

Uncovering Latent Diversity: Steps Towards Understanding 'What Counts' and 'Who Belongs' in Engineering Culture

Ms. Brianna Shani Benedict, Purdue University, West Lafayette

Brianna Benedict is a Graduate Research Assistant in the School of Engineering Education at Purdue University. She completed her Bachelor's and Master's of Science in Industrial and Systems Engineering at North Carolina Agricultural & Technical State University. Her research interest focuses on interdisciplinary students' identity development, belongingness in engineering, and recognition.

Dina Verdín, Purdue University, West Lafayette

Dina Verdín is a Ph.D. Candidate in Engineering Education and M.S. student in Industrial Engineering at Purdue University. She completed her undergraduate degree in Industrial and Systems Engineering at San José State University. Dina is a 2016 National Science Foundation Graduate Research Fellow and a 2016 Ford Foundation Honorable Mention. Her research interest focuses on first-generation college students focusing on engineering identity development, negotiating multiple identities, and ultimately changing deficit base paradigms by providing asset base perspectives for understanding this community.

Rachel Ann Baker

Dr. Allison Godwin, Purdue University, West Lafayette

Allison Godwin, Ph.D. is an Assistant Professor of Engineering Education at Purdue University. Her research focuses what factors influence diverse students to choose engineering and stay in engineering through their careers and how different experiences within the practice and culture of engineering foster or hinder belongingness and identity development. Dr. Godwin graduated from Clemson University with a B.S. in Chemical Engineering and Ph.D. in Engineering and Science Education. Her research earned her a National Science Foundation CAREER Award focused on characterizing latent diversity, which includes diverse attitudes, mindsets, and approaches to learning, to understand engineering students' identity development. She is the recipient of a 2014 American Society for Engineering Education (ASEE) Educational Research and Methods Division Apprentice Faculty Grant. She has also been recognized for the synergy of research and teaching as an invited participant of the 2016 National Academy of Engineering Frontiers of Engineering Education Symposium and 2016 New Faculty Fellow for the Frontiers in Engineering Education Annual Conference. She also was an NSF Graduate Research Fellow for her work on female empowerment in engineering which won the National Association for Research in Science Teaching 2015 Outstanding Doctoral Research Award.

Thaddeus Milton

Thaddeus is a junior majoring in Civil Engineering with a concentration in Transportation at Purdue University. He works with Dr. Godwin and her team in the UPRISE Research Department analyzing code and interview transcript, creating academic posters, and providing valuable insight to research papers. Thaddeus is also an executive board member to both the Black Student Union and National Pan-Hellenic Council here at Purdue.

Uncovering Latent Diversity: Steps Towards Understanding “What Counts” and “Who Belongs” in Engineering Culture

Abstract

Curricular expectations for engineering students are steadily expanding to encompass a diverse set of competencies and skills that ensure students are prepared to address the global challenges of engineering. This expansion highlights a need for educators to not only rethink how they educate the next generation of engineers, but also a need to cultivate “diversity of thought” within the culture of engineering. Earlier studies about diversity have focused on understanding how to increase the number of underrepresented students (i.e., women, students of color, and first-generation college students) who persist in STEM fields. However, there is a shift in how we (i.e., society, industry, and academia) define what it means to be diverse. In this paper, we examined how 12 diverse first-year engineering students described how their peers enact different ways of thinking and being in engineering, as well as how those differences influence whether their peers are perceived as someone who belongs in engineering. The participants acknowledged the cultural and gender differences among their peers; however, they primarily described how their peers were different based on their skill-set (i.e., technical, creative, and interpersonal), ways of thinking, and interests. These findings begin to help us understand how students define normative attitudes in engineering and the perception of what it means to be an engineer.

Introduction

Diversity and inclusion is a complex and dynamic phenomenon that affects how engineers create solutions and for whom they create those solutions [1]. The global push for diversity and inclusion is a matter of equity and accessibility, as well as ensuring innovation in engineering [1], [2]. Despite the efforts to mitigate the concerns of underrepresentation in STEM degree pathways of women, racial/ethnic minorities, and students with disabilities, the percentage of students from these minoritized groups have not dramatically increased over the past two decades [3]. As a response, researchers in academia and industry are expanding the current understandings of diversity in STEM to look beyond the readily visible social identities, like race/ethnicity and gender, to latent, or underlying, diversity of attitudes, beliefs, and mindsets [3].

The traditional strand of diversity research has discussed the underrepresentation of women and students of color in engineering, as well as how those students experience a lack of belonging because they do not identify with the dominant culture [4]–[8]. The dominant culture not only concerns how some students’ cultural capital is not valued in engineering, but how students are at-risk for leaving engineering because they do not identify with the underlying characteristics associated with engineering [5], [9]. In addition to academic research, industry leaders are assessing what it means to be diverse and inclusive in today’s workforce [8]. Smith and Turner [8] administered a 62-item survey to understand the similarities and differences among generational perspectives on diversity and inclusion. This research study highlighted how there is a need for a culture that supports diversity of thought and problem-solving in the workforce [8]. These are examples of prior studies that highlight how dominant ways of thinking and being

influence whether individuals, in higher education and corporate organizations, feel a sense of belongingness in engineering.

This paper focuses on how students define diversity, in terms of underlying attitudes, beliefs, and mindsets (i.e., latent diversity), and how their definition influences their own and their peers' belongingness in engineering. In order to drive innovation in engineering, there is a need to broaden how we conceptualize what it means to cultivate a diverse and inclusive culture. Latent diversity as a framing of diversity that takes an asset-based approach rather than focusing on the deficits of students on which some research in diversity has focused (e.g., deficiencies in academic preparation, less understanding of high education systems, lack of support systems, etc.). Students, regardless of background, bring diverse and unique ways of thinking and ideas to the table. If engineering culture privileges particular ways of thinking or being as what it means to be an engineer, it may be alienating for latently diverse students. Recognizing the diversity of students' attitudes, beliefs, and mindsets provides a way to support all students in engineering.

We would like to note that a focus on latent diversity is not a replacement for work focused on understanding the structural issues in engineering education that create inequity for minoritized students. Engineering has historically been constructed as white, male, and heteronormative [10], and that culture is problematic and exclusionary to a vast group of students. We believe that more work is needed to challenge the norms of engineering culture and to change engineering at its core. However, we also note that there have not been significant shifts in the representation within engineering in the past two decades [11]. We hope that by taking a different approach (i.e., latent diversity) to understand how students navigate their development as engineers, we may be able to make engineering more inclusive for all students. As discussed in more detail in a previous paper [6], we describe a latent identity approach to first understand students underlying attitudes, beliefs, and mindsets that are shaped by their multiple, intersecting social identities (e.g., race, gender, socioeconomic status, etc.). Focusing on latent diversity is not an opportunity to ignore visible diversity or to find the “right” students for engineer, but rather to make space in engineering culture to redefine “what counts” as engineering and “who belongs” as an engineer.

Theoretical Frameworks

A Sense of Belonging

Individuals are instinctively drawn towards creating and sustaining a sense of belonging. Baumeister and Leary [12] described the need to belong as a fundamental human motivation. Strayhorn [13] defined a sense of belonging as “perceived social support on campus, a feeling or sensation of connectedness, the experiences of mattering or feeling cared about, accepted, respected, valued by, and important to the group (e.g., campus community) or others on campus (e.g., faculty, peers)” [p. 17]. A student’s sense of belonging extends from relationships with peers and faculty to a more global feeling of being connected to the larger university community. Multiple studies conducted on middle school and high school students found a positive connection between a sense of school belonging to academic motivation [14], higher grade point average [15], [16], and better social-emotional functioning. Similarly, at the college level, a sense of belonging has been found to be a significant determinant of academic achievement [12] and persistence [5], [13]. Additionally, in a study by Zumbrunn et al. [17] belongingness was linked to two motivational factors, students’ sense of self-efficacy and task value. Self-efficacy is

defined as a students' beliefs about their capabilities to succeed in a given task [18], and task value refers to beliefs students' hold about the potential importance, utility, and enjoyment associated with an academic task [19]. Both motivational factors were found to predict classroom engagement and achievement [17].

The seminal work of Seymour and Hewitt [20] found that a lack of belongingness drove many talented women, as measured by grade point average, to switch out of their STEM undergraduate programs to non-STEM programs. In their study, Seymour and Hewitt [20] noted that the culture in various STEM programs undermined women's sense of belonging. Similar results have been found in later studies regarding belongingness being a contributor to students who leave engineering [21]–[23]. Students with high self-reported GPAs “indicated that their feeling of not belonging in engineering was more of a factor in their transfer decision [21, p. 10].” Godfrey and Parker showed that, in engineering, a sense of belonging is closely related to particular hegemonic masculine norms such as competitive, aggressive, dominant, and stands up under pressure [24]. These findings support the role of belonging in sustaining engineering students' interests in pursuing an undergraduate engineering degree, as well as the need to provide a culture that values belongingness of all students, irrespective of their gender or other social identities. Our research expands the literature to recognize the significance of student belongingness, specifically focused on characteristics that are not readily visible such as their attitudes, beliefs, and mindsets, which we term latent diversity.

Latent diversity

Latent diversity focuses on non-visible diversity such as students' attitudes, beliefs, and mindsets [6]. Focusing on latent diversity calls into question the privileged ways of thinking and *being* that currently exists in engineering. This approach favors alternate mindsets, experiences, and thinking that students who enter engineering programs hold, as well as move away from the notion of enculturation. Culture is defined by Schein [25] as

...a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid, and therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems [p. 17]

Often, these patterns of adaptation and integration implicitly lead students to believe that, to be an engineer one must “look like an engineer, talk like an engineer, and act like an engineer” [24, p. 355]. Engineering culture implicitly imposes a set of prescribed attitudes, mindsets, and beliefs that students are expected to take on in order to be an engineer. Succeeding in engineering would involve integration into the culture of engineering, a process that requires identifying as someone that can do or become an engineer [5]. Latent diversity as a framework shifts the focus onto students' underlying diversity and acknowledges that “students have different levels of motivation, different attitudes about teaching and learning, and different responses to classroom environments” [25, p. 57]. Engineering educators will have a better chance of “meeting the diverse learning needs of all of their students” when we understand how latently diverse students form identities as engineers [25, p. 57]. Understanding students who are latently diverse will provide an opportunity to shift the engineering culture to support a multitude of differences in engineering development.

Ways of Thinking

A report by the National Academies of Engineers [28] highlighted key attributes the engineers of 2020 are expected to hold, i.e., strong analytical skills, practical ingenuity, creativity, professionalism, and leadership. These skills have been echoed in the work of Godfrey and Parker [29] who collected data from engineering faculty and students of ways of thinking and knowing relevant to engineering. Their work found that both faculty and students described ways of thinking as its applicability to real-world problems (e.g., “engineers aren’t interested in things for only academic interest”), communicating through mathematics (e.g., “we use math like a language—a language to express ideas”), and innovative/creative ways of problem solving through design (e.g., “engineer’s role in developing optimal, innovative solutions to real rather than theoretical problems” [27, pp. 10-11]. These examples emphasize how particular ways of thinking that are valued in engineering; however, how engineering students prefer to think is equally important as how well they think like engineers.

For example, Boaler and Greeno [30] found that students who saw themselves as creative thinkers and identified with this characteristic tended to have lower interest in traditionally taught math classes. They perceived these traditionally taught classes to inhibit their own thinking and agency. These students had higher levels of satisfaction in reformed math courses where students worked together to solve math problems. In contrast, students who identified as good rule-followers had the opposite experience in a reform-oriented classroom. In another study, “Inez,” a student who wished she “belonged more in this whole engineering thing,” illustrated the disenfranchising experiences of particular students with alternative ways of thinking [5]. She felt alienated by the traditional pedagogies taught in her engineering and science classrooms like problem-solving algorithms and balancing chemical equations but did well and generally enjoyed using hands-on skills and reasoning through problems in the classroom (practices that many would argue are more representative of successful engineering skills). While this student “found her place in engineering,” her pathway through engineering could have been easier, if she was familiar with the culture of engineering. Her story may be similar to other students who do not make it through the gauntlet of engineering, and, instead, find fulfillment outside of engineering.

Research Questions

This study is a first step in characterizing how students describe particular attitudes, beliefs, and mindsets, i.e., latent diversity, that make their peers and themselves belong in engineering. While not comprehensive, this work allows us to understand the norms perceived by engineering students as well as how they describe latent diversity in their own words. We used qualitative research methods to answer the following research questions:

1. How are engineering students defining what it means to be and think differently from their peers (i.e., latent diversity—attitudes, mindset, and beliefs)?
2. How do those definitions influence who students believe belong in engineering?

Methods

Overview

Students in a first-year engineering program at a large Midwestern university were selected for interviews based on their completion of an attitudinal survey during Fall 2015. This survey measured students' underlying attitudes including motivation, identity, personality, grit, and other characteristics (see [31] for more details). This survey was given to over half of the first-year engineering student population for a total of 1,054 responses. Students also reported their demographic information and email addresses for follow up studies.

For this study, we selected students from the original survey to maximize the variation in both latent (i.e., underlying attitudes, beliefs, and mindsets) and social identity characteristics (e.g., demographics). We chose these participants to provide varied perspectives and rich descriptions of their individual experiences in engineering. These can be used as powerful examples in understanding how students conceptualize diversity and feel that they belong in engineering. These “small N” studies challenge the status quo of what it means to do “rigorous” research as well as provide counter-narratives to the dominant narrative in engineering [32]. We do not aim for generalizability or a complete accounting of all of the different ways that students can describe latent diversity in engineering. Instead, we focus on understanding a variety of ways in which diverse students both latently and demographically describe belongingness in engineering.

We used a semi-structured protocol to interview these engineering students during the Fall 2016 academic term about their experiences in engineering including their pathways into engineering, identities, and belongingness in engineering. These interviews were transcribed verbatim and inductively analyzed for emergent themes. We describe the process of analysis in more detail below.

Participants

Each of the aforementioned participants were in their second semester of the first-year engineering program. We purposefully recruited the students to maximize the number of women, students of color, first-generation college students, students with visible and non-visible disabilities, and students who identify as members of the LGBTQ+ community, as well as attitudes and experiences in engineering as identified on a survey. The 12 students (7 women and 5 men) described themselves as first-generation college students ($n = 4$), non-first-generation college students ($n = 4$), first-generation college students' status unknown ($n = 1$), and first-generation college student status not disclosed ($n = 3$); visible and non-visible disability ($n = 2$); LGBTQ+ community ($n = 1$); international student ($n = 1$) and some students reported that their parents/guardians were born outside of the U.S. Here we report the overall demographic identities of each student to illustrate the diversity in the pool of participants, See Table 1. We will only give each student's major as identifying information in the results and discussion of this paper to reduce the risk of re-identification from providing multiple demographic characteristics for each student. Each student was given an opportunity to select a pseudonym to protect their anonymity; however, some students preferred for the researcher to select a pseudonym.

Table 1. Students' Self-Identified Demographics.

| Demographics | | Count | |
|--|---|-------|-------|
| Race/Ethnicity | | Man | Woman |
| | African-American/ Caribbean-American | 1 | 2 |
| | Asian (Chinese, Indian, Vietnamese) | 1 | 2 |
| | Latina | - | 1 |
| | white | 1 | 2 |
| | Peruvian-American | 1 | - |
| | Turkish | 1 | - |
| Visible and Non-Visible Disability | | 1 | 1 |
| 1 st Generation College Student | | 1 | 3 |
| LGBTQ+ Community | | 1 | - |
| International Student | | - | 1 |

Interview

Each student engaged in a one-on-one interview where a semi-structured interview protocol in which we asked the following set of interview questions: 1) Can you think of someone in engineering that thinks differently than you (or is different from you)?; 2) Can you describe that person or persons?; 3a) If yes, do you feel that person or persons belongs in engineering?; and 3b) If no, why do you think it is difficult to think of someone who thinks differently than you? These questions were designed to elicit students' perceptions of difference in engineering as well as their sense of how the engineering culture did or did not foster belonging for those types of differences describe. We intentionally did not prescribe what types of difference we were asking about, but instead allowed each participant to define difference from their own experiences. Each interview was approximately 40 minutes in duration and conducted by one researcher. The interviewer identified as Latina, first-generation college student who received her degree at a Hispanic Serving Institution in the Southwest.

Analysis

The interviews were analyzed inductively using constant-comparative methods to understand the emergent themes associated with how students described what it meant to "think differently" in engineering, and whether these types of people belonged or felt included in engineering. This process allowed the research team to use multiple passes through each interview and compare emerging results across interviews. Throughout the process, the research team engaged in memoing to document the process and emerging findings. They met weekly to discuss results and come to a consensus on any discrepancies in coding.

Results

This paper reports our findings regarding students' descriptions of latent diversity and how those aspects provided opportunities to belong as well as feel excluded in engineering. In our results, we focus on students' descriptions of latent diversity. However, in some students' interviews

these aspects of their identities were often intertwined with their social identities. In cases where students discussed both social and latent identities, we report both sets of results to maintain the integrity of the students' voices.

Below, we discuss how latent diversity creates connections with and separation from what it means to be an engineer in the current climate of the engineering community. We identified four big ideas that were conveyed from the students. These ideas include 1) Students recognize the advantages of increasing diversity in engineering, however, they are also aware of the preferred ways of being and thinking like an engineer; 2) The public perception of "what counts" as an engineer is bounded by the ideals of historical stereotypes and confirmed the notion that gender bias is ingrained in the culture; 3) Engineering students acknowledge and appreciate latent diversity because it enhances their learning experiences; 4) The student perception of "what counts" also includes their interests outside of curricular experiences. We highlight how these connections, or lack thereof, influence how students describe if they or their peers belong in engineering.

Latent diversity is good but ...

Our findings highlight how students value and acknowledge latent diversity in engineering. Naomi indicated how "diversity is good," since "identical engineers who all thought the same way" would not make a "very successful team of engineers." However, the students also acknowledged how some identities are valued more in the engineering community, as opposed to students who fail to fit within the parameters of a stereotypical engineer. Students are well-aware of "what counts" in engineering; however, this imbalance creates a tension if they do not fit the perceived norms of what it means to be an engineer. In the following section, students describe ways that their peers were different from them but belong in engineering because they fit the norms of engineering in ways of thinking, being, and problem-solving.

Engineering "poster child"

When asked to describe someone who thought differently than them and someone who belonged in engineering, several students described a traditional engineer. Many of the women in our study discussed male peers who were the "poster child" for engineering. They described men who were "book smart," "technical" thinkers, and "socially awkward." When asked if they belonged in engineering, these women felt that they also belonged, but not for the same reasons as their male peers who fit the stereotype of an engineer.

Naomi (agricultural and biological engineer) discussed how her peer was different by being a "technical" thinker, as well as his ability to build connections with his knowledge of mathematical and science concepts to visualize the big picture of problems. In contrast, Ayida (aeronautical engineer) described how her peer who is "book smart" did not identify efficient solutions because he overcomplicated problems. However, she continued to share how this student would be considered a "fabulous engineer," according to university standards. She believed that he belonged in engineering because he was "the poster child" in engineering. Casey (industrial engineer) described a peer who belonged because he fit the "typical engineer" stereotype of being "socially awkward." These trademarks, "poster child" and "typical engineer," provide exposure to how historical perceptions of engineers persist in today's climate of engineering, despite the efforts to defy the stereotypes of who belongs in engineering. Students'

comments about the “ideal engineer” were similar to cultural norms and values highlighted by Godfrey and Parker [29] in describing the cultural landscape of engineering.

Diversity of thought is valued for novel solutions

Ten out of the twelve students described how their peers thought differently, while two of the students believed that their peers had similar ways of thinking. These students highlighted aspects of their own or their peers’ latent diversity that made them different than the described norms described by Naomi, Ayida, and Casey above. These students focused on personality (mainly introversion and extraversion), people who solved problems differently (top-down or bottom-up approaches), and work ethic as ways in which their peers showed aspects of latent diversity that made them belong in engineering.

The interview process provided an opportunity for students like Nathan (mechanical engineer) to clarify how he felt about diversity of thought in engineering. When asked about diverse ways of thinking, Nathan focused on the introversion and extraversion dimension of personality. Nathan initially began to justify how introverted students were better at engineering because they could think through problems independently. During this discussion, he also acknowledged that extraverted students were better at communicating and implementing their ideas. Nathan also described how different aspects of engineering required different types of thinking. He said, “if you’re on the technical side, it would be more introverted thinking” and “if you’re on the design team, then all of your brainstorming is specifically extraverted thinking.” This statement led to him retracting his statement about which personality was preferred in engineering. He said, “Each type of thinking is important for engineering. Just different parts.” As a result, he came to the conclusion that the two types of personalities are complementary and depends on the role required at the time.

Penny (industrial engineer) also focused on the extraversion and introversion dimensions of personality when asked about differences in her peers’ ways of thinking. She described extraverts as “very outgoing” and “good at talking and communicating with people.” She valued this particular personality trait in other engineering students and felt that it was different than many engineers.

Additional differences described by the students included how people solved complex engineering problems, especially in design. Nathan described how some engineers valued communication with the end user to ensure they were satisfied with the product. Nathan shared that he did not implement this user-centric design thinking in his design project:

That wasn’t in my design project. I was aware we were designing for a person, but I didn’t think it needed to be that finely ingrained into the design process. I guess, yeah, that’s one way that ... what was it, difference, how people thought differently about engineering. I’ve taken that obviously like you can’t afford not to take that and adopt it to your own type of engineering because that amount of information is way too valuable.

This quote is another example of how Nathan described how there are various ways of thinking in engineering that are complementary to one another. While he acknowledged differences, in his

peers and his own ways of thinking, he did not seem to value a particular way of thinking or being over others. Instead, he described how difference provided varied perspectives that were valuable to solving engineering problems as teams rather than individually.

Ashley (biological engineering) described a peer who used visual representation to solve engineering problems as someone who thought differently than her. She said, “when we work together it usually turns out pretty well because it’s like...he’s good at drawing out the whole thing.” She expressed how people who think differently often produce non-traditional solutions and create “something new.”

Students also acknowledged additional reasons why latent diversity was valuable in engineering. Casey said:

Engineering's about creative problem solving and if you have the same people with same backgrounds trying to solve a problem, they're going to tend to think about it the same way. I think that having diversity in engineering, because everyone having different backgrounds and having different perspectives is going to change the way you solve problems.

With regard to problem-solving, Anika (electrical and computer engineer) described the differences in how her peer approached problem-solving. Anika preferred to understand the overall problem first, then she broke the problem down into sections (i.e., top-down), while her peer preferred to look at each section separately (i.e., bottom-up). Despite their differences, she valued his approach, as long as it solves the problem efficiently. She believed that he belonged in computer engineering because he was knowledgeable about the courses in the curriculum and highly interested in cybersecurity and other topics in the field. Other differences she discussed included students who were analytical and engaged in deep thinking, which she felt was necessary for their first-year engineering courses and physics.

Mr. Rhee (student chosen pseudonym; electrical engineer) mentioned how his peers were different from him because of their work ethic. He insisted that they had a “talent or knack for the curriculum” which made them understand the material faster, due to their previous experiences. He also described how the material came naturally to his peers, while he struggled with grasping abstract concepts and had to regularly attend teaching assistant hours and study sessions. He believed his peers felt included in engineering because they were passionate about engineering and sought out other opportunities to shape their future in engineering. He also described how he was different than his peers because of his tendency to “overthink” problems, instead of “working smart” like his peers. However, he found value in critically thinking through problems, as well as his peers’ approaches to solving problems.

Nick (civil engineering) also discussed how one of his peers was different based on his ability to be disciplined yet calm while studying. As opposed to himself, who he described as very “high strung” because he wanted to be sure his work was “perfect.” He described a peer who felt included because of his strong interest in his degree program and strong networks with other students who were passionate about acoustic engineering, his degree area.

Eight out of the twelve students acknowledged different ways of thinking and being in engineering (e.g., personality, problem-solving approaches, and attitudes in engineering) that they perceived as valuable and that made their peers belong in engineering. Penny was unsure whether her peer felt a sense of belonging based on their ways of thinking. Some students did place a higher value on these aspects of latent diversity like Mr. Rhee and Nick, but four students explicitly described how diversity of thought was necessary for engineering for innovative solutions. Students repeatedly discussed interest or passion as a reason why their peers belonged in engineering. Overwhelmingly, students described interest as a main reason for belongingness over particular skills or ways of thinking and being.

Interest is a defining feature of belongingness

Students discussed differences in interests as an example of latent diversity that did or did not promote belongingness in engineering. Anika was interested in art and entrepreneurship; however, she did not identify a connection between her interest in art and computer engineering. Similarly, she met other students who had interests outside of engineering contexts such as photography and sports. She described how one of her peers was an upperclassman that loved electrical engineering. Anika said, “She’s the one who’s super passionate about it. On her snap stories [i.e., a social media application], it’s always like, oh my gosh, love my major. So far, I haven’t felt that yet, so it’s like, wow, I want to feel that way too. That’s really different.” Other students expressed differences between their peers and themselves within the same major. Casey described how her peers in industrial engineering were different because they were interested in manufacturing and how they intended on using their knowledge about process improvement. She wanted to use process improvement to “make things better” as opposed to her peers who wanted “to save the companies money.” She believed they belonged in engineering because the curriculum was primarily focused on manufacturing; however, she still considered industrial engineering “home” because she believed that there are diverse ways of thinking in industrial engineering.

Conversely, Richard (mechanical engineer) did not think engineering was diverse because engineering students had similar hobbies. In his experiences, he could not recall any of his peers who were not “gamers.” In addition to hobbies, he believed that engineers “love tinkering and computers” and that was what made you an engineer. He felt that if he did not have those types of interest within an engineering context, he did not belong. The discussion from Richard along with the comments from Anika and Casey illustrate that there seemed to be a typical set of interests or passions that students in engineering held. Deviations from those perceived norms served to make some students feel as if they belonged less in engineering.

Interest, whether aligned with engineering norms or outside of engineering, seems like a key reason for how students felt like they or their peers belonged in engineering. Students, like Anika, did feel like they belonged in engineering but also compared themselves to their peers who they perceived as having even stronger interests in engineering-related topics or hobbies. These comments illustrate how students are not only comparing themselves to their peers to determine who belongs within engineering contexts in the university setting but also how students gauge belongingness as related to interest in particular engineering topics or activities. These results highlight the hidden norms in engineering culture that may signal belonging based on alignment with or deviation from particular interests or activities.

Discussion

The purpose of this paper was to understand how first-year engineering students defined latent diversity, in comparison to their peers, and whether those students belonged in engineering. We identified four big ideas regarding the current perceptions of engineering. These ideas include 1) Students recognize the advantages of increasing diversity in engineering, however, they are also aware of the preferred ways of being and thinking like an engineer; 2) The public perception of “what counts” as an engineer is bounded by the ideals of historical stereotypes and confirmed the notion that gender bias is ingrained in the culture; 3) Engineering students acknowledge and appreciate latent diversity because it enhances their learning experiences; 4) The student perception of “what counts” also includes their interests outside of curricular experiences.

The students in our study made connections between latent diversity and creating innovative solutions, learning, and design experiences. Eleven out of the twelve students felt that they and their peers belonged in engineering regardless of diversity in their underlying attitudes, beliefs, and mindsets. However, interest in engineering topics and a passion for their major seemed to be a defining way in which students gauged belongingness in engineering. Despite these reported advantages of latent diversity, students consistently discussed hidden messages of engineering culture implicitly in their interviews of who was a “poster child” in engineering or who belonged more in relation to conforming to the undefined but present expectations of what it means to be an engineer.

We found that at least five students explicitly recognized the value of diversity in engineering because it changed the way problems are solved and contributed to the success of teams. This finding is consistent with theories that suggest diversity improves cognitive processing, creativity, and problem-solving [33]. We also identified how certain ways of thinking and being are considered necessary characteristics for being successful in engineering. When Naomi, Ayida, and Casey described their peers, they were extremely confident that despite being socially inept, book smart, and solely technical, those students definitely belonged and were going to be successful engineers. Despite the call for engineers to be good communicators; practical; aware of social, economic, and cultural factors; and synthesize various sources of knowledge to achieve innovative solutions, these students believe the university values the attributes of stereotypical engineers over students who do not fit that “poster child” mold [28]. Previous literature has encouraged the need to “reorient” what ways of being and thinking in engineering are valued to be more inclusive to a diverse set of identities [34]. Reorienting the engineering culture involves *recognizing* alternative traits of a successful engineer beyond the traditionally valued traits [34]. This literature further supports the role recognition plays in students forming their identities as an engineer as well as the need to understand how to incorporate recognition into student experiences.

Understanding the various ways students describe how their peers are different from themselves highlights the diversity of perspectives within today’s population of engineering students. Studies show that students who are in the Millennial and younger generations often frame diversity not as demographic differences but as individual difference [8]. We see a similar trend in the discussion of diversity in our work. Promoting and encouraging diversity of thought is as

important as supporting diversity and inclusion of underrepresented groups (i.e., women, minority students, students in the LGBTQ+ community, and those living at the intersection of multiple identities). “Diversity of thought is fundamental to understanding the power of diversity and inclusion” [33, p. 1]. This belief was echoed by Casey’s account of the value of diversity in engineering as a need for using different perspectives as a way to change the way we solve problems. Diversity of thought not only embraces differences of perspectives but also recognizes differences in approaches [35]. Students acknowledged the value of these differences in their narratives of their interest in engineering and ways of thinking. For example, Casey saw herself as different than her peer because she approached industrial engineering as “making things better” as opposed to “saving the companies money” even though both approaches were important within the field. Similarly, Ashley described how working with a peer who took a different approach produced non-traditional solutions and created “something new.” Eight out of twelve students recognized the value of contrasting ways of thinking and personality types.

However, this acceptance of diverse ways of thinking and personality types is different than prior studies of diversity. Prior literature suggests that “male introverts, intuitors, thinkers, and judgers” were predicted to be more successful in the first-year engineering program and graduate in four years, when compared to their extroverted peers [25, p. 59], [34], [35]. Other work has shown that particular ways of thinking [9] or navigating a landscape of engineering norms and disciplinary knowledge [38] is what defines who stays and belongs in engineering. Instead of asking students to conform to the norms of engineering as “what counts” and “who belongs,” we need to identify ways to recognize the benefits of various types of students who can succeed in engineering. Thus, we posit that an innovative culture is not dependent on who thinks better, instead, we need to learn how to leverage the various ways of thinking to drive innovation, as well as inclusion.

We know from the prior literature that students, specifically women, are at higher risks of leaving engineering due to a lack of belonging or perceived lack of fit [20], [21], [39]. Whereas other scholars have pointed to the masculine social norms embedded within engineering that deter some women [24]. In our study, we found that alignment with particular interests that seem more like the “poster child” of engineering, as compared to a stereotype of engineering and peers, maybe one reason students feel like they belong more or less in engineering. Anika struggled with finding compatibility between her personal interest (e.g., art) and engineering, but Casey saw synergy between her interest in approaching industrial engineering problems and the method used by her peers. This result suggests that students whose interests diverge too much from engineering may be finding it more difficult to feel a sense of belonging and happiness necessary to sustain interest in pursuing an engineering career [39]. Contrary to Anika who saw her passion for art separate from engineering, Richard thought *all* engineers had similar hobbies (i.e., gaming, tinkering). Prior research has found that out-of-school experiences, tinkering with mechanical or electrical devices, for women, “decreased the likelihood of reporting feeling like an engineer both now and in the future” [38, p.9]. Unsurprisingly, men were more likely to report they have tinkered with mechanical or electrical devices as part of an out-of-school experience, possibly as a hobby [40]. In our previous work, seeing oneself as an engineer predicted students belongingness both in the engineering major and in their engineering classrooms [41]. These findings are consistent with literature that insist women find it hard to identify connections between engineering and their personal identity (and interests), in relation to their male peers

[39]. Matusovich and her colleagues also describe the notion of reorienting engineering to recognize alternative activities that could promote identity development, in hopes that students would be able to make connections between their interests and engineering. Our results also point to the need to reorient “what counts” and “who belongs” in engineering based on students’ latent diversity.

Conclusions

These research findings begin to characterize how students are conceptualizing diversity in engineering, as well as who they believe belongs in engineering. We asked students to describe how their peers were different and whether those students belonged in engineering or not. All of the students suggested that their peers belonged in engineering, especially those who shared normative engineering traits such as being a “technical person” or “socially awkward.” Our work highlights how particular engineering traits define “what counts” and “who belongs,” despite studies that suggest the need to broaden what we recognize as an important identity trait in engineering culture [34]. Further work needs to examine how to cultivate innovative mindsets and students who are situationally aware of social, economic, environmental, and cultural factors involved in being an engineer [42]–[44] in addition to identifying various ways students’ feel that they belong in engineering. Our future work includes using this research to identify interventions to support the various modes of diversity in engineering to develop engineering environments that promote a broad range of ways of thinking and support for students in engineering.

Acknowledgements

This work was supported through funding by the National Science Foundation under a CAREER Grant No. (1554057). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. The authors wish to thank the STRIDE team and the interview participants for their participation in the study.

References

- [1] The United States Department of Education, “Stem 2026 A Vision for Innovation in Stem Education,” *U.S. Dep. Educ. Work.*, p. 55, 2016.
- [2] D. P. Giddens, R. E. Borchelt, V. R. Carter, W. S. Hammack, L. H. Jamieson, J. H. Johnson, V. Kramer, P. J. Natale, D. a. Scheufele, and J. F. Sullivan, *Changing the conversation: messages for improving public understanding of engineering*. 2008.
- [3] N. S. Foundation, “Women, Minorities, and Persons with Disabilities in Science and Engineering: 2017 Digest,” 2017.
- [4] L. L. . ESPINOSA, “Pipelines and Pathways: Women of Color in Undergraduate STEM Majors and the College Experiences That Contribute to Persistence.,” *Harv. Educ. Rev.*, vol. 81, no. 2, pp. 209–240, 2011.
- [5] C. E. Foor, S. E. Walden, and D. A. Trytten, “I Wish that I Belonged More in this Whole Engineering Group:’ Achieving Individual Diversity,” *J. Eng. Educ.*, vol. 96, no. 2, pp. 103–115, 2007.
- [6] A. Godwin, “Unpacking Latent Diversity,” in *ASEE Annual Conference and Exposition*,

- 2017.
- [7] D. Bogosian and C. Rousseau, "How and Why Millenials are Shaking Up Organizational Cultures," *Rutgers Bus. Rev.*, vol. 2, no. 3, pp. 386–394, 2017.
 - [8] C. Smith and S. Turner, "The Radical Transformation of Diversity and Inclusion The Millennial Influence for inclusion," 2015.
 - [9] B. A. Danielak, A. Gupta, and A. Elby, "Marginalized Identities of Sense-Makers: Reframing Engineering Student Retention," *J. Eng. Educ.*, vol. 103, no. 1, pp. 8–44, 2014.
 - [10] E. A. Cech and T. J. Waidzunas, "Navigating the heteronormativity of engineering: The experiences of lesbian, gay, and bisexual students," *Eng. Stud.*, vol. 3, no. 1, pp. 1–24, 2011.
 - [11] C. Hill, C. Corbett, and A. St Rose, *Why so few? Women in science, technology, engineering, and mathematics*. ERIC, 2010.
 - [12] R. F. Baumeister and M. R. Leary, "The Need To Belong - Desire for Interpersonal Attachments as a Fundamental Human-Motivation," *Psychol. Bull.*, vol. 117, no. 3, pp. 497–529, 1995.
 - [13] T. L. Strayhorn, *College Students' Sense of Belonging*, 1st ed. New York: Taylor & Francis, 2012.
 - [14] L. H. Anderman and E. M. Anderman, "Social Predictors of Changes in Students' Achievement Goal Orientations," *Contemp. Educ. Psychol.*, vol. 24, no. 1, pp. 21–37, 1999.
 - [15] L. H. Anderman, "School belonging academic and social perceptions as predictors of change in middle school students' sense of school belonging," *J. Exp. Educ.*, vol. 72, no. 1, pp. 5–22, 2003.
 - [16] E. M. Anderman, "School effects on psychological outcomes during adolescence," *J. Educ. Psychol.*, vol. 94, no. 4, pp. 795–809, 2002.
 - [17] S. Zumbrunn, C. McKim, E. Buhs, and L. R. Hawley, "Support, belonging, motivation, and engagement in the college classroom: A mixed method study," *Instr. Sci.*, vol. 42, no. 5, pp. 661–684, 2014.
 - [18] A. Bandura, *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs: Prentice Hall, 1986.
 - [19] J. S. Eccles and A. Wigfield, "Motivational Beliefs, Values, and Goals," *Annu. Rev. Psychol.*, vol. 53, pp. 109–32, 2002.
 - [20] E. Seymour and N. Hewitt, *Talking about leaving: Why undergraduates leave the sciences*. Boulder: Westview Press, 1997.
 - [21] R. Marra, B. Bogue, D. Shen, and K. Rodger, "Those that leave: Assessing why students leave engineering," in *Proceedings of the 37th ASEE/IEEE Frontiers in Education Conference*, 2007.
 - [22] R. M. Marra, D. Shen, K. A. Rodgers, and B. Bogue, "Leaving engineering: A multi-year single institution study," in *Annual Meeting of the American Educational Researcher's Association*, 2009.
 - [23] B. N. Geisinger and D. R. Raman, "Why They Leave : Understanding Student Attrition from Engineering Majors," *Int. J. Eng. Educ.*, vol. 29, no. 4, pp. 914–925, 2013.
 - [24] M. A. Cejka and A. H. Eagly, "Gender-Stereotypic Images of Occupations Correspond to the Sex Segregation of Employment," *Personal. Soc. Psychol. Bull.*, vol. 25, no. 4, pp. 413–423, 1999.
 - [25] Schein, Edgar H, "ORGANIZATIONAL CULTURE Organizational Culture and

- Leadership, 3rd Edition.pdf.” 2004.
- [26] J. Jorgenson, “ENGINEERING SELVES Negotiating Gender and Identity in Technical Work,” *Manag. Commun. Q.*, vol. 15, no. 3, pp. 350–380, 2002.
 - [27] R. Felder and R. Brent, “Understanding Student Differences,” *J. Eng. Educ.*, vol. 94, no. 1, pp. 57–72, 2005.
 - [28] National Academy of Engineering, *The engineer of 2020: Visions of engineering in the new century*. Washington, D.C.: The National Academies Press, 2004.
 - [29] E. Godfrey and L. Parker, “Mapping the cultural landscape in engineering education,” *J. Eng. Educ.*, vol. 99, no. 1, pp. 5–22, 2010.
 - [30] J. Boaler and J. G. Greeno, “Identity, agency, and knowing in mathematics worlds,” in *Multiple perspectives on mathematics teaching and learning*, J. Boaler, Ed. Westport, CT: Ablex Publishing Corp., 2000, pp. 171–200.
 - [31] A. Kirn, A. Godwin, L. Benson, G. Potvin, J. M. Doyle, D. Verdín, and H. Boone, “Intersectionality of Non-normative Identities in the Cultures of Engineering (InIce),” *Proc. 123rd ASEE Annu. Conf. Expo.*, p. abstract accepted, final paper due Feb. 1, 2016, 2016.
 - [32] A. E. Slaton and A. L. Pawley, “The power of politics of STEM research design: Saving the ‘Small N,’” *2015 ASEE Conf.*, 2015.
 - [33] S. H. Cady and J. Valentine, “Team innovation and perception of consideration: What differences does diversity make?,” *Small Gr. Res.*, vol. 30, no. 6, pp. 730–750, 1999.
 - [34] E. Cech, “Engineers and Engineeresses? Self-conceptions and the Development of Gendered Professional Identities,” *Sociol. Perspect.*, vol. 58, no. 1, pp. 56–77, Mar. 2015.
 - [35] H. Woods and S. Woods, “Thinking About Diversity of Thought,” pp. 1–4, 2008.
 - [36] P. A. Rosati, “Psychological Types of Canadian Engineering Students,” *J. Psychol. Type*, vol. 41, no. 33–37, 1997.
 - [37] P. A. Rosati, “Student Retention from First-Year Engineering Related to Personality Type,” in *Frontiers in Education Conference*, 1993.
 - [38] R. Stevens, K. O’Connor, L. Garrison, A. Jocuns, and D. M. Amos, “Becoming an engineer: Toward a three dimensional view of engineering learning,” *J. Eng. Educ.*, vol. 97, no. 3, pp. 355–368, 2008.
 - [39] H. M. Matusovich, R. A. Streveler, and R. L. Miller, “Why Do Students Choose Engineering? A Qualitative, Longitudinal Investigation of Students’ Motivational Values,” *J. Eng. Educ.*, vol. 99, no. 4, pp. 289–303, 2010.
 - [40] A. Godwin, G. Sonnert, and P. M. Sadler, “The Influence of Out-of-school High School Experiences on Engineering Identities and Career Choice,” in *ASEE Annual Conference and Exposition*, 2015.
 - [41] D. Verdín and A. Godwin, “Understanding how Engineering Identity and Belongingness Predict Grit for First-Generation College Students,” in *Proceedings of the Collaborative Network for Engineering and Computing Diversity Conference*, 2018.
 - [42] C. J. Steiner, “Educating for innovation and management: The engineering educators’ dilemma,” *IEEE Trans. Educ.*, vol. 41, no. 1, pp. 1–7, 1998.
 - [43] S. Beder, “Beyond Technicalities: Expanding Engineering Thinking,” *J. Prof. Issues Eng. Educ. Pract.*, vol. 125, no. 1, pp. 12–18, 1999.
 - [44] Accreditation Board for Engineering and Technology, “Criteria for Accrediting Engineering Programs for implementation in the 2019-2020 accreditation cycle,” 2019.