Online-Journals.org

iJEP International Journal of Engineering Pedagogy

iJEP | eISSN: 2192-4880 | Vol. 14 No. 1 (2024) | OPEN ACCESS

https://doi.org/10.3991/ijep.v14i1.41633

PAPER

Ways of Being Smart in Engineering: Beliefs, Values, and Introductory Engineering Experiences

Amy Kramer(✉), Rachel Louis Kajfez, Emily Dringenberg

The Ohio State University, Columbus, OH, USA

Kramer.659@osu.edu

ABSTRACT

Common discourse conveys that to be an engineer, one must be "smart." Our individual and collective beliefs about what constitutes smart behavior are shaped by our participation in the complex cultural practice of smartness. From the literature, we know that the criteria for being considered "smart" in our educational systems are biased. The emphasis on selecting and retaining only those who are deemed "smart enough" to be engineers perpetuates inequity in undergraduate engineering education. Less is known about what undergraduate students explicitly believe are the different ways of being smart in engineering or how those different ways of being a smart engineer are valued in introductory engineering classrooms. In this study, we explored the common beliefs of undergraduate engineering students regarding what it means to be smart in engineering. We also explored how the students personally valued those ways of being smart versus what they perceived as being valued in introductory engineering classrooms. Through our multi-phase, multi-method approach, we initially qualitatively characterized their beliefs into 11 different ways to be smart in engineering, based on a sample of 36 engineering students enrolled in first-year engineering courses. We then employed quantitative methods to uncover significant differences, with a 95% confidence interval, in six of the 11 ways of being smart between the values personally held by engineering students and what they perceived to be valued in their classrooms. Additionally, we qualitatively found that 1) students described grades as central to their classroom experience, 2) students described the classroom as a context where effortless achievement is associated with being smart, and 3) students described a lack of reward in the classroom for showing initiative and for considerations of social impact or helping others. As engineering educators strive to be more inclusive, it is essential to have a clear understanding and reflect on how students value different ways of being smart in engineering as well as consider how these values are embedded into teaching praxis.

KEYWORDS

first-year engineering, multi-method, equitable classroom practices

Kramer, A., Kajfez, R.L., Dringenberg, E. (2024). Ways of Being Smart in Engineering: Beliefs, Values, and Introductory Engineering Experiences. *International Journal of Engineering Pedagogy (iJEP)*, 14(1), pp. 129–148. https://doi.org/10.3991/ijep.v14i1.41633

Article submitted 2023-05-22. Revision uploaded 2023-09-15. Final acceptance 2023-09-16.

1 INTRODUCTION

Common public messaging promotes the narrative that to become an engineer, one must be considered "smart," and being recognized as smart is frequently linked to high academic achievement in math and science [1, 2]. Students who pursue engineering degrees consistently report being institutionally identified within their K-12 education as smarter than others and, therefore, as good candidates to become engineers [3]. Engineering students and faculty alike believe that engineers are generally high academic achievers [4]. Indeed, researchers have directly observed that the cultural practices within undergraduate engineering classrooms work to position some individuals as being "not cut out for engineering" [5, p. 57]. Being positioned in this manner has tangible social implications. Our previous research has demonstrated that engineering students believe that being recognized as smart by their peers and instructors is essential for gaining access to the resources needed for success in engineering (e.g., support from faculty, input in teams, scholarships, etc.) [6].

The assumption that not everyone is "smart enough" to participate in engineering is problematic because who and what gets recognized as smart is biased. Researchers have consistently demonstrated that perceptions about what it means to be smart can function in exclusionary ways, maintaining inequitable social hierarchies [7–11]. For instance, the practice of tracking students in the pre-college American education system based on perceived ability perpetuates inequities related to social class and race [8]. By exploring the different ways that undergraduate students believe one can be smart in engineering, along with examining how these perceptions are valued on a personal level and within introductory engineering classrooms, we can gain insight into how our individual and collective assumptions about what it means to be smart enough to pursue engineering hinder efforts to be inclusive of diverse individuals, knowledge systems, and motivations to study engineering.

2 LITERATURE REVIEW

2.1 Beliefs about what counts as smart are culturally dependent

Researchers have long argued that our perceptions of intelligence are culturally dependent [12, 13]. In other words, what it means to act intelligently or what is considered smart in one cultural context may not be considered smart in another [13]. For example, researchers found that American-born parents believed that a person could be intelligent but lazy, while Asian-American parents believed that intelligence was inherently linked to hard work [14]. Another study on beliefs about intelligence revealed that individuals from India were more likely to believe that everyone has the potential to become highly intelligent compared to citizens of the United States [15]. In addition to variations across different cultural groups, specific professional groups may also hold different shared beliefs about what it means to be smart. Within the engineering field, researchers have demonstrated that greater emphasis is placed on analytical ability and technical skills rather than on ethical or social knowledge and skills [16–18]. Similarly, a study of engineering faculty found that the non-technical aspects of engineering (e.g., aspects related to the social sciences) are the least valued [19].

2.2 Theorizing smartness as a cultural practice considers both social forces and individual agency

Beth Hatt [20] theorized smartness as a distinct cultural practice that occurs in schools. Instead of simply stating that various cultures acknowledge different ways of being smart, she used the work of Holland et al. [21] to argue that students' fundamental ideas of who they are in school come from engaging in the cultural practice of smartness. In other words, smartness can be understood not as an inherent trait of any individual, such as an IQ score or a specific skill, but rather as an ongoing, interactive process involving multiple people in a specific context through which meaning is produced. In this research project, we adopt Hatt's [20] theoretical perspective, which posits that beliefs about what it means to be smart are commonly held among students and are shaped by their participation in the cultural practice of smartness in general, in educational systems and collegiate engineering education.

The framing of smartness as a cultural practice is significant because it acknowledges that cultures not only have rules, guidelines, and social forces (e.g., broader systems of power and privilege) that influence individual behavior but also that individuals have the agency to behave in ways that influence culture [21]. For example, Hatt's ethnographic study in an elementary school classroom revealed that social forces, including biased behavior from the teacher, led to Black boys receiving less recognition and being positioned as less smart compared to their White counterparts [20]. Additionally, Hatt demonstrated that marginalized students show resilience by leveraging their agency to redefine their value (e.g., identifying as "street smart") within unjust systems [22].

In our specific context, Hatt's theorization of smartness as a cultural practice implies that as students engage in society, pre-college education, and then introductory engineering courses, they are engaging in the cultural practice of smartness, through which they learn and collaboratively form common beliefs about what it means to be smart in the field of engineering. It also means that we acknowledge the agency of students in co-constructing these common beliefs. In other words, it is important to investigate not only the common beliefs in a given context but also to compare 1) how students personally value the different ways of being smart that exist within a context with 2) how those ways of being smart are enacted as valuable in the context.

3 PURPOSE AND RESEARCH QUESTIONS

While engineering is often linked with being "smart," limited research has explicitly examined the beliefs and values held by students regarding what it means to be smart in the field of engineering. In this study, we aimed to: 1) qualitatively characterize the range of ways that undergraduate engineering students believe one could be smart in engineering; 2) quantitatively compare the personal value students placed on these different ways of being smart in engineering with how they were valued in their introductory engineering classrooms; and 3) analyze qualitative data from students discussing their classroom experiences as they justified their ranking of the values enacted in classrooms to explore the connections between beliefs, values, and classroom experiences. Specifically, we will address the following research questions:

1. What are the common beliefs that students hold about ways of being smart in engineering?

2. What are the differences between students' personal valuations of being smart and what is enacted as valuable in their introductory engineering classrooms?
3. What did students draw on to justify the differences they reported between their personal values and the values enacted in their introductory engineering classrooms?

4 METHODS

We utilized a multi-phase, multi-method approach, which involved conducting a series of three one-on-one interviews with engineering students enrolled in first-year engineering courses over the course of approximately one calendar year. Figure 1 presents an overview of the research design, organized by phase and research question (RQ).

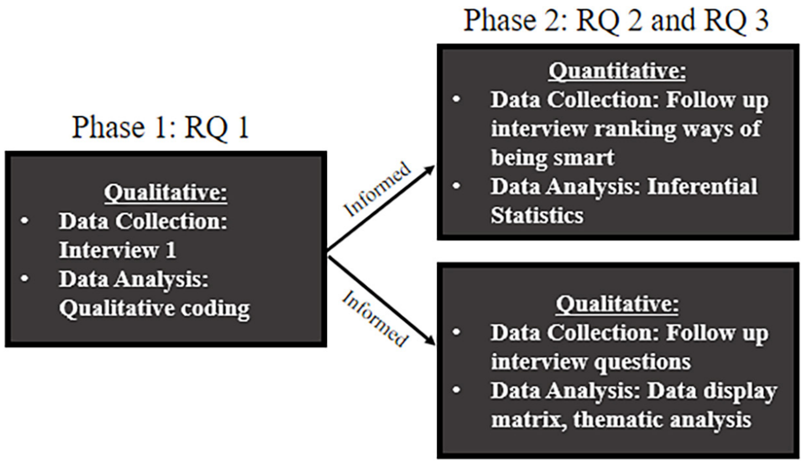

Fig. 1. Overview of research design

4.1 Participants and context

We recruited first-year engineering students at a prominent research-focused university in the Midwest. With approval from the university's institutional review board, we selected 36 first-year engineering students to participate in the study during the spring of 2020. We purposefully sampled students from various institutional pathways into engineering at the university. These pathways included: 1) community college, 2) regional campuses, 3) an alternative math starting point, 4) standard, 5) residential learning cohorts, and 6) honors. Each pathway provides a version of the same two-semester first-year engineering course sequence, which is a mandatory requirement for an engineering degree at the institution that grants the degree. The two-semester course sequence aims to introduce students to topics such as engineering problem-solving, graphics, computer-aided design, programming, teamwork, and oral and written technical communication. We include students from various pathways to enhance diversity in our sample, particularly in terms of the contexts in which they were introduced to engineering.

We experienced some attrition during the research study, with only 28 out of the initial 36 participants completing both the first and follow-up interviews. Although we aimed to have an equal number of participants in each pathway, there was greater attrition in the alternative math starting point and community college pathways compared to the others. Table 1 presents a list of participants who took part in both the initial and final interviews, along with their pseudonyms, pathways, gender, and race. The participants were given the opportunity to choose their own pseudonyms (or use their real names), as well as indicate gender and racial identity. We have included these demographic details to enhance the transferability of the findings and to align with the call to "shift the default" [23] by being transparent about the race and gender of the participants involved in this study.

Table 1. Participants' pseudonyms, institutionalized pathways, and social demographics

Pseudonym	Pathway	Gender	Race
Ace	Honors Program	Male	White, Hispanic/Latinx
Anna	Standard Program	Female	White, East Asian
Apple	Honors Program	Male	White
Carrie	Alt. Math	Female	White
Charlie	Residential Cohort	Male	White
Daisy	Community College	Female	Hispanic/Latinx
Daniel	Honors Program	Male	White
David	Honors Program	Male	East Asian
Emma	Residential Cohort	Female	White
Frank	Regional Campuses	Male	White
Hailey	Standard Program	Female	Asian
Hannibal	Regional Campuses	Male	White
J	Honors Program	Transgender Male	White
Jack	Honors Program	Male	South Asian
Jackie	Residential Cohort	Female	White
James	Regional Campuses	Male	White
Jimmy	Residential Cohort	Male	White
Kaylee	Regional Campuses	Female	White
Kelvin	Standard Program	Male	East Asian
Lynn	Regional Campuses	Female	White
Magic	Standard Program	Male	African American, White
Molly	Residential Cohort	Female	White
Nehemiah	Alt. Math	Male	White
Paul	Community College	Male	White
Robert	Community College	Female	White
Sarah	Honors Program	Female	White
Skylar	Standard Program	Female	White
Wyatt	Residential Cohort	Male	White

4.2 Beliefs and values as research constructs

This project focused on students' beliefs as a research construct. Beliefs are a complex construct that lacks a working definition within or across fields [24]. We operationalized beliefs as students' espoused beliefs about ways of being smart in engineering. This operationalization is evident in our methods for Phase I. We explicitly asked students to discuss what defines an engineer, a smart person, and a smart engineer. Of course, espoused beliefs, or beliefs that one can explicitly articulate, do not capture (and may contradict) the implicit beliefs that operate outside of our conscious awareness but may still influence our worldview and behavior [25, 26].

In Phase II, which focuses on values as the research construct, we asked students to rank the common beliefs about ways of being smart in engineering from Phase I. Values refer to the importance we attribute to an idea, and our beliefs are embedded within our values [27]. Having them rank the order twice enabled us to specifically compare their personal values with the values enacted in their introductory engineering classroom. This distinction is also important as we focus on the values that were implemented through the classroom practices they experienced, which may not necessarily reflect the values of the instructor or institution [28].

4.3 Data collection and analysis: Phase 1–characterizing the common beliefs about ways to be smart in engineering

In the initial semi-structured, one-on-one interview, we inquired about participants' beliefs about engineering, beliefs about being smart, and how (or if) they identified as smart and an engineer. Interview questions were piloted and refined prior to the interviews to ensure that they would prompt participants to provide responses that addressed the primary research questions [29]. The interview validation process consisted of pilot interviews and an iterative, collaborative refinement process, as detailed in a previous publication [29]. The interviews took place during the second semester of the participants' introductory engineering course sequence. Each interview lasted approximately 60 to 90 minutes and took place either in person or via the video communication platform Zoom. After transcribing and cleaning the interviews, two members of the research team analyzed them using a structural coding technique to condense the data and organize it according to the major constructs of interest, such as beliefs about smartness, beliefs about engineering, identity as smart, and identity as an engineer.

Two members of the research team then analyzed each excerpt resulting from the structural coding to develop emergent and distinct codes based on the students' shared beliefs within the categories [30]. Through an iterative and collaborative process that included weekly analysis meetings over the course of three months, we collectively developed 11 common beliefs about the ways of being smart in engineering. We considered a belief to be common if it was explicitly espoused by at least approximately half of the participants in an interview transcript.

4.4 Data collection and analysis: Phase 2–quantitatively comparing personal and enacted values of the different ways of being smart in engineering

We conducted follow-up interviews approximately one year after the initial interviews. Similar to the initial interviews, the follow-up interviews were conducted one-on-one, lasted approximately 60 minutes, and were held using the online video communication platform Zoom. We asked participants to reflect on their experience in their introductory engineering sequence. We presented the 11 different ways to be smart in engineering, which were generated in Phase 1, as a list. Then, we asked the participants to rank the 11 different ways twice, once based on each of the following:

1. What personally makes them feel smart enough to be an engineer.
2. What people did to be recognized as smart enough to be engineers in their introductory engineering course.

We designed this phase of data collection to enable us to quantitatively compare the common beliefs about the different ways of being smart in engineering to assess which beliefs were 1) personally valued by students, representing their agency when participating in smartness as a cultural practice, and 2) enacted as valued in introductory engineering courses, representing the social forces that influence students as they participate in the cultural practice of smartness in introductory engineering classrooms. We conducted a quantitative analysis of the interview rankings to determine the overall average rank value for each item, considering both personally held and classroom-enacted values independently. We then conducted a paired t-test with a 95% confidence interval to determine the statistical significance of the personal value and enacted value for each way of being smart in engineering.

4.5 Data collection and analysis: Phase 3–qualitatively exploring differences in personally held values and the values enacted in classrooms

After students ranked the different ways of being smart in engineering twice during the follow-up interview, we asked probing questions to understand the basis for their rankings and to provide us with a rationale or justification. The probing questions included asking them to provide specific examples from their introductory engineering classrooms that influenced their ranking. We used this qualitative data to provide context and make sense of the participants' quantitative rankings. We utilized a data display matrix to condense the interview data from all participants and followed it up with a thematic analysis [30]. Two members of the research team conducted the analysis independently and then convened at weekly meetings over the span of two months to discuss their findings. We utilized a collaborative and iterative approach to identify themes based on what students drew from their introductory classroom experiences to justify their ranking of the items.

4.6 Researcher positionality

Acknowledging the influence of our positionalities on the research process, we recognize the importance of reflecting on and being transparent about the aspects of our identities that shape our work [31]. In this study, our race, gender, and roles as engineering educators and researchers are especially relevant. We all identify as White women who have benefited from White privilege. We have all been identified as "gifted" throughout our educational experience and hold advanced degrees in engineering. Therefore, our participation in smartness as a cultural practice has largely positioned us as smart and has also influenced our beliefs and values regarding ways of being smart. Nevertheless, as women in the engineering field, we have encountered scrutiny regarding our abilities. Gendered aspects of the cultural practice of smartness have negatively impacted each of us in various ways and at different times. Additionally, all the authors of this paper have taught in the introductory engineering course sequence at the center of this research. Therefore, we feel personally responsible for the experiences of students and the values enacted during their classroom experiences, as these reflect the classes in which we hold positions of power. Drawing on our positions, including our privileged perspectives, positioning as smart, and lived experiences as women, we were motivated to undertake this study. By examining students' beliefs about smartness and reflecting on our experiences as educators in the classroom, we aim to critically analyze the cultural practice of smartness within introductory engineering classrooms and provide pedagogical recommendations to challenge its perpetuation of the status quo.

5 RESULTS AND FINDINGS

5.1 RQ 1: What are the common beliefs that students hold about ways of being smart in engineering?

Through our qualitative analysis of the initial round of student interviews, we identified 11 common beliefs about ways of being smart in engineering based on the expressed beliefs of the participants. Table 2 presents the 11 common ways along with their definitions and an example quote to illustrate how the way of being smart was represented in the data. The different ways of being smart are provided in the table in alphabetical order.

Table 2. Students' common beliefs about ways of being smart in engineering

Way of Being Smart in Engineering	Definition	Example Quote	Number of Participants Out of Initial 36
1. Achieving with little effort	Smart engineers achieve with little effort. Achievements primarily included getting good grades in their engineering courses.	*"If you're already really smart, you don't always have to put as much effort into things in order to get the same amount of output or even greater output at times." – Jackie*	*20*
2. Applying math and science	Smart engineers can appropriately apply math and science to solve problems.	*"What does it mean to be smart? I feel like I think smartness is the ability to be able to figure something out in like the analytical sense. You would be given a problem like math, physics or whatever, and you have the skills and ability to figure that problem out." – Molly*	*15*
3. Being born with innate ability	Smart engineers are born with innate abilities. This can include innate problem-solving abilities or innate abilities in math and science.	*"Some people are just born more gifted at problem solving than others. And of course, that also comes from, like, nature." – Ace*	*18*
4. Communicating well in teams	Smart engineers communicate well in teams and are good at collaborating with others.	*"[Engineers] are good communicators...really good at teamwork because I feel like without teamwork you cannot be an engineer." – David*	*19*
5. Getting good grades	Smart engineers get good grades in their engineering courses.	*"They get good grades; I think that's what makes people smart." – Jack*	*21*
6. Helping others/ making the world better	Smart engineers help others and work on projects that make the world better.	*"[Good engineering] is creating new inventions to help or benefit the world. Just trying to progress things past where they are right now." – Anna*	*20*
7. Showing initiative	Smart engineers show initiative, which can include taking on leadership roles and being confident.	*"[A smart engineer] is always striving. He's always at the top. You can see that he's always doing good and he's always taking leadership for all the projects and stuff." – Dwight*	*18*
8. Solving complex problems	Smart engineers solve complex problems.	*"Problem solving, that's like an extremely, important characteristic to have for being smart and being an engineer. That's pretty much like your job as an engineer is to problem solve." – Carrie*	*27*
9. Thinking creatively	Smart engineers think creatively to come up with outside of the box solutions to problems.	*"[Smart engineers] kind of think outside the box and like come up with, like, new ideas, creative." – Wyatt*	21

(Continued)

Table 2. Students' common beliefs about ways of being smart in engineering *(Continued)*

Way of Being Smart in Engineering	Definition	Example Quote	Number of Participants Out of Initial 36
10. Working efficiently	Smart engineers are efficient, which can mean solving complex problems quickly, understanding concepts quickly, or getting good grades with minimal effort.	*"I saw these people who could take these problems and actually solve them pretty efficiently that I just considered to be pretty smart." – Apple*	*20*
11. Working hard	Smart engineers work hard, which can include being dedicated and persistent.	*"You always have to keep trying if you want to be smart, because it's always evolving and pushing." – Robert*	*18*

Our findings reveal that students commonly believe in a variety of ways of being smart in engineering. This demonstrates that these different ways of being smart are embedded in the discourse and broader experience of engaging in smartness within engineering education.

In the following sections, we will further explore the beliefs of engineering students by examining the differences in how they personally valued the various ways of being smart with what they perceived as valuable in their introductory engineering classrooms.

5.2 RQ 2: What are the differences between students' personal valuations of being smart and what is enacted as valuable in their introductory engineering classrooms?

In Table 3, we present the results of the inferential statistical analysis considering the average ranked values across all participants for each way of being smart: what students personally value as a way of being smart and what was considered valuable in their introductory engineering classrooms. Overall, our findings indicate a statistically significant difference in how students ranked six out of the 11 ways of being smart in engineering. Additionally, in Figure 2, we present a graphical representation of the average ranked values across all participants for each way of being smart in engineering.

Table 3. Value ranking of ways of being smart in engineering – statistical overview

Statistical Significance	Way of Being Smart in Engineering	Enacted in Classroom		Personal		p-Value
		Mean	Std. Dev.	Mean	Std. Dev.	
More value enacted in classroom	Getting good grades	4.07	3.10	6.93	2.89	**0.00**
	Achieving with little effort	7.03	3.24	8.86	2.11	**0.01**
	Born with innate ability	7.55	3.01	9.28	2.12	**0.01**
More valued personally	Working hard	4.76	2.72	3.34	2.07	**0.01**
	Showing initiative	6.83	2.82	5.21	2.93	**0.01**
	Making the world better/ helping others	8.62	2.92	7.03	2.81	**0.01**

(Continued)

Table 3. Value ranking of ways of being smart in engineering – statistical overview *(Continued)*

Statistical Significance	Way of Being Smart in Engineering	Enacted in Classroom		Personal		p-Value
		Mean	Std. Dev.	Mean	Std. Dev.	
No significant difference in value	Solving complex problems	4.07	2.59	4.90	2.67	0.16
	Working efficiently	5.24	2.63	4.45	2.70	0.11
	Thinking creatively	5.45	2.92	4.17	2.59	0.06
	Communicating well in teams	6.10	2.67	5.72	2.80	0.61
	Applying math/science	6.28	2.59	6.10	2.72	0.70

Note: Participants ranked each way in order of value with 1 = most valued and 11 = least valued.

In their introductory engineering classroom, students ranked getting good grades and solving problems as the most valuable ways of being as smart, making the world better or helping others was considered the least valuable. In terms of personal values, students ranked working hard as the most valuable, while being born with innate ability was considered the least valuable.

There was a statistically significant difference between the value placed on getting good grades, innate ability, and achieving with little effort with more value placed in the classroom than students' personal valuation. While students ranked working hard, showing initiative, and making the world better or helping others as personally valued at significantly higher levels than how they are valued in the classroom.

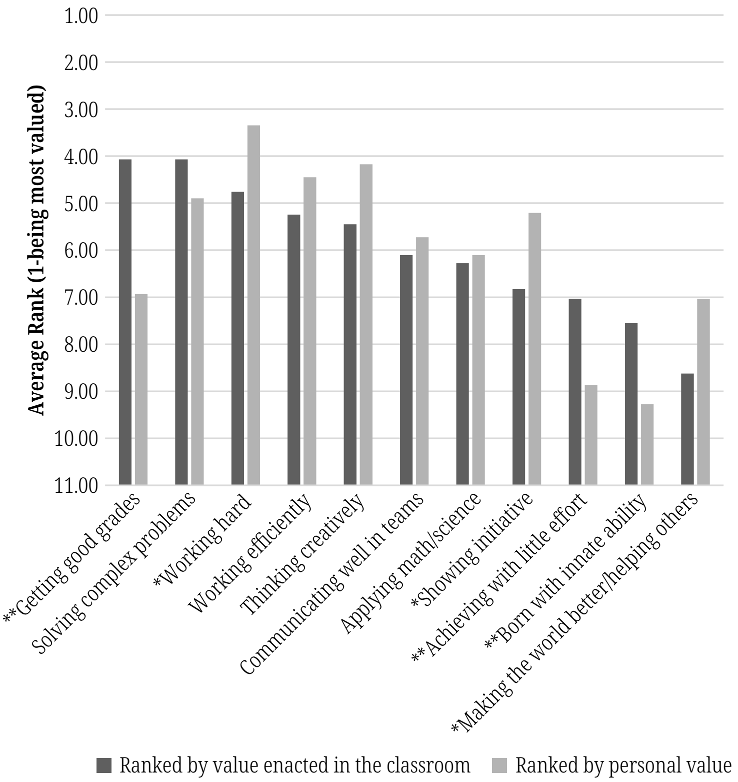

Fig. 2. The average rank of the value of ways of being smart in engineering

Note: *Indicates statistical significance (more value held personally by students), **indicates statistical significance (more value enacted in the classroom).

5.3 RQ 3: What did students draw on to justify the differences they reported between their personal values and the values enacted in their introductory engineering classrooms?

By utilizing interview transcripts along with participants' explanations to justify their rankings, we were able to conduct an additional in-depth qualitative analysis of the experiences that students draw upon when discussing the different ways of being smart in engineering and how they are valued. Overall, we developed three findings from the qualitative analysis. Table 4 provides an overview of the qualitative findings in alignment with the key quantitative results. The qualitative findings are elaborated on in the subsections.

Table 4. Qualitative findings connecting classroom experiences to statistically different values placed on the different ways of being smart in engineering

<table>
<tr><th>Classroom Experience</th><th>Common Belief</th><th>Value</th></tr>
<tr><td>1. Students described grades as central to their classroom experience</td><td>Getting good grades</td><td rowspan="3">More value enacted in the classroom</td></tr>
<tr><td rowspan="3">2. Students described the classroom as a context where effortless achievement is associated with being smart</td><td>Achieving with little effort</td></tr>
<tr><td>Born with innate ability</td></tr>
<tr><td>Working hard</td><td rowspan="3">More valued personally</td></tr>
<tr><td rowspan="2">3. Students described a lack of reward in the classroom for showing initiative and for making the world better</td><td>Showing initiative</td></tr>
<tr><td>Making the world better/helping others</td></tr>
</table>

Students described grades as central to their classroom experience. We found that receiving good grades was overwhelmingly described as the primary method by which students are recognized as smart in their introductory engineering classrooms. Grades were considered the "bottom line" or the "benchmark" for determining who is smart. Interestingly, students also discussed how the emphasis on achieving good grades is prioritized as the "main goal" in their engineering classroom, often overshadowing the importance of grasping the conceptual understanding of the material. For example,

> *"In the class, I feel my main goal is to get a good grade and that's my only goal and I feel if I do that, I think that in the class I am being smart." – Jack*

> *"A lot of things are based off of grades. [Instructors] don't care about our understanding. They care about how we can play the system to get an A." – Anna*

Additionally, it is important to note that many of the participants who ranked "getting good grades" as lower in value when being recognized as smart in the classroom still described the items they ranked higher as ultimately leading to good grades. For instance, students might argue that being recognized as smart in their classroom was based on working efficiently and solving complex problems, which would ultimately result in a good grade. Therefore, getting a good grade was still a valuable way to be acknowledged as smart in engineering classrooms.

The students also discussed the significance of grades as the sole formal feedback they receive in their engineering classrooms. They emphasized the importance of this source of information in helping them gauge their performance relative to their peers. For example, Hailey simply states that grades provide a tangible means of comparing oneself to others in the class.

> *"I think it's the good grades because it's a tangible kind of thing that you can see how you're doing compared to others in your class." – Hailey*

Similarly, another participant, Paul, described grades as a way of "setting up the hierarchy" in engineering classrooms, allowing students to understand how they compare to their peers. Furthermore, Emma described achieving good grades as a means of "asserting intellectual dominance" in an engineering classroom. Ultimately, the students recognized the significance of grades in their engineering classrooms, as grades are utilized to gauge their standing relative to their peers.

Although many students expressed the personal importance of receiving grades to feel smart in engineering, they also acknowledged the limitations of using grades as the sole measure of their abilities as engineers. They were often resistant to the emphasis placed on grades in their classrooms. The two primary reasons students provided for grades being less personally significant to their self-perception of smart in engineering were: 1) the belief that grades are not the most accurate measure of their engineering abilities (i.e., one can still be smart and not get good grades), and 2) the belief that grades are inconsequential in a professional engineering environment and only hold relevance within the context of their educational experiences. This finding is significant because it emphasizes that, despite their personal reservations about prioritizing grades as the primary indicator of being smart in engineering, students still recognize the pivotal role that grades play in being recognized as smart within the context of their introductory engineering classrooms.

Students described the classroom as a context where effortless achievement is associated with being smart. Achieving with little effort and being born with innate ability were both described as important factors for being recognized as smart in an engineering classroom. The primary way students described the demonstration of effortless achievement or innate ability in the classroom was by comprehending complex concepts or completing assignments quickly and effortlessly. Indeed, the most common example given by students to illustrate how they recognize smartness in their peers is based on their perception of who is able to achieve with the least amount of effort. For example,

> *"When you're in class and you see someone tackle a problem that you don't even know where to begin with and they have an answer in 30 seconds, it seems like a pretty natural ability." – Anna*

Additionally, students emphasized the need to work quickly, effortlessly, and efficiently in engineering due to the heavy workload and time constraints in their classes. For example, Apple describes how perceived efficiency is a key metric for understanding how someone is smart given the limited amount of time available to students to complete their work.

> *"I think I put efficiently mainly because the scope of the class, we didn't have unlimited time. I saw these people who could take these problems and actually solve them pretty efficiently that I just considered to be pretty smart. We had this time constraint and being able to use that time in a smart way and an efficient way, I just saw that as pretty good." – Apple*

Finally, students also described how the ability to work quickly, effortlessly, and efficiently was perceived as smart in the classroom because they observed that their engineering professors do not slow down for struggling students and instead set the pace in their classrooms based on those who quickly grasp a concept or complete an example problem.

Students described a lack of reward in the classroom for showing initiative and for helping others or making the world better. We found that students in introductory engineering classrooms described a lack of reward for taking initiative, helping others, or contributing to making the world a better place. First, students described how they are not rewarded for demonstrating initiative; more specifically, they are not graded on their ability to show initiative. They described showing initiative as taking on leadership roles in project teams, being confident, producing creative solutions, and working hard. In their introductory engineering classes, they observed that they were rarely given the chance to demonstrate initiative. Instead, they were encouraged to complete assignments in the precise manner the instructor specified. For example, Robert described how her grade suffered whenever she deviated from the specific practices advocated by the instructor while learning 3D modeling in her introductory engineering course.

> *"There were lots of times where we were doing 3D models and there were multiple ways to get it done, and if you thought outside of the box and did it differently, the teacher may not like how you did it and may take points off if you didn't do it the way he was originally intending you to do it." – Robert*

Additionally, students described how some instructors mentioned that engineering design has a real-world impact, such as making the world better and helping others. However, the course curriculum did not allow for reflection or explicit connection regarding how the content in the course assignments or design projects would matter in a real-world scenario. For example, Lynn describes how, by the end of her first-year design project, she lost sight of how it was supposed to contribute to making the world a better place.

> *"In the scenarios that they would give you, it was supposed to represent making the world better. But you lose sight of that a lot...finishing the project, at least I didn't even relate [it] to making the world a better place. I forgot about the scenarios by the time we were done." – Lynn*

Although students personally valued making the world a better place and helping others more than what was believed to be practiced in the classroom, it was generally one of the least valued ways of being smart in engineering. Indeed, students questioned whether it should even be included on the list of what makes a smart engineer. They made statements about how it was more related to being an ethical or moral engineer than simply being smart. This is important to note because it reflects how smartness is being practiced in engineering classrooms, creating implicit boundaries around what ways of being smart are a part of the broader discourse on the role of engineers in society but are not valued or acceptable in classroom practices within engineering. For example, James stated that within his engineering courses, the idea of making the world a better place is "disconnected" from the conventional definition of smart for most people.

"Making the world a better place and helping others is something that was just kind of overtly disconnected from intelligence for most people. They would recognize we're helping people out and being a good person...But plenty of just really bad people, and for lack of a better word, assholes, are smart." – James

Taken together, these qualitative findings are concerning because they highlight how students' experiences in introductory engineering classrooms prioritize grades and efficiency over conceptual understanding. Additionally, they indicate a lack of value placed on showing initiative, helping others, and connecting to social impact.

6 DISCUSSION

Our findings indicate that students observe values being practiced in classrooms that are different from their personal beliefs. We must address this significant gap in engineering education culture, as these aspects are often implicit but have significant implications for students' learning, beliefs, identities, and educational aspirations [6, 20, 32]. We organized the discussion around the ways of being smart in engineering, highlighting the significant differences between the students' personal values and the values enacted and practiced in the classroom.

6.1 Grades in engineering classrooms

Our findings indicate that students considered letter grades to be the only feedback "that matters" and are the most important factor in being recognized as smart. We find this troubling because it indicates that students are receiving the message that a high grade is more significant than conceptual understanding or personal growth. This stands in direct contrast to literature that emphasizes the importance of promoting a growth mindset and mastering learning behavior [34]. Additionally, researchers suggest that low-stakes formative assessments (e.g., feedback that does not significantly impact overall course letter grades) with practice opportunities, during which students can implement feedback, are essential to student learning and development [33].

Further, it was revealed that grades are the primary means by which students assess themselves in comparison to others in their classroom. They perceive this comparison as an understanding of their position within the hierarchy of their engineering program. Again, this is troubling because these social comparisons can enforce dominant values that reproduce smartness in oppressive ways and maintain the status quo [20].

6.2 Innate ability, achieving with little effort, and hard work in engineering classrooms

The most common examples given when discussing how values are demonstrated in the classroom in terms of recognizing who is considered smart in engineering were instances of students who could perform in ways that appeared effortless, fast, and efficient. We consider this problematic because it fails to normalize the idea that productive struggle leads to learning [34]. Furthermore, the emphasis on effortless achievement and innate ability is consistent with widespread cultural beliefs in the U.S. that intelligence is an inherent and individual trait [15, 34]. It also aligns with previous research on smartness in engineering, which suggests that undergraduate engineering students perceive intelligence as an individual's ability to work efficiently based on their perceived ratio of outcome (e.g., a test score) to effort (e.g., the amount of time spent studying) [35]. Although being efficient may seem like a positive trait, researchers have shown that when students make judgments about the efficiency of others, many assumptions are made that introduce bias into their judgments [35]. For instance, students often make speculative assumptions about the amount of time their peers spend studying as well as their prior knowledge or experiences. This introduces ambiguity and draws on problematic stereotypes. For example, students from non-dominant groups are assumed to have to exert more effort to achieve the same outcome as members of dominant groups. The stereotypes about the level of effort expected from students in certain groups to succeed in engineering have implications for who is seen as suitable for a career in engineering. Indeed, researchers have found a widespread belief within the field of engineering that not everyone is capable of excelling in engineering, as well as the assumption that a certain number of students are expected to fail [36].

6.3 Showing initiative and considerations for making the world better in engineering classrooms

Students personally value demonstrating initiative, helping others, and contributing to a better world. However, they also indicated that in introductory engineering classrooms, what is valued as smart is not associated with initiative, concern for others, or the potential positive impact of their work on the world. This is unsurprising, given the pervasiveness of the social-technical divide in engineering and the overall emphasis on technical skill over all else in engineering spaces [16–18]. This finding further aligns with existing research indicating the presence of a "culture of disengagement" in engineering; meaning that the way engineering programs emphasize technical skills, such as math and science over social and ethical issues, leads engineers to disengage from social welfare concerns (e.g., helping others or contributing to a better world) [18]. By not focusing on how engineers can help others and how our work can contribute to making the world better in our classrooms, we are contributing to this lack of engagement.

7 PEDAGOGICAL RECOMMENDATIONS

As educators and researchers, we need to explicitly acknowledge and reflect on what engineering students believe it means to be smart in engineering as well as consider how our classroom practices influence those beliefs. In the following section, we present three specific recommendations for engineering educators: 1) consider critically how assessment practices enact particular values and work to align them with student values; 2) normalize effort and the role of prior experience in learning; and 3) reflect on the discourse of engineering and how that aligns with values being enacted in classrooms.

7.1 Consider critically how assessment practices enact particular values

Given the stark disparity between how students personally value grades and how they perceive them in the classroom, we first recommend that engineering educators critically consider how our assessment practices embody specific values and strive to align them with student values. Indeed, researchers studying culturally responsive pedagogy have demonstrated that understanding and taking into account students' beliefs and values can enhance student achievement and well-being [37]. We strongly recommend that practitioners review their assessment practices and evaluate the extent to which they convey that only grades matter while disregarding the process of learning and mastery that we assume results in the grade, as found in our data. For instance, educators could strive to comprehend their students' values and then endeavor to incorporate them into the semester's assessment. If students express the value of showing initiative, then a portion of their project grade could be based on documenting and reflecting on how their initiative (e.g., leadership, creativity) contributed to the final product or deliverable.

7.2 Normalize effort and the role of prior experiences in learning

Learning requires effort. When someone completes a task quickly, it is more likely due to the learning opportunities they have had prior to that task, rather than any innate ability. Additionally, researchers have shown that concentrated effort through challenges is a productive component of the learning process [34]. We recommend that educators first reflect on their assumptions about who is suited for engineering and approach their course design with the belief that all students can achieve success. We explicitly recommend reviewing classroom practices and policies that may be sending messages to students that promote achievement with little effort. For example, we found that students explicitly mentioned the workload of their engineering classes as a factor contributing to their belief that being smart is more about speed than comprehension. Educators are encouraged to critically evaluate the workload required in their courses and assess their contribution to a meaningful understanding of the course learning outcomes. In addition, we recommend that educators reconsider practices such as imposing time limits on exams or pacing classroom instruction solely based on feedback from the most outspoken students. Finally, we recommend that educators explicitly acknowledge within their classrooms, especially in introductory engineering courses, that students enter engineering programs with diverse levels of prior experience and knowledge.

7.3 Reflect on the discourse of engineering and how that aligns with values being enacted in classrooms

Engineering is a crucial profession for society. The National Academy of Engineers has emphasized the importance of discussions that reflect how engineering contributes to making the world a better place [2]. Additionally, researchers have shown that many efforts are aimed at diversifying engineering feature interventions that focus on social impact and sustainable design [38]. However, our research shows that these values are not put into practice in the introductory classrooms of our context. We recommend that practitioners evaluate the objectives of their introductory course or engineering program and consider how those objectives align (or not) with the desired portrayal of engineering as a field. For instance, if you are teaching in a first-year program and you introduce students to engineering by emphasizing its significance in solving real-world problems and advancing society, but your assessments do not align with or evaluate this, then that value is not being put into practice. We recommend that engineering educators not only contextualize and integrate considerations for how different members of society would benefit (or not) from the projects they assign but also explicitly reward students (e.g., make it a component of their grade) for engaging in such exercises. Furthermore, integrating sociotechnical aspects of engineering into course material will not only align more with student values but also make engineering content more memorable [39].

8 CONCLUSIONS

Our research contributes to an empirical understanding of what engineering students believe are the different ways of being smart in engineering as well as how they are valued by students both personally and in the classroom. We identified 11 ways of being smart that were commonly recognized by engineering students and found significant differences in six of the 11 ways between how they were valued personally by students compared to how they believed they were valued in their introductory engineering classrooms. We analyzed qualitative data to provide context for the quantitative differences in values. The results are concerning because they provide evidence that, smartness is being practiced in introductory engineering classrooms in ways that 1) prioritize grades over learning, 2) showcase achievement with minimal effort, and 3) do not reward students for helping others or considering the social impact of engineering work.

As educators, we must reflect on our role in shaping the cultural perception of smartness in engineering programs, as it profoundly influences students' learning as well as their beliefs and identities. These beliefs and cultural constructs have significant implications for determining who is considered "capable" in engineering and who is excluded from the discipline or labeled as "not cut out for engineering" [5]. As the discipline aims to expand and become more inclusive, it is essential to have a clear understanding and reflect on how smartness operates as a cultural practice in classrooms in order to cultivate equitable educational systems within engineering.

This study was limited in that it was conducted at a predominately White institution. That meant that our sample did not represent the full range of human identities. This limitation impacts the transferability of the results. Future research could explore the beliefs of students in a wider variety of educational settings. Additionally, the study was limited in that it only considered the students' self-described experiences in their introductory classrooms. Future research employing ethnographic methods could provide a deeper understanding of how smartness is being practiced in engineering classrooms.

9 ACKNOWLEDGMENT

This material is based on work supported by the National Science Foundation under Grant No. 1920421. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. We would like to express our gratitude to postdoctoral researcher Bailey Braaten for her significant contributions to the project, including data collection and project management. We would also like to thank undergraduate researcher Yiqing Li for her contributions to the data analysis. Finally, we would like to express our deepest gratitude to the participants of the study for sharing their stories and insights. Without their contributions, this work would not have been possible. We are deeply grateful for their participation and willingness to be open during the data collection.

10 REFERENCES

[1] N. Sochacka, J. Walther, J. Wilson, and M. Brewer, "Stories 'Told' about engineering in the media: Implications for attracting diverse groups to the profession," in *IEEE Frontiers in Education Conference (FIE) Proceedings*, Madrid, Spain, 2014. https://doi.org/10.1109/FIE.2014.7044009

[2] National Academy of Engineering, *Changing the Conversation: Messages for Improving Public Understanding of Engineering*. Washington D.C.: National Academies Press, 2008.

[3] A. Kramer, C. Wallwey, G. Thanh, E. Dringenberg, and R. Kajfez, "A narrative-style exploration of undergraduate engineering students' beliefs about smartness and identity," in *2019 IEEE Frontiers in Education Conference (FIE)*, Cincinnati, Ohio, 2019: IEEE, pp. 1–9. https://doi.org/10.1109/FIE43999.2019.9028388

[4] E. Godfrey and L. Parker, "Mapping the cultural landscape in engineering education," *Journal of Engineering Education,* vol. 99, no. 1, pp. 5–22, 2010. https://doi.org/10.1002/j.2168-9830.2010.tb01038.x

[5] S. Secules, A. Gupta, A. Elby, and C. Turpen, "Zooming out from the struggling individual student: An account of the cultural construction of engineering ability in an undergraduate programming class," *Journal of Engineering Education,* vol. 107, no. 1, pp. 56–86, 2018. https://doi.org/10.1002/jee.20191

[6] E. Dringenberg, A. Kramer, and A. Betz, "Smartness in engineering education: Undergraduate student beliefs," *Journal of Engineering Education,* vol. 111, no. 2, pp. 283–307, 2022. https://doi.org/10.1002/jee.20452

[7] T. Carroll, A. Kramer, and E. Dringenberg, "Intelligence and smartness in engineering: A gatekeeper to diversity and inclusion," in *Collaborative Network for Engineering and Computing Diversity*, Crystal City, Virginia, 2019.

[8] J. Oakes, *Keeping Track*. Yale University Press, 2005. https://doi.org/10.1126/stke.2772005tw114

[9] Z. Leonardo and A. Broderick, "Smartness as property: A critical exploration of intersections between whiteness and disability studies," *Teachers College Record,* vol. 113, no. 10, pp. 2206–2232, 2011. https://doi.org/10.1177/016146811111301008

[10] B. Hatt, *Racializing Smartness*, ed: Taylor & Francis, 2016. https://doi.org/10.1080/13613324.2016.1168537

[11] G. Gutiérrez y Muhs, Y. F. Niemann, C. G. González, and A. P. Harris, *Presumed Incompetent: The Intersections of Race and Class for Women in Academia*. Utah State University Press, 2012.

[12] R. J. Sternberg, "Who are the bright children? The cultural context of being and acting intelligent," *Educational Researcher,* vol. 36, no. 3, pp. 148–155, 2007. https://doi.org/10.3102/0013189X07299881

[13] R. J. Sternberg, "Culture and intelligence," *American Psychologist,* vol. 59, no. 5, p. 325, 2004. https://doi.org/10.1037/0003-066X.59.5.325

[14] L. Okagaki and R. J. Sternberg, "Parental beliefs and children's school performance," *Child Development,* vol. 64, no. 1, pp. 36–56, 1993. https://doi.org/10.1111/j.1467-8624.1993.tb02894.x

[15] A. Rattan, K. Savani, N. Naidu, and C. S. Dweck, "Can everyone become highly intelligent? Cultural differences in and societal consequences of beliefs about the universal potential for intelligence," *Journal of Personality and Social Psychology,* vol. 103, no. 5, p. 787, 2012. https://doi.org/10.1037/a0029263

[16] W. Faulkner, "Nuts and bolts and people' gender-troubled engineering identities," *Social Studies of Science,* vol. 37, no. 3, pp. 331–356, 2007. https://doi.org/10.1177/0306312706072175

[17] W. Faulkner, "Dualisms, hierarchies and gender in engineering," *Social Studies of Science,* vol. 30, no. 5, pp. 759–792, 2000. https://doi.org/10.1177/030631200030005005

[18] E. A. Cech, "Culture of disengagement in engineering education?" *Science, Technology & Human Values,* vol. 39, no. 1, pp. 42–72, 2014. https://doi.org/10.1177/0162243913504305

[19] P. P. Jiménez, J. Pascual, and A. Mejía, "Educating engineers under a social justice perspective," *International Journal of Engineering Pedagogy (iJEP),* vol. 10, no. 3, pp. 82–97, 2020. https://doi.org/10.3991/ijep.v10i3.13673

[20] B. Hatt, "Smartness as a cultural practice in schools," *American Educational Research Journal,* vol. 49, no. 3, pp. 438–460, 2012. https://doi.org/10.3102/0002831211415661

[21] D. Holland, W. Lachicotte Jr, D. Skinner, and C. Cain, *Identity and Agency in Cultural Worlds*. Harvard University Press, 1998.

[22] B. Hatt, "Street smarts vs. book smarts: The figured world of smartness in the lives of marginalized, urban youth," *The Urban Review,* vol. 39, no. 2, pp. 145–166, 2007. https://doi.org/10.1007/s11256-007-0047-9

[23] A. L. Pawley, "Shifting the 'default': The case for making diversity the expected condition for engineering education and making whiteness and maleness visible," *Journal of Engineering Education,* vol. 106, no. 4, pp. 531–533, 2017. https://doi.org/10.1002/jee.20181

[24] M. F. Pajares, "Teachers' beliefs and educational research: Cleaning up a messy construct," *Review of Educational Research,* vol. 62, no. 3, pp. 307–332, 1992. https://doi.org/10.3102/00346543062003307

[25] A. C. Smith, *Cognitive Mechanisms of Belief Change*. Springer, 2016. https://doi.org/10.1057/978-1-137-57895-2

[26] M. H. Connors and P. W. Halligan, "A cognitive account of belief: A tentative road map," *Frontiers in Psychology,* vol. 5, p. 1588, 2015. https://doi.org/10.3389/fpsyg.2014.01588

[27] J. Saldaña, *The Coding Manual for Qualitative Researchers*. Sage, 2016.

[28] D. Polly and M. J. Hannafin, "Examining how learner-centered professional development influences teachers' espoused and enacted practices," *The Journal of Educational Research,* vol. 104, no. 2, pp. 120–130, 2011. https://doi.org/10.1080/00220671003636737

[29] A. Kramer, E. Dringenberg, and R. Kajfez, "Development and refinement of interview protocol to study engineering students' beliefs and identities," in *The American Society of Engineering Education Annual Conference and Exposition, Virtual*, 2020.

[30] M. B. Miles, A. M. Huberman, and J. Saldaña, *Qualitative Data Analysis: A Methods Sourcebook*. Sage publications, 2018.

[31] S. Secules *et al.*, "Positionality practices and dimensions of impact on equity research: A collaborative inquiry and call to the community," *Journal of Engineering Education,* vol. 110, no. 1, pp. 19–43, 2021. https://doi.org/10.1002/jee.20377

[32] N. T. Long and P. Van Son, "Awareness of cultural approach in engineering teaching by lecturers: A literature review," *International Journal of Engineering Pedagogy,* vol. 12, no. 1, 2022. https://doi.org/10.3991/ijep.v12i1.24961

[33] S. A. Ambrose, M. W. Bridges, M. DiPietro, M. C. Lovett, and M. K. Norman, *How Learning Works: Seven Research-Based Principles for Smart Teaching*. John Wiley & Sons, 2010.

[34] C. Dweck, *Mindset: The New Psychology of Success*. NY: Random House, 2006.

[35] E. Dringenberg, A. Kramer, and A. Betz, "Smartness in engineering education: Undergraduate student beliefs," *Journal of Engineering Education.* 2022. https://doi.org/10.1002/jee.20463

[36] K. O'Connor, F. Peck, J. Cafarella, and J. McWilliams, "Working in the weeds: How do instructors sort engineering students from non-engineering students in a first-year Pre-calculus course," in *American Society for Engineering Education Annual Conference*, 2016.

[37] E. Montenegro and N. A. Jankowski, "Equity and assessment: Moving towards culturally responsive assessment," *Occasional Paper,* vol. 29, no. 6, pp. 10–11, 2017. https://doi.org/10.1002/au.30117

[38] G. Gopakumar, "Public leadership framework: Studying approaches to diversify engineering education," *International Journal of Engineering Pedagogy*, vol. 4, no. 1, pp. 43–48, 2014. https://doi.org/10.3991/ijep.v4i1.3269

[39] D. A. Chen, M. H. Forbes, G. D. Hoople, S. M. Lord, and J. A. Mejia, "The 'Who' in engineering: Sociotechnical engineering as memorable and relevant," *International Journal of Engineering Pedagogy,* vol. 13, no. 5, pp. 72–90, 2023. https://doi.org/10.3991/ijep.v13i5.36571

11 AUTHORS

Amy Kramer, P.E., Ph.D., is a Lecturer in the Department of Engineering Education at The Ohio State University. Dr. Kramer earned her B.S. and M.S. in Civil Engineering and worked as a structural engineering consultant prior to earning her Ph.D. in engineering education from The Ohio State University. Through innovative scholarship and pedagogy, Dr. Kramer aims to broaden conceptions of what it means to think like an engineer and engages engineers in critical reflection on the relationship between engineering and society. Her goal is to foster critically conscious, socially responsible, and inclusive engineers equipped with the knowledge, skills, and critical frameworks necessary to address complex societal issues (E-mail: Kramer.659@osu.edu).

Rachel Louis Kajfez, Ph.D., is an Associate Professor in the Department of Engineering Education at The Ohio State University. She earned her B.S. and M.S. degrees in Civil Engineering from Ohio State and earned her Ph.D. in Engineering Education from Virginia Tech before joining the faculty at Ohio State in 2013. Her research interests focus on the intersection between motivation and identity of undergraduate and graduate students, first-year engineering programs, mixed methods research, and innovative approaches to teaching. She is the principal investigator for the RIME Collaborative.

Emily Dringenberg, Ph.D., is an Associate Professor in the Department of Engineering Education at Ohio State University. She holds a B.S. in Mechanical Engineering (Kansas State '08), a M.S. in Industrial Engineering (Purdue '14) and a Ph.D. in Engineering Education (Purdue '15). Her team, Beliefs in Engineering Research Group (BERG), utilizes qualitative methods to explore beliefs in engineering. Her research has an overarching goal of leveraging engineering education research to shift the culture of engineering to be more realistic and inclusive--especially with regard to beliefs about diverse approaches to engineering design decision making, smartness, and the causes of race- and gender-based minoritization. In general, she is always excited to learn new things and work with motivated individuals from diverse backgrounds to improve the experiences of people at any level in engineering education.