, students also expected there be cost associated with incorporating such content into engineering curricula. Importantly, across each of these three themes we see evidence of the technical/social dualism prevalent within engineering.

Table 2. Codes developed using Eccles' Expectancy x Value Theory

Construct	Definition
Engineering Culture	
Engineering	Beliefs about the field of engineering
Diversity	Beliefs about the concept of diversity
Diversity & Engineering	Beliefs about how diversity influences or relates to the field of engineering
Learning Environments	
Learning	How learning about diversity could (or could not) occur
Teaching	Pedagogical practices for teaching diversity
Content	Content used to teach students about diversity
Perceived Difficulty	Challenges due to how content would be taught or could be learned
Subjective Task Value	
Attainment	Degree to which diversity is a part of their own identity
Interest	Degree to which an individual found engaging with diverse groups or learning about diversity enjoyable
Utility	Personal usefulness of both knowing about and having diversity
Cost	Potential reasons to not engage in learning related to diversity

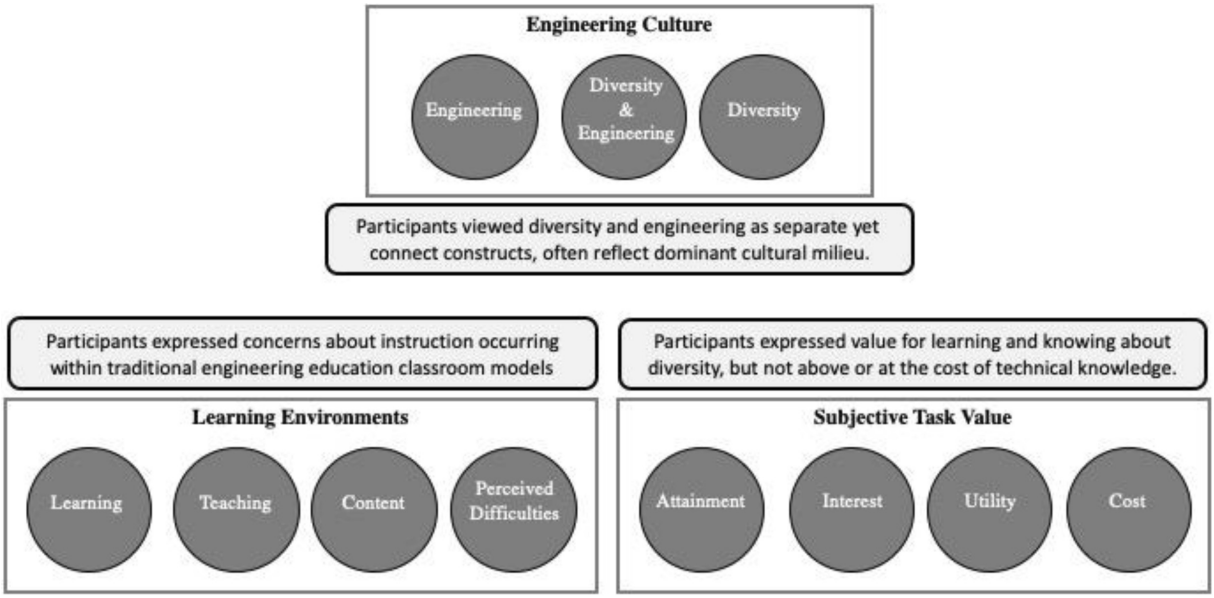

Fig. 2. How students perceived the relationship between learning about diversity and engineering classrooms through an EVT lens.

4.1 The Cultural Milieu at the Intersection of Engineering and Diversity

Although participant's conceptions of engineering and diversity were not novel, conceptions at the intersection of engineering and diversity were complex and nuanced. For example, participants' conceptions of engineering primarily referenced the work done by engineers (e.g., solving problems through application of math and science) and who becomes engineers (e.g., men and people with poor professional skills).

> "To me, engineering is applying math and science towards real-life applications and real-life problems and using those methods and those ideas to solve real-world problems." [UG_9, White woman]

> "It's [read: engineering] more of a logical train of thought that is applied in daily lives, by engineers of course. A lot of people take this step towards becoming an engineer, in order to make decisions in a daily basis, based on some principles that are defined as engineering. Apart from all that, I believe it's probably commonsense with a bit of Science. Yeah, that's about it." [GS_10, Asian man]

The focus here is centered on notions of using engineering science concepts in real-world scenarios. Such views were supported by and related to beliefs about the kind of people that tend to become engineers. In the following passages, a graduate student and undergraduate student articulate their beliefs about the dominant demographics and characteristics within engineering.

> "I think it's perceived as very low. . . engineers have very low professional skills, have issues to communicate, have issues to understand different points of view, have issues to accept other fields as valid fields of knowledge. I think it's a very masculine discipline, I would say it's a very white-masculine discipline. I think there's a general perception [that] engineers will have this mindset. It would be very difficult to work with them; it would be very difficult to communicate with them. They are difficult." [G_22, Hispanic man]

> "Just that when you're thinking about a problem. [Engineers] Think about it more logically and just in general, even things that aren't directly related to a project or to school. Engineers I've known have tended to think of things more logically and less of just how they feel at that moment." [UG_12, White woman]

These beliefs about engineering highlight both what engineers do and the kinds of people who do it.

With regard to diversity, U.S. participants mentioned differences among people with regard to common demographic measures of race, gender, etc.

> "Different backgrounds. Different ways of thinking. Different skin color. Different gender, age, pretty much anything you can use to separate different types of people." [UG_15, White man]

> "When I think of diversity, yes, usually I think of race." [GS_13, Native American woman]

On the other hand, some international students (i.e., students from other countries) mentioned divergent topics such as engineering disciplines, countries of origin, etc.

> "I think about engineers from different countries. They have different educational backgrounds. Also, males and female engineers. Diversity sounds like a really big word. Probably different areas of engineers, like me, I'm from chemical engineering, and mechanical engineering, and electronic engineering, they cooperate with each other. Let me see. That's probably the very

first things I would think about." [G_14, Asian woman, International]

As noted, these beliefs are not necessarily surprising and align with common cultural notions of engineering and diversity. What is novel about our study, however, is that at the intersection of engineering and diversity, a majority of participants viewed these constructs as both separate and connected, which aligned with technical/social dualisms. For example, the following quote illustrates how perceptions of engineering as a primarily technical discipline raises questions about the relevance of diversity-focused learning happening within engineering curricula:

"I feel like technical engineering classes are there for you to learn technical things about inanimate objects typically because we're engineers. I think diversity is important for engineering, and like professional development, and building who you are as an employee and as a future engineer. It's important in those technical classes when you're working with others to do projects and create solutions, but to be taught in a technical class, like, 'All right, we're going to pause talking about equations and this diagram and we're going to talk about diversity, and culture.' I think those are just two separate, you don't need to talk about diversity in a technical class, but you do need it to happen if you're going to do the group project, I would say." [UG_1, Asian woman]

Although this participant declares that technical content and diversity content are different, and that the latter does not belong in a class focused on the former, we note the contradiction in that she also says diversity is important to the group projects associated with technical classes. Another participant similarly struggled to imagine ways in which diversity-focused topics might show up in an engineering education context, due in part to their disconnect from "principles that are science related."

"[I]n engineering, it's a little bit less like that. It's not like we're going to sit down with our professors and have a conversation about diversity, because we're talking about some other principles that are science related. So, I think it's a little bit less direct conversation and interactions." [GS_17, White woman]

When considering the ways in which diversity and engineering might intersect, some participants reflected a more sophisticated understanding of the relationship between issues of diversity and engineering and complex challenges that arise when one considers them simultaneously:

"It's obviously not a tangible product that you can put out that would solve the issue of diversity but there are definitely steps that having a diversity background in engineering would be able to impact things like, for instance, malaria and HIV issues in Africa. The rest of the world just sees that as those poor people over there, they would not be able to deal with whatever we have here but they're lesser humans than us, so we'll give them this little charity. Whereas seeing it as those are people who are equal to us. What circumstances led me to be in this position to decide whether or not to give them money versus them being in that situation where they can't avoid that disease?" [G21_White man]

Consistent with notions of diversity as a social, and therefore non-technical topic, the participants recognize some of the inherent complexities surrounding the incorporation of diversity-focused content into engineering problem solving. Another student connects diversity to alternate ways of thinking and, in turn, problem solving approaches.

"It's very important for me as an engineer to learn about diversity. [. . .] I just really enjoy seeing what the world of culture is about and how different people think and approach problem solving and from each of those situations, I learned a great deal about how I can improve my own approaches." [GS_19, Black women]

Participants in this study made a range of different connections between ideas of diversity and engineering while also maintaining boundaries around the two subjects.

4.2 Engineering Learning Environment

Expectations for diversity-focused education echoed beliefs related to technical/social dualisms. Participants here noted a range of challenges in learning about diversity in terms of the content, structure, and pedagogy of an engineering course.

Consistent with viewing diversity as technical knowledge, participants talked about content in terms of learning basic facts and figures:

". . . an overview of how diverse [the institution] is, which you can get off the website. It's not a big deal. Probably give some positive stats about how diverse [institution] is being becoming, since some point of time. How it's positively impacted funding and the number of papers published, and how many awards received and stuff like that." [G_10, Asian man]

They further anticipated that this instruction might take place within their current models of engineering teaching practices of lectures and PowerPoint slides followed up by some kind of quiz.

"I guess there would probably be some PowerPoint slides about diversity topics, but I don't really know what would be a good way to do it. I feel like if you just had a whole semester of PowerPoints on diversity that wouldn't really get anywhere. Maybe some kind of people interacting with people not equal to themselves, I guess, would be interesting, but I don't know how much that would get forced to interact with other people, learn about other people. I don't know how beneficial that would be." [G_12, Multi-raced man]

Although suggested as an option, lecturing is not a desired way to learn about diversity. One participant said:

> "As I've been saying it's very, very difficult to promote it directly in the classroom. It's nearly impossible, because no one's going to listen to you if you lecture them on diversity. People might listen to the words you're saying, but it's not going to affect them, because they're not experiencing diversity." [UG_16, White man]

Thinking about diversity-focused education as technical content tended to lead to thinking about a teaching and learning environment consistent with traditional lecture-based classroom environments.

Some participants expressed conflict regarding the process for learning about social topics in a setting designed to teach technical content. That is, they argued diversity could not be taught and that it simply had to be experienced. Specifically, participants discussed the need to create a diverse environment as opposed to talking about it:

> "The professor doesn't need to talk for three hours about diversity but he can always point it out during his classes or her classes. The other thing would be just allowing the students to interact and to work and to study in a diverse environment." [G_20, Hispanic man]

> "I don't know if there's a real way to teach it other than just experiencing. Go through with it, like more diverse classes. Ensure that there's a nice blend of people. It's more of a- I don't know. You get a feel for diversity instead of actually being taught like 'Oh you need to include this person, this person, and this person.' I think it's more of an acquired behavior." [UG_19, White woman]

In addition to emphasizing the experiential nature of diversity-focused education, some participants believed learning could also take place through engaging in scholarship. Explaining how they became more knowledgeable on the topic, a participant offered the following statement:

> "I try to talk to people, I read a lot. I'm very interested in, you know, like different articles that are about diversity issues all over. I actively work to expand my knowledge. Conferences, seminars, articles, and just talking to people in general." [G_13, Native woman]

Despite seeing diversity as a type of technical content, with varying views on if and how it could be taught, these expectations often pointed to the importance of interpersonal interactions and genuine experiences with diverse people and knowledge. Participants recognized that there was no "one-size-fits-all" approach to learning (or teaching) about diversity, and that the content of those learning experiences needed to fit the context.

When discussing learning about diversity in the social context of engineering, participants also noted that such learning would be difficult. For example, the following quote explains how beliefs around what can be learned introduces difficulty in becoming knowledgeable.

> "I think it's too complicated and I think I will never be able to understand, to be in other people shoes, because it just not possible. I don't know how other people that hasn't lived my experiences feel when something happen to them. I think I want to learn as much as possible. I think I want to respect as much as possible, but I don't think I have the knowledge about it." [G_22, Hispanic man]

To this participant, the expectations of what would be learned entailed knowing someone else's lived experiences, making formal teaching and learning ineffective. Similarly, beliefs about how the learning process happens limits the knowledge someone can actually possess:

> "You can never know enough to know, but I don't know. Probably somewhere down the road, I want to claim that I would. I don't know how I'll know that, at that point, but I really don't know how to answer that. It's more about an experience, you know? I guess, the more time you spend with different types of people and work in teams and try to do things and achieve goals, probably you pick up diversity on the way. You start to learn to accept and understand, which is good. Yeah, I really don't have the knowledge right now." [G_10, Asian man]

To this participant, the difficulty associated with having enough experiences to be truly knowledgeable about diversity is what makes learning about it such a challenge.

When introducing diversity focused content, most participants expected the learning to follow similar models as those currently in place within most engineering curricula for technical content (i.e., lectures and problem sets). At the same time, however, these participants noted the inherent limitations in such an approach when it comes to diversity education in particular. It seems important that engineering educators consider these student beliefs and expectations when making choices about including diversity-focused content.

4.3 Learning about and Knowing about Diversity is Valued, But Not Above Technical Knowledge

Overall, our data reveal that participants value knowledge about diversity, but do so in ways that prioritize technical knowledge. We saw evidence of interest, attainment, and utility value towards learning about diversity particularly associated with problem-solving and stakeholder considerations. However, in the cost value, we also saw echoes of the tension between technical knowledge and diversity knowledge, i.e., the cost of learning about diversity is that it replaces learning of technical knowledge learning or more highly valued activities.

4.3.1 Interest Value

Participants expressed varied levels of interest in engaging in learning about diversity in general and did not comment on interest in relation to the specific aspects of engineering (i.e., technical knowledge vs. interpersonal interactions). Potentially because they had to volunteer for the interview, most participants described positive interest values for learning about diversity:

> "Yeah, I mean, I'm very interested. I like talking to people, and hearing their stories, and what they think, and where they come from, and why people do things the way they do. We all have little things that we do that is because of our backgrounds, and where we come from, and who we are. I like learning those stories." [G_13, Native American woman]

However, not all participants found such learning fun or enjoyable:

> "Speaking about diversity is pretty boring. I guess that's my own opinion. People enjoy video games. They enjoy sports and cars, and building stuff and code. Diversity is not seen as a thing really. It's more of a concept that people are like, how's the diversity at your school? Terrible. Diversity equals mixing of races. It's not something that is interesting or provides them with pleasure to think about. Provides them with like . . . It gives them nothing. They don't get any benefit from learning about it. They don't see any benefit from wanting . . . They don't want to learn about it." [UG_13, White man]

As shown in this quote, the lack of interest may be associated with a lack in other values, utility value in this case, where the participant indicates that there is no benefit to learning about diversity.

4.3.2 Attainment Value

Participants often evaluated the personal importance of engaging in diversity-focused content based on part of their identities as both engineers and as members of various social groups. In doing so, some participants called on aspects of their own identities to articulate their beliefs about the perceived attainment value of engaging in diversity-focused content in engineering. For example, a participant offered the following statement:

> "Diversity is extremely important to me because I am a person who entered engineering and the adult world in a community where I look very different than mostly everybody there, in fact, everybody there. The unnecessary compromises to my ability to perform in the environment as others were to perform in the environment due to biases and just lack of interest in inclusion. That's what I think of when I am concerned about diversity in engineering." [G_19, Black woman]

The idea of considering diversity as an important part of problem-solving also emerged in association with engineering identity, i.e., engineers are people who solve problems:

> "It's very important. It should be important in what we do in engineering. Because if we were all of the same thought process, there wouldn't need to be so many of us. It informs every type of problem you can think of. Because I come at a problem from one specific angle, but somebody else from a different background or a different thought process will come at it from a completely different angle. Those two thought processes then meld to create one solution. The diversity in thought is how and why engineering functions as a discipline." [G_17, White woman]

The above quote illustrates how a "different background or a different though process" can enhance the problem-solving process and lead to more effective solutions.

It is important to note that not all participants saw diversity as personally important. The following quotes demonstrate some of the indifference toward diversity focused-learning we observed:

> "Diversity is pretty important I guess. It's not something I think about every day, or keeps me awake at night but it's always good to have it." [UG_11, White woman]

> "In that sense, I don't consider [diversity in engineering] very important because I try not to be concerned with the way people look. Whether you're African American, White or Caucasian, it's like I try to not have that be a big deal in my mind. It's more along the lines of what do you know, what are you skilled in." [G_11, White man]

Though no one expressed outright disdain for the topic, participants varied in the degree to which diversity-focused learning in engineering was personally important as well as the basis for that importance.

4.3.3 Utility

Like attainment value, expressions of utility value related to the importance of diversity-focused education centered on the value of diversity in knowing how to interact with others and in creating better design or problem solutions. For example, the following quote illustrates the importance of understanding how to communicate and work with diverse groups is essential for effective decision-making:

> "Again, [learning about diversity is] pretty important because in the workforce, you are not going to be isolated to people who are only like you. It's just not going to happen. Especially – I had a chance to work with [a government agency] when I was an undergrad. The amount of diversity that's present at [the government agency] is crazy. I worked under a Pakistani woman who was absolutely phenomenal. But we had very different cultural backgrounds and therefore we had different work expectations. So learning how to talk about things like that, and just communication skills in general with people who aren't like you are really important." [G_17, White woman]

Participants also identified utility in diversity-focused learning when they equated it to being in diverse groups and interacting with diverse individuals.

> "As we become more diverse, we end up with some more problems that we have to address, but we also end up with a lot more solutions. We work together more, and in my opinion, diversity, if done correctly, just fosters that teamwork of all these different people and when you can bring them together, they can really do some incredible thing. They can work from different perspectives and viewpoints and solve problems quickly and in new ways that people wouldn't necessarily be able to do just kind of in a sheltered community by themselves." [UG_6, White man]

In this instance, knowing about diversity helps participants work with diverse groups, which generates diverse (i.e., better) solutions.

In general, it was promising that most participants viewed having competencies associated with diversity as useful, regardless of whether they personally believed engineering curricula was the most advantageous source. Like attainment value, utility value was not tied to technical content or technical aspects of engineering.

> "I think it is important [for me as an engineer to learn about diversity] in the fact that we design for people. I think it has some inherent benefits that way. I also think engineering is a social process, as we always work in teams and we work with others. Going back to my background in maximizing potential of an organization, I think it informs how we conduct our daily practice, or at least it should. Maybe if we continue to get people to consider it, maybe it will one of these days." [G_6, White man]

This participant sees diversity as integral to solving problems and conducting engineering practice.

4.3.4 Cost

Though not prevalent in the dataset in general, participants did perceive a cost associated with learning about engineering. When present in the dataset, costs associated with learning about diversity in engineering curricula sat at the tension between technical and social aspects of engineering. Perceived costs included taking away time from more central technical discussions, or reducing time spent on activities that were perceived as more directly contributing to their goals as engineers. For example, one participant implied the secondary importance of discussing diversity as:

> "It's not like we're going to sit down with our professors and have a conversation about diversity, because we're talking about some other principles that are science related. So I think it's a little bit less direct conversation and interactions." [G_17, White woman]

Another participant explained that how frequent she thought about diversity was influenced by the amount of extra time she had available to think about it:

> "[The amount I think about diversity] depends upon how busy I am. [. . .] when I get into my really heavy weeks, like the last three weeks I've had six tests and a ton of projects and I'm not thinking about diversity at all. I'm not thinking about anything except for deadlines. I feel like that's the hard thing, is in the undergraduate lifestyle, we have so much going on that it's hard to step back and analyze. If there are any issues about diversity that we need to address, I'm so consumed by other things that it's not something I think about daily." [UG_14, White woman]

Across participants, the costs associated with learning about diversity, though uncommon, were rooted in participants' notions about the relevance of such learning in engineering contexts and concerns about the time that must be given up as a result of participation.

5. Discussion and Implications

The purpose of our study was to understand how students perceive the relationship between learning about diversity and engineering classrooms in the United States. To address this purpose, we framed our research around one key question: *How do students pursuing an engineering degree in the U.S. envision diversity-focused education being incorporated in the engineering curriculum?* To address this question, we framed our results in terms of student beliefs about engineering culture, the perceived value associated with diversity-focused learning, and expectations about learning environments and specific implementation of diversity education.

Based on our findings regarding culture, we argue that instructors should consider students' beliefs about engineering, diversity, and the relationship between the two, paying close attention to what students conceive of as engineering work and who becomes an engineer when designing diversity-focused education activities. Based on our findings concerning value, we argue that instructors should leverage the personal importance, enjoyment, and utility potentially associated with engaging in diversity-focused education in engineering while exploring opportunities to mitigate concerns about engineering learning needing to be sacrificed. Similarly, based on our findings relative to learning tasks, we argue that instructors should consider students' expectations for diversity-focused education tasks as well as their perceived difficulty, remaining open to innovative pedagogies and seeking opportunities to facilitate authentic interactions among students. Collectively (and as noted in each

section), the findings from this study have implications for students, educators, and researchers. Though we focus exclusively on diversity-focused content, we also believe these lessons have implications for any content that might be considered as "soft" under the dominant engineering paradigm.

5.1 Cultural Beliefs about Engineering and Diversity

Our results show that participants' conceptions of engineering, diversity, and their intersection (along a technical/social dualism) often reflect dominant cultural narratives. For example, engineering is math, science, and problem-solving; and people who are poor communicators do these things. In fact, many of these common narratives have become stereotypes of engineers and engineering that are mocked [27] and reproduced in popular media (e.g., [45]), despite the realities of engineering practice [46, 47]. Our finding of consistency with historical cultural themes dominant in engineering is disappointing and unfortunate for many reasons but the focus here is on the devaluing of social components of engineering, which are the very components that are likely to intersect with diversity in meaningful ways. Despite the many social, or non-technical, elements of engineering [46, 48, 49], such activities are nonetheless perceived as non-engineering because of the emphasis placed on technical problem solving [33, 37, 39]. If engineering students echo dominant, albeit false and problematic, cultural narratives about engineering, they are likely to question the relevance of learning activities that focus on social interactions or that require non-technical skills. It is thus important that engineering educators interested in integrating diversity-focused education acknowledge this culture and actively help students overcome misconceptions related to the nature of engineering practice.

We argue that initial efforts to make diversity more central will require instructional strategies that clarify and explicate the relationship between technical and social concerns in engineering through intentional educational efforts. One way that educators can reposition engineering is to leverage Hynes and colleagues' [50, 51] construct for framing the humanistic side of engineering. They highlight the "people part of engineering" and position engineering as a task that is done as people, with people, and for people as a way to include social science and humanities knowledge into engineering. By positioning the discipline as humanistic, educators can more readily identify opportunities to acknowledge and address diversity issues that are already present, or absent, from existing engineering contexts.

5.2 Task Perceptions of Teaching and Learning Diversity-Focused Content

In addition to considering how students see the culture of engineering, it is important that educators consider students' existing expectations for what learning about diversity would entail in an engineering setting. These expectations point to students' outlooks about both what classroom instruction might entail and what content might be encountered in an engineering classroom, and tended to be driven by their experiences with and perspectives of the more dominant pedagogical practices for delivering technical content. In our study, many participants expected to be lectured to about demographics, diversity efforts, and cultural differences – lower-level objectives according to Bloom's taxonomy (e.g., facts, basic and concepts) [52]. In terms of pedagogy, participants often expected some combination of lectures, homework, quizzes, and participation grades. These expectations are consistent with prominent descriptions of teaching and learning in engineering [3], though there are certainly notable exceptions (e.g., capstone, cornerstone).

In addition to expectations related to content, students' expectations related to teaching and learning are also important to note. In our study, while participants expected classroom activities to be behavioral and cognitive (e.g., stepped presentation of content), their expressed beliefs about learning mostly aligned with a more situated perspective [53]. That is to say, while participants may see diversity-focused education in engineering as something that should occur through authentic experience and interaction (i.e., not through remembering facts and figures), they simultaneously expected instructors to simply present information for them to memorize and later repeat. This misalignment is important to future efforts because it suggests that even if students believe learning about diversity is possible and valuable, they may not expect content to be delivered in such a way that encourages meaningful learning and thus be reluctant to engage. In light of this misalignment, educators should explore novel pedagogical approaches and make these choices clear to students if they do not align with what is likely expected given their local context. Prior work incorporating innovative, experiential pedagogies in engineering (e.g., [34, 54, 55]) provides a strong foundation on which to devise educational approaches that meaningfully address diversity-focused learning, but much remains to be done.

5.3 Subjective Task Values of Diversity-focused Education

Lastly, we explored students' subjective task values

concerning diversity-focused education. Participants generally described diversity-focused education as a valuable task – citing personal importance, interest or enjoyment, and professional utility as supporting reasons. Predictably, some participants also expressed a cost to incorporating diversity-focused education. These participants viewed the learning experience as zero sum, where an increase in activities focused on diversity meant a decrease in time spent learning about engineering. These results are consistent with previous research. For example, given student beliefs about the centrality of problem solving in engineering, it is not surprising that participants viewed diversity as an important means to enhance problem solving processes, consistent with notions that diversity is critical for creativity [56]. Students' views of cost were also aligned with previous research on opportunity costs that highlights time as key factor in making choices about where to devote energy (e.g., [20]).

We recommend that educators implement strategies aimed at each of the subjective task value constructs (interest, attainment, utility, and cost) when incorporating diversity-focused education in the engineering curriculum. Targeting each of the value constructs will increase the likelihood of reaching more students in a way that is personally important or interesting to them. Jones [57] provides a comprehensive guide for addressing constructs similar to subjective task values. Though his recommendations are not content specific, they provide a useful starting point as it relates to diversity-focused education. For example, educators can work towards promoting interest in diversity-focused education by avoiding gimmicks (i.e., novel activities with little intrinsic value) and including authentic social interactions. Waterman, Reid, Garfield and Hoy [58] demonstrated that by providing opportunities to interact with and learn from LGBTQ+ scholars, students in a human sexuality class moved from an interest in why people identify as LGBTQ+ to the position of an ally who is interested in supporting others from such communities. Educators should integrate diversity-focused education into existing courses so that the engineering education community not only avoids adding to a packed curriculum, but also sends clear messages that diversity and engineering are, in fact, related and knowledge of those relationships is critical to an engineer's skill set. Because identifying such opportunities may be beyond the expertise of those trained in engineering, we also suggest that engineering faculty work to cultivate collaborations across departments. For example, administrators leading a living-learning community in engineering collaborated with a scholar from the Intercultural Engagement Center [59].

6. Limitations and Future work

Though our study offers a foundation for integrating diversity-focused education in the engineering curriculum, several methodological aspects of this research should guide inferences made from our results and the direction of future work. First, the data that comprise the present study is likely influenced by selection bias. Those willing to volunteer for an interview about diversity in engineering are probably more likely to have positive things to say than those who would opt out of participation. Still, as shown, some participants had less than positive beliefs about the relevance of diversity-focused education within engineering classrooms. Further research is needed to explore the differences across institutional contexts and student populations. Additional studies should also explore other engineering populations (e.g., faculty, practitioners) to determine how common these views are with respect to the broader engineering community.

Next, though students were able to speak hypothetically about what diversity-focused education might look like in engineering and the ways it would be or should be taught, it is unclear whether their perceptions of the tasks actually lead to diversity-focused competencies in engineering. Consequently, much work remains in terms of solidifying these learning experiences and resultant competencies. Moreover, educators need to work to identify desired diversity-focused competencies broadly. By defining the specific competencies associated with an understanding of diversity in engineering, educators can more effectively design both learning environments and assessment tools to develop those competencies. As such, future work should focus on clarifying which knowledge, skills, and attitudes associated with diversity-based competence are most appropriate for engineering curricula. Development of concrete learning outcomes and assessment criteria for diversity-focused education will enhance the adoption of such efforts.

Lastly, unlike other studies in which a common definition or understanding of the task could be assumed (e.g., [60]), we opted to first explore participants' task perceptions, answering Eccles' call [61] to operationalize less commonly studied constructs within EVT. In doing so, we revealed that there is not a single shared understanding of what it means to teach or learn about diversity in engineering, yet it is believed to be important. Having a framework was an asset in this study because it gave us a structured way to think about

an ill-defined concept (diversity education) and to do so in a way that connects to other educational research, i.e., essentially in line with the purpose of frameworks in educational research [62]. We were able to use EVT to elicit what was similar and different about learning engineering to other similar learning tasks. As a result, our approach can serve as a model for other researchers examining tasks that are difficult to define. At the same time, framing learning about diversity as a task can promote a product vs process orientation that may over simplify what it means to engage in diversity-focused education. Certainly, EVT was not the only framework we could have chosen for this study and future studies might use critical approaches to interrogate this topic further and specifically consider what causes the misalignment between the content, pedagogical, and learning expectations. This misalignment is important to understand as students and teachers navigate how to engage in diversity-focused education.

7. Conclusion

If educators are strategic and intentional, there are opportunities to incorporate diversity-focused education in engineering classrooms. In addition to clearly demonstrating the value of diversity, educators will also need to address uncertainty regarding the structure of such a task as it may increase the likelihood of (dis)engagement. The current cultural milieu of engineering positions diversity as something peripheral to core disciplinary knowledge and, as a result, sends students messages that diversity-focused education is somehow non-engineering. As an activity itself, learning about diversity is valued, though not necessarily perceived as valuable enough to take the place of more technical engineering content. Moreover, dominant teaching and learning approaches in engineering give students cause for concern about the potential of diversity-focused education – even if they express interest in such activities. Nonetheless, students tend to see value in diversity in general, and utility in particular. By framing engineering as a problem-solving discipline, students were able to connect diversity to increased effectiveness in problem solving activities through the incorporation of multiple perspectives.

We acknowledge that there remains much work to be done at this intersection, but argue that an understanding of student expectations is critical to the development of concrete competencies and assessment approaches that legitimate and, consequently, drive diversity closer to the core of a modern engineering education. Our work has demonstrated how the culture of engineering influences the ways people position topics such as diversity; illustrated the interactions between teaching, learning, and difficulty beliefs; and described the different ways that engineering students express their value of diversity in engineering. As engineering educators continue to advance discussion of diversity, we hope this work can provide support for their efforts.

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