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Underrepresented minority students' portrayal of engineering and what engineers do

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Underrepresented-minority students' portrayal of engineering and what engineers do

Introduction

Diversity in engineering plays a vital role in addressing the challenges currently facing our world. The COVID-19 pandemic underlined the importance of global collaboration among diverse groups of experts to overcome such challenges. However, some individuals may face systemic barriers to inclusion and participation in engineering that can be multifaceted and interconnected, often influenced by gender, culture, and societal norms.

Women and underrepresented-minority (URM) students in STEM disciplines often report facing unwelcoming, discriminatory, and biased campus and classroom environments, which adversely affect their academic performance, interest, persistence, and sense of belonging in their disciplines. Additionally, URM STEM students often report feeling invisible and culturally irrelevant and experiencing negative classroom stereotypes, leading to self-isolation [1], dropout [2], and even higher levels of self-reported anxiety and stress. Such experiences are also correlated with a reluctance to self-identify as an engineer [3].

Study shows that belongingness and identifying as an engineer are strongly related [4]-[5]. Engineering identity (EI) represents how strongly someone identifies with being an engineer and serves as an indicator for other key metrics like retention and persistence [6]. There are several ways of measuring EI. One of the most widely used in engineering education research is made up of three interconnected constructs: performance/competence, interest, and recognition [7]-[9]. However, the interplay between these three constructs and intersectional factors such as gender, race, generational status, etc., remains underexplored [10].

Jones et al. [11] showed that engineering identity is a crucial factor in predicting persistence, while the ability to do engineering (competence) is a significant predictor of achievement, particularly among women. Another study suggests that interest in engineering, internal recognition, and a sense of belonging in the classroom foster persistence beliefs among minoritized women [12]. According to Verdin et al. [13], first-generation college students demonstrate “persistence of effort” when they possess a sense of belonging and see themselves as people who can do engineering. In another study, Verdin and Godwin [4] examined the factors influencing first-generation students’ identification as current and future engineers. They suggested that performance and competence in engineering can predict whether these students feel like engineers in the present, while a sustained interest in engineering fosters their identification as engineers in the future. Additionally, they found that although the Latina first-generation students who participated in their study demonstrated a high level of academic self-efficacy, they faced challenges in developing a sense of belonging [14]. Rodriguez et al. [15] examined the experiences of Latina engineering undergraduates to understand the meaning-making process of identity formation. They found that Latina engineering students developed

professional identities through interactions with family members and engagement with identity-based organizations in relation to their other identities.

Tonso [16] reviewed engineering identity from different perspectives, including engineering identity conceived from a developmental psychology perspective and sociocultural perspectives (such as professional identity, i.e., how someone sees themselves in a social situation, technical/social dualism, and other social identities). From a developmental psychology perspective, researchers have looked into what students believe makes a good engineer, including the qualities, attitudes, personality traits, and values that are essential for success in the engineering field [17]-[19]. Faulkner [20] interviewed engineers in various work environments and discovered that engineering identity involves having technical skills and social competencies. However, the engineers involved in her research found it challenging to balance their technical expertise with the ability to account for social considerations in their work (i.e., technical/social dualism). She discovered that this reported discomfort was deeply rooted in gender stereotypes among her study group that associate technical abilities with masculinity and social considerations with femininity.

A brief review of the literature above reveals that identifying as an engineer is a multifaceted aspect that can have roots in one's college/work experiences and manifests in their self-beliefs, sense of belonging, and internal recognition. In this paper, we employed a qualitative approach to examine self-belief and perceptions of engineering and what engineers do among URM engineering students in their senior year. The research questions that informed this study are as follows:

1. How do URM (engineering) students in our study describe engineering, engineers, and what they do?
2. What values or attitudes do they have that help them identify (or not identify) as engineers?
3. In what way do URM students receive recognition (or fail to be recognized) as engineers from others?

A thematic analysis approach was used to analyze the interview transcripts. The study is part of a project funded by the National Science Foundation (NSF) Research Initiation in Engineering Formation (RIEF). The larger project intends to investigate the prevalence and patterns of disagreement in student teams, illuminating how engineering identity (EI), gender, and other student-specific background demographics explain the likelihood of a team disagreeing on tasks, processes, and other teamwork constructs. The study was conducted at a primarily undergraduate and Hispanic-serving institution in the Western US.

The participating students in this study shared insightful perspectives that highlight their sense of belonging to the community of engineers, which might be deeply rooted in their college experiences. Some students reported a lack of a strong sense of belonging that can stem from the challenges they had to face in college. Another notable finding showed some students set a high standard for themselves to identify as a current engineer and prefer to consider themselves as future engineers once they have finished their coursework and have a "real" engineering job.

Understanding students' perceptions of engineering and what engineers do can help us identify and address the existing barriers, stereotypes, or biases that may discourage particular groups, such as women and URMs, from pursuing engineering as a profession. Additionally, addressing misconceptions and stereotypes can increase retention rates, as students will better understand the field and its potential – in short, they will better understand the profession that they are being asked to identify *with*. Since identification with engineering may not be stagnant in time and space, this study further emphasizes the need for and importance of designing interventional and culturally relevant practices to improve the college experiences of women and URM students and enhance their sense of belonging and persistence in the profession, ultimately contributing to a more diverse and inclusive STEM workforce. Educators and career advisors can leverage this knowledge to effectively address potential concerns and misunderstandings and steer students toward career paths that best fit their unique interests and objectives in engineering.

Methods, Data Collection, and Analysis

As part of our larger two-year study, we collected 268 student responses through a voluntary survey in Spring and Fall 2022 across four engineering majors: civil engineering (CE), mechanical engineering (ME), electrical engineering (EE), and computer engineering (CompE). We also conducted 28 follow-up semi-structured Zoom interviews between Spring and Fall 2022, each about an hour long. Informed by the works of Danielsson and Berge [21] and Matusovich et al. [22], the interview protocols had four themes: introduction and warm-up, engineering identity, teamwork, and conclusion. The interview protocol and other applicable parts of our study design have been approved by our institution's human subjects review process and are available in earlier publications [23]-[25].

After conducting an initial assessment of interview transcripts, we compared and analyzed student responses to the Engineering Identity questions in the quantitative and qualitative (interview) data, and noticed several intriguing themes emerged. Many students exhibited a strong interest in learning about engineering subjects and disciplines, and a good performance in their academic work. However, when asked if they identify as an engineer or to what aspects of engineering they identify with, some reported challenges related to their social experiences in engineering classrooms, conferences, etc., which we believe has led to their poor sense of belonging and internal recognition as engineers. This observation inspired us to delve deeper into

students' self-belief and perceptions of engineering that we believe have shaped their sense of belonging and could be deeply rooted in their college experiences, their perceived social expectations, and the stereotypes they had experienced. We concluded that it is insufficient to analyze student responses through the three EI constructs and comment on their EI or its strength. Rather, we concentrated on understanding their self-beliefs and their perceptions of engineering, including what engineers do and the aspects of engineering they found easier or more difficult to relate to.

In this paper, we focus on a subsample (n = 6) of students who provided very insightful responses to the EI interview questions and shared at least one of these traits: female, first-generation, Pell-recipient, Hispanic, Black/African American, Native Hawaiian, or Pacific Islander. We refer to them as URM engineering students throughout the paper. Table 1 summarizes the demographics of the participating students. We'll draw attention to the aspects of engineering that have helped them to feel (or do not feel) stronger about being an engineer and identify some obstacles that may have contributed to their lower sense of belonging and internal recognition. We'll conclude by making recommendations for future efforts to help address these challenges and provide more inclusive environments to help all students strive.

Table 1. Student Demographics

Pseudonym (major)	Gender	Race/Ethnicity	Generational status	Pell-recipient?	Year of Study
Gus (Comp E)	Male	Asian	First-generation	Yes	Senior
Teddy (ME)	Male	Hispanic	First-generation	Yes	Senior
Amelia (ME)	Female	Asian	Continuing generation	No	Senior
Mia (ME)	Female	Hispanic	First-generation	Yes	Senior
Olivia (ME)	Female	Black/African American	First-generation	Yes	Senior
Alex (CE)	Other	White	First-generation	Yes	Senior

Findings

In the following, we summarize student responses to four interview questions regarding their understanding of engineering and their engineering identities.

1. *What are some words and phrases to describe engineering or what engineers do?*

Students used different phrases to answer this question. A few themes emerged in their responses, which can be summarized as follows:

- **altruism** was described as “helping others”, “engineering ethics”, “safety [of people and structures]”, “respect for the environment,” “[having] good morals,” “philanthropists”
- **adaptability** was described as “constructive criticism”, “flexibility [in a team environment]”
- **planning and analytical thinking**, described as “thinking before doing”, “[engineers are] analytical and critical thinkers”, “designers [and] evaluators”, “[following instructions like a] recipe”; structural and detail-oriented)
- **effective team players**, described as ”ability to collaborate”, “good team players”, “smart [and] good communicators”.

2. *What does it mean to be an engineer? What do practicing engineers do, think or believe?*

Most students used relatively similar terms to describe engineering or what engineers do, including those who did not strongly identify as engineers when we popped the question directly during the interview. Two themes emerged when students described common traits and attitudes of engineers:

- **Tinkering** was described as “making”, “designing”, “building”, “creating”, “system design [and refinement]”, “thinking out of the box”, “innovation”, “problem-solving”, “providing [reliable] solutions”, “lifelong learning”, “creativity”, “critical thinking”, “following steps and like a recipe [...] very structured and analytical”, “building with one’s hands”.
- **Behaving responsibly** was described as “serving the community”, “helping others”, “time management”, “collaboration”, “effective communication”, and “teamwork”.

3. *What characteristics, values, or attitudes do you hold that influence whether you consider yourself an engineer or not?*

Gus reported low performance in some engineering courses: "*I am not that good at taking tests and being able to regurgitate that information. But, I’d say, from a passion standpoint, from just a mentality [I identify as an engineer].* " However, he considered himself an engineer due to some of his other skills: "*[my] thought process, time management, motivation mindset ... and [being] able to put that information into a subdued format so that anyone can understand [makes me feel like an engineer]*."

Amelia wants to hold herself to a higher standard by identifying herself as a future engineer because she has not finished her coursework and doesn’t have an engineering job yet.

Olivia pictured engineers working a lot with machinery and having a passion for building with their hands. She does not strongly identify as an engineer since she is "*not very passionate about making things using her hands*", as she puts it. Her pre-college perception of engineering was "*[being] super passionate and competitive*", as opposed to being "*friendly and collaborative*" with other people, as she described it. Her views of engineering slightly changed while in college after realizing that she had some qualities that could be applied to a job related to engineering in the future, such as project management, project design, or simply being middle person.

Teddy was drawn to engineering for its job prospects and promises of financial stability for himself and his immigrant parents. However, he does not feel like an engineer when he compares himself with how he perceives engineers. He shared, "… *I can imagine [engineers] with hardhats [...] I don't know – just very sophisticated, very much technical. They know what they're doing. And I feel like me, I just don't know what I'm doing, and that's part of the problem*".

Mia hesitated to identify as an engineer throughout the interview and waffled about which aspects of engineering she identified with. Initially, she shared that doing research in an engineering lab and serving as the president of an engineering student association have helped her feel like an engineer. However, she has struggled to identify with the inflexible, rigid, and critical aspects of engineering practice.

A sense of achievement drew Alex to engineering because they saw it as a goal that was difficult to achieve, but this also prevented them from identifying as an engineer due to so many obstacles they had to face in college: *"the classes themselves are so difficult and emotionally taxing … it's hard for me to place myself in the position of being an engineer because it seems like something that has been so unachievable*".

4. *Do other people (such as family, friends, peers, or professors) see you as an engineer? Is it important to you that other people see you as an engineer?*

Student responses to this question exhibit how external validations, particularly by strangers through social interactions in college, in a conference, in an engineering classroom, or off-campus during an internship, are reflected in some students' sense of belonging and self-beliefs about being an engineer.

People in Mia's inner circle, i.e., family, friends and some peers, who are aware of her pursuit of engineering, consider her to be an engineer, as she mentioned. However, she believes that if asked, strangers would not identify her as an engineer. She drew a connection between her gender identity and her perceived standing within the community to elaborate this:

> *"When you think of an engineer, even as a woman, they definitely portray a certain image of how they're supposed to look like a videogame girl or like not so girly and just kind of nerdy. It's a stigma that comes off, and, for me especially, I'm a girl [..] I like to dress up [.. and] wear makeup [..]. And I'm Latina. I can wear my hoops, and there's certain times where I don't dress a certain way [...], because I'm afraid of how I will be treated [...] and I feel like if I were to go to any place or any [class]room where no one knew [who I was], I think the last thing they would think is I'm an engineer."*

Mia clearly did not receive the recognition she anticipated from society; this fact was brought up several times during other parts of the interview, e.g., walking into an engineering classroom when she was told the class was just for engineering students, feeling like an outsider in a professional conference due to her appearance, i.e., her outfit and makeup, or when she was automatically given all the answers when working with peers in engineering classes, assuming she needed help. Mia described her fear of "*not get[ting] respected*" and "*get[ting] mansplained*" or being judged for her perceived lack of competence because of "*[being] too busy caring about how [she] looked*."

Mia's reflections illustrate her struggle for recognition and acceptance in environments where stereotypes prevail, emphasizing the challenges faced by women, especially those from diverse backgrounds, in achieving confidence and a sense of belonging in engineering.

Since joining the engineering program, Alex yearned for a strong sense of belonging; having a great desire for personal growth and making social connections in both professional and educational contexts, achieving academic success, and integrating into the community were named as some of their goals as a university student. Alex's engineering identity was bolstered when they were mistaken for a professional engineer during an internship.

Discussion and Conclusion

When describing engineering and what engineers do, students in our study highlighted both technical (e.g., building, problem-solving, critical thinking, etc.) and social aspects (e.g., the ability to work with others, serving the community, etc.) of engineering. This is pretty consistent with Faulkner's [20] definitions of engineers. These qualities, such as the ability to work in a team, engineering ethics, respect for others, serving the community, etc., are highly valued by accreditation boards and employers. For some individuals, having (or not having) a strong passion for engineering and landing an engineering job was mutually crucial for feeling (or not feeling) like an engineer now, and some preferred to identify with a future engineer after completing their coursework and getting an engineering job. Additionally, students' sense of belonging to engineering was both positively and negatively influenced by social validations and

their perceived societal expectations. Self-identification with being an engineer and a sense of belonging were bolstered when the participating students received social recognition from individuals outside their family and friends. On the contrary, a deficiency in social validation from peers, e.g., through classroom interactions, the fear of being judged, rigidity, and lack of flexibility, weakened their sense of belonging to engineering. Moreover, gender identity was cited as a negative stereotypical trait associated with engineering, particularly for individuals from underrepresented backgrounds.

Our study highlights how factors such as gender, societal expectations, and lack of recognition can lead to stereotypes and feelings of social irrelevance, impacting one's sense of belonging and confidence in their discipline. It underscores the need to address challenges within the engineering community, including a lack of flexibility, competitiveness, biases, and insufficient social and cultural relevance faced by students. Notably, students with multiple oppressed identities in STEM (e.g., women, first-generation, Hispanic, African American, low-income) often struggled to identify with traits typically associated with engineers or faced technical and social dualism, as explained by Faulkner [20].

Our findings reveal that simply measuring engineering identity through conventional constructs like performance/competence, interest, and recognition (PCIR) falls short of capturing the true essence of what it means to be an engineer. PCIR does not provide a comprehensive understanding of the factors influencing an individual's connection to the engineering community. This limitation is especially pronounced for women and underrepresented minority (URM) students, whose experiences often differ significantly from others.

Our study further emphasizes the importance of broadening the definition of what it means to be an engineer beyond technical ability, including social and collaborative skills, while also challenging stereotypes that portray engineers as purely technical individuals lacking interpersonal or creative skills. For example, by highlighting ethical and societal aspects of engineering, educators can help students see their role beyond technical tasks. Additionally, it is important to embrace unconscious bias in engineering classrooms, raise awareness among educators, and offer training for more inclusive teaching and learning practices to foster a more inclusive and supportive environment within engineering.

Study Limitations

The participants were all full-time and domestic students in their senior year, indicating that they had a keen interest in engineering and had persisted in their disciplines thus far. We are aware of the impact of the COVID-19 pandemic on students' lives to some extent, but we did not measure its impact on their academic performance or mental health, which may have largely influenced their college experiences, particularly among marginalized groups.

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