”I see myself as an engineer”: Disentangling Latinx Engineering Students’ Perspectives of the Engineering Identity Survey Measure

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Introduction

Considerable effort has been made to understand undergraduate students' engineering identity formation and its effect on student success. Engineering identity development is a critical psychological construct impacting student experiences within engineering. Particularly, engineering identity has been linked to improved feelings of belonging [1], [2], [3], [4], motivation to enroll in an engineering program [5], leads to greater certainty of graduating with an engineering degree [1], [2], [4], [6], [7] and career certainty [8]. To address research questions regarding students' engineering role identity, researchers have been using the survey measure "*I see myself as an engineer*" to represent students' holistic view of their identity as engineers [2], [4], [6], [9], [10]. However, there are debates among researchers concerning the use of a single-item measure to capture complex and abstract psychological or affective concepts such as engineering role identity (e.g., [11], [12], [13]). Specifically, some arguments against using single-item measures are that they lack depth and provide limited insights into the abstract constructs of interest. Additionally, single-item measures cause concern for contextual bias, provided that one survey question might not fully capture the context, nuances, or intricacies of a psychological phenomenon, potentially leading to biased, incomplete, or inconsistent responses [11], [12]. When only one measure is used, it becomes more probable for respondents to interpret the question differently based on their lived experiences or current perspectives, thus leading to response bias or inaccuracies. With the possibility of different interpretations of a question, the validity and reliability of the item come into question [14]. Despite the criticisms of the use of single-item measures, there are studies to support its use even when measuring complex and abstract cognitive and affective constructs. For example, many studies employing diverse survey scales have shown that a single-item measure can yield satisfactory or comparable results compared to multi-item measures [15], [16], [17], [18].

In the context of engineering identity research and the use of the survey measure "*I see myself as an engineer,*" there is an inadequate understanding of the ways respondents are interpreting the measure. Whether respondents interpret the statement as a present- or future-oriented perspective is unclear. Students may be responding to the measure through an aspirational lens, an identity that can be claimed in the future, or as an identity they already claim in the present. Moreover, it should concern researchers who use this measure as they may not fully understand students' intended responses and may not be drawing adequate conclusions from their results. This study uncovers how undergraduate engineering students, predominantly of Latinx backgrounds, reflect upon the statement "*I see myself as an engineer*" and the justification they provide to explain their time perspective. Specifically, this study will focus on answering the following research question: In what ways are students reflecting on the question "*Do you see yourself as an engineer?*" and why?

Theoretical Framework

Engineering Role Identity

Our conceptual understanding of engineering identity begins with the theory of role identity. A role identity is based on an individual's social position and is defined by the meanings and expectations associated with the role in a given context [19]. These sets of expectations can relate to behaviors, meanings, and attitudes society anticipated individuals in a role to have. Role identity

is tied to the external expectations and internalized meaning an individual has taken on to fulfill a role [19]. People receive external messaging that influences how they understand the expectations of taking on a role. A culture around a role is constructed through the various messages that perpetuate what it means to be and act in a particular role. However, an individual also can author an idiosyncratic definition of the role. Through their internalized definitions and the feedback from their environment, individuals begin to understand who they can become in the context of their social positions [19], [20].

In the context of engineering, students receive messages of the meanings and expectations tied to the role of an engineer and are expected to act and behave in ways congruent to those established norms. Whether it is believing that engineers are good at math and science, studious, or hands-on individuals, messages about what it means to be an engineer within the context of a student's social position (i.e., their place within a social structure) are perpetuated before college, even if a student has had no prior connection to engineering. The internalized messages and expectations also extend to students' understanding of what it means to be and perform the role of an engineer. For students studying engineering, their current social position in the postsecondary context implies that the meanings and expectations they take on to author an engineering role identity include: 1) being interested in engaging and re-engaging with the subject, 2) being able to demonstrate or display their competence, skillsets or know-hows, 3) receive external recognition, and 4) internalizing the recognition into their self-concept and eventually begin to see themselves as engineers [21], [22], [23].

Carlone and Johnson's [21] seminal work investigated the experiences of Women of Color in science, mainly focusing on how internal and external recognition impacted their sense of self within science. The women's distinct science identities were influenced by how they created their meaning of science and whom they relied on for their sense of recognition as scientists. In their study, all the women saw themselves as science people; that is, they identified as scientists. Their internalized recognition, coupled with the recognition by meaningful others, further reinforced women's identities as scientists. As such, external recognition played a critical role in validating their competence as knowledgeable science people. All of the women in Carlone and Johnson's [21] study were professionals or working towards a terminal degree, thus maintaining a steadfast interest in their career pursuits. Hazari et al.'s [22] study provided evidence of the importance of explicitly integrating *interest* in the identity framework as it helped students establish an identity as a science or physics person.

Godwin [23] adapted survey items through the works of Hazari et al. [22], Carlone and Johnson [21], and Cribbs et al. [24] to create the engineering role identity measures. The survey items measure early undergraduate engineering students' interest, performance/competence, and recognition [21]. These survey measures continue to be instrumental for researchers focused on understanding how students develop an engineering role identity.

Purpose

We were interested in how students responded to the question *Do you see yourself as an engineer?* Our aim was to understand what students may be thinking about when answering the survey measure; *I see myself as an engineer*. We followed up by asking them to elaborate on their response, paying particular attention to the time perspective they situated their responses.

Methodology and Methods

This study used mixed methods to answer our research question. A mixed methods research study integrates qualitative and quantitative approaches to obtain breadth and depth [25]. We collected quantitative and qualitative data from engineering students at one Hispanic-Serving Institution (HSI) in the Southwest, who were enrolled in Statics, Strength of Materials, and Embedded Systems courses. The three courses were selected as part of a larger project to decrease the high DFW rate, or rate at which students fail or withdraw from a course, by restructuring the curriculum into mastery-based grading [26]. However, the data presented in this paper is focused on understanding students' interpretation of a widely used survey measure that claims to capture students' holistic identification as an engineer (i.e., *I see myself as an engineer*).

To better understand students' interpretation of the survey measure, we used an explanatory sequential mixed methods design, Figure 1. The explanatory sequential design represents a mixed methods approach where the researcher initiates with a quantitative phase and then proceeds with a subsequent qualitative phase to delve deeper into specific outcomes derived from the quantitative analysis [27]. The qualitative phase of the design aims to provide a deeper understanding of the initial findings, aiming to elucidate, elaborate, or contextualize the quantitative results. The 'explanatory' essence of the mixed method design signifies the critical role the qualitative data has in offering additional insights that augment and elaborate upon what is found in the quantitative phase [27].

The qualitative data was analyzed thematically to identify emergent themes or nuanced explanations. In the final phase of the design process, we integrated the results of both datasets, merging quantitative trends with qualitative explanations. By integrating the results, we provide a more holistic understanding of the research question and enrich our findings' interpretation and implications [27].

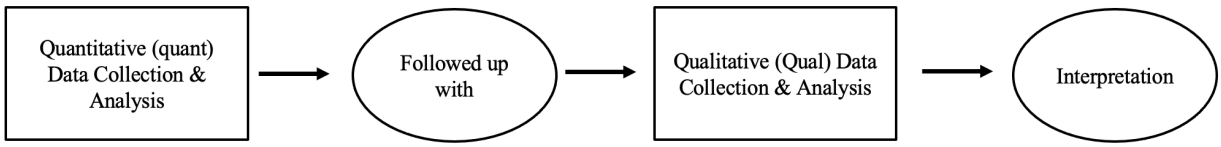

Figure 1
Diagram of explanatory sequential mixed methods design [27]

About the datasets

Survey data were collected at the beginning of the Spring 2022, Fall 2022, and Spring 2023 semesters in one HSI. The three semesters were combined to help increase our sample size. This dataset is considered cross-sectional. Together, our dataset consists of n= 298 students. Seventy-six percent of these students identified as Latinx (76%), while 13% were Asian, and the other races/ethnicities each represented less than 10% of the sample. Additionally, more men (79%) responded to the survey than women (16%), and our sample was predominantly comprised of first-generation college students (76%). For this paper, we only focused on the questions related to engineering identity. Participants were asked to indicate their level of agreement towards statements regarding their identity as an engineer, specifically these three questions: 1.) "*I feel like an engineer* now," 2.) "*I will feel like an engineer in the future,*" and 3.) "*I see myself as an*

engineer." Participants used a seven-point scale with anchors of 0 – "Strongly disagree" to 6 – "Strongly agree" to respond to the statements.

Students who completed the survey in Fall 2022 were invited to participate in semi-structured interviews. Our choice to recruit participants during the Fall 2022 semester aligned with the larger mission of the NSF grant. Eight students agreed to be interviewed; two identified as women and six as men. Five participants indicated they were in their junior year, while three were in their sophomore year. Seven participants were the first in their families to attend college, i.e., first-generation college students, and seven participants identified as Latinx. Table 1 summarizes additional demographic information for each participant, along with pseudonyms. Participants engaged in a 60 to 90-minute semi-structured interview. The interview asked students to reflect on three main topics: 1) their perceptions of an engineer's way of thinking and doing, 2) how (if at all) they saw themselves as engineers, and 3) a reflection on the importance of seeing oneself as an engineer in the present or future. Participants drew from their personal and academic experiences, or lack thereof, to inform their responses to questions within each topic.

Table 1 Interview Participants Summary of Student Demographics

Pseudonym	**Major**	**Year in School**	**Transfer Student?**	**Race/ Ethnicity**	**Gender**	**First-Gen?**
Alexander	Electrical Engineering	2nd year	No	Latinx	Male	Yes
Amy	Mechanical Engineering	3rd year	Yes	White	Female	Yes
Andres	Mechanical Engineering	3rd year	Yes	Latinx	Male	No
Diego	Mechanical Engineering	3rd year	Yes	Latinx	Male	No
Fernando	Mechanical Engineering	2nd year	No	Latinx	Male	Yes
Jack	Mechanical Engineering	3rd year	Yes	Asian	Male	Yes
Nicole	Mechanical Engineering	3rd year	Yes	Latinx	Female	Yes
Rafael	Mechanical Engineering	2nd year	No	Latinx	Male	Yes

Note. A first-generation college student is defined as neither parent having a bachelor's degree

Data Analysis Procedure

Survey Data. Using R software, a bivariate two-tailed Pearson's r correlation test was conducted to understand the relationships between the statements "*I feel like an engineer now,*" "*I will feel like an engineer in the future,*" and "*I see myself as an engineer.*" We provide mean and standard deviation rating scores for additional statistical descriptions of all participants sampled.

Interview Data. Participant responses were analyzed collaboratively using online software (i.e., NVivo) and tabletop coding. Concept coding was used to break down the three main topics from the interview protocol into concepts discussed at the interview, such as "engineers' behavior" and "engineers' way of thinking." Participants' responses to each concept were written on sticky notes to visualize everyone's thoughts and interpretations. Tabletop coding allowed us to move participants' responses into groups based on similarities and differences. Grouping the data

allowed for higher-level themes to arise. The research team worked to collaboratively label each grouping with a theme that properly encapsulated the participants' experiences, perceptions, and conceptualizations to help answer our research question.

Results

The aim of our study was to gather evidence to decode how students were interpreting the survey measure: "*I see myself as an engineer."* We were specifically interested in understanding if students responded to the survey statements through a present-oriented and/or future-oriented perspective. To help us interpret responses, we compared the survey measure "*I see myself as an engineer"* with two other measures that more clearly signal present and future perspectives. In Table 2, we provide descriptive statistics (i.e., Pearson's correlation, average scores, and standard deviation) to aid our understanding of students' interpretations. Following the descriptive statistics, we present interview data of eight students who, by answering the question "Do you *see yourself as an engineer?*" provided an understanding of the time perspective. We summarize the time perspective of each participant in Table 3 to provide an overall representation of their response profiles.

Response patterns of present and future-oriented scales (quantitative findings)

We examined the dataset (n = 298) to understand the relationship between each engineering identity-related survey measure. Pearson's correlation values were evaluated to understand the strength of relationships between the survey measures: "*I feel like an engineer now*," "*I will feel like an engineer in the future*," and "*I see myself as an engineer.*" We focused on the strength of relationships to help discern which time perspective is more closely aligned with the survey measure in question. We found a strong relationship between the future-oriented measure, "*I will feel like an engineer in the future,*" and the measure, "*I see myself as an engineer*" ($r = .57$, $p < .001$). There was a slightly weaker, albeit still significant, relationship between the present-oriented measure "*I feel like an engineer now*" and the measure "*I see myself as an engineer*" ($r = .45$, $p < .001$). In addition to examining the correlation values, we also noticed that students showed a higher average endorsement score to the survey measure "*I see myself as an engineer*" (M = 4.51, SD = 1.55) and the future-oriented measure (M = 5.85, SD = 1.27). In contrast, on average, students had a lower agreement score on the survey measure "*I feel like an engineer now*" (M = 2.85, SD = 1.47). The descriptive statistics show a stronger relationship between students' future-oriented identification and the measure "*I see myself as an engineer.*" Based on the sampled data (n = 298), evidence suggests that students' conceptualization of the statement "*I see myself as an engineer*" is more closely aligned with a future-oriented perspective.

Table 2
Correlation matrix, means, and standard deviations are in the diagonal (n = 298)

	1	2	3
1. I see myself as an engineer	**4.51** (1.55)		
2. I feel like an engineer now *(explicit present-oriented)*	.45***	**2.85** (1.47)	
3. I will feel like an engineer in the future *(explicit future-oriented)*	.57***	.42**	**5.85** (1.27)

Note. *p < .05, **p < .01, ***p < .001

Understanding students' time-perspective responses to "Do you see yourself as an engineer?" (qualitative findings)

We began the interview by asking students: Do you see yourself as an engineer? We further probed their responses by asking why or why not. We were cautious not to impose a specific time perspective. We wanted students to think about their lived experiences, determine whether they identified as engineers in the present or future, and the reason for the time perspective. After allowing students ample time to describe the experiences that led to their responses, we asked another clarifying question to help us understand students' thought process; specifically, we asked, "When you hear the question, "do you see yourself as an engineer?" and when thinking about the answer to that question, are you thinking about the answer in the present, future, or both?"

Some students looked to their past engineering-related experiences or industry experiences to describe if and how they saw themselves as engineers. The quality and meaningfulness of the experience differentiated students who saw themselves as engineers in the present versus the future. Most of the students in our sample stated that they saw themselves as engineers in the future, except for two students who shared meaningful experiences that helped validate their identification as engineers in the present. Table 3 provides a high-level overview of students' responses based on their time perspective. We categorized the interview data into three themes that captured students' responses to help understand what led some students to identify as engineers now and why others responded through an aspirational future-oriented perspective.

Table 3
Students' immediate response to the "Do see yourself as an engineer?"

Pseudonym	Immediate responses	When?
Andres	"I would say so … I have done work with it, I've even helped my dad solve some design issues …"	Present
Amy	"Yes, I can see myself as an engineer … I am an engineer"	Present
Rafael	"At this moment, I don't think so because I still need to learn more …"	Future
Nicole	"I don't see myself, currently. But I hope to see myself that in the future …"	Future
Alexander	"Yes … because I'm trying to achieve something like say renewable energy…"	Present and Future
Jack	"Yes, I do …"	Present and Future
Fernando	"I'm starting to think of feeling myself as engineer … kind of kind of… not yet, but the more I work on stuff with my hands, I feel like I'm start feeling confident that I'm an engineer…"	Present and Future
Diego	"I think I can do it… I could see myself as an engineer."	Present and Future

Theme 1: Students who saw themselves as engineers in the present had meaningful engineering-related experiences that validated that identity.

Students who had examples of past hands-on experiences (i.e., tinkering at home or industry experience) felt more like engineers in the present. Andres, whose father is a mechanical engineer, had many experiences growing up that helped him feel like an engineer in the present. In his interview, he described fixing cars and often finding himself fixing objects around the house.

> "I have done work with it, I've even helped my dad solve some design issues, or we're trying to fix something and then we're having to run into some issues. I've helped my dad solve some certain problems for that specific task. And my dad would be like, "Oh sweet, thanks. You just saved me a couple hours right there." I would say I see myself as an engineer ..."

> "Besides working with my dad quite often [fixing cars], I would say, yeah, I mean, I always liked building and then fixing things. My dad says I have a mechanical mindset, that mechanical engineer mindset."

In addition to being able to single out moments in which he took on the role of an engineer by fixing problems, Andres also received validation from his engineering father, which contributed to his confidence in feeling like an engineer in the present. Amy, who also felt like an engineer in the present, pulled from her past industry experiences to inform her identity as an engineer. She explained how her ability to fulfill the role of an engineer in her company grounded her identity as an engineer, which she describes in the following quote:

> "I'm capable of doing the work of an engineer. A lot of people at my current company respect my opinion, the things I say. I'm able to solve the problems. I mean, when I was there about a week in, the founder of the company came to visit, which was founded in 1995, the year I was born. And I was making an improvement to a process, and he was asking me why I was doing it. And I was able to explain it. And then they implemented that change at all of their other sites. So getting recognition from the founder of the company when I was a week in was ... It also helped me cement that I am an engineer."

Amy's meaningful engineering industry experience solidified her capability to succeed and helped her actualize a present-oriented engineering role identity. Amy was the only participant with industry experience; she stated that she "worked [*her*] way up to an engineer" before enrolling in an engineering degree program. Amy and Andres's responses highlight the power of meaningful experiences, as both could draw from their repertoire of experiences to validate their engineering identity in the present moment; their confidence to feel like engineers at present was reinforced.

Theme 2: Students without quality engineering-related experiences saw themselves as engineers in the future instead of the present.

Some participants felt they lacked meaningful engineering-related experiences, which hindered their ability to feel like an engineer at present. As such, those who perceived they lacked quality experience situated their engineering identity as an aspirational future-oriented goal they were working towards achieving. For example, Rafael described how being asked "Do you see yourself as an engineer?" was subconsciously asking him to seek meaningful examples that characterize him as an engineer, stating:

> "I start thinking about what I have done that could possibly characterize me as an engineer. But there really isn't much besides that one robot competition that I've done … Oh and then last semester actually to build a ROV ... a little submarine that we built to go underwater and move around and be able to race it. That's the only two projects that I've worked on."

> "If I have a job as an engineer right now or working on machinery, or into a field that I want to, with a mechanical engineering background, then that's when I would consider myself as an engineer. But for now, since it's the present and I'm not doing any of that currently, I wouldn't characterize myself as an engineer yet… I don't think just because of taking the knowledge during school and everything, it would automatically make me an engineer. It'll give me the traits of an engineer, but I would become an engineer once I put those traits and knowledge to use in my career."

For Rafael to see himself as an engineer at present, he needed meaningful experiences rooted in his interest to help validate his engineering-related skills. Nevertheless, he anticipated becoming an engineer once he became a practicing engineer who could apply his knowledge and skills to a career he was interested in. Similarly, at present, Nicole did not see herself as an engineer but acknowledged that meaningful real-world engineering-specific experiences would help develop her identification. While Nicole did not feel like an engineer in the present, she was optimistic about forthcoming experiences. When asked to think about what she considers when answering the guiding question, "*Do you see yourself as an engineer*?" she responded:

> "When that's asked, mostly I just think, "Well I have no experience working in any engineering field. My family has no experience. My friends have no experience. I just know nobody who has any experience." So, I'm like, "Oh, I have no experiences as well." So, I don't see myself as an engineer yet, only someone studying to be an engineer, and that's it."

Nicole's inability to point out a meaningful engineering-related experience or an exposure to an engineering-related experience through family affected her ability to see herself as an engineer at present. When asked to provide examples of ways she could feel more like an engineer, she said:

> "Just working as an engineer, having an internship, only because I know I can't really get that type of experience at home. I won't find it here for sure. So that's why I feel like I need to find it in an internship, or even just working outside the classroom … there's one thing to do it in the classroom and another thing to put it out there in an internship. I feel like I would feel more as an engineer because I've done it. It's not just as a hypothetical in the classroom."

Nicole's ability to see herself as an engineer in the future was not inhibited, while at present, she positioned herself as "only someone studying to be an engineer;" she nevertheless anticipated feeling more like an engineer after getting exposure to valuable engineering-related work via internships.

Rafael and Nicole's reflective responses were similar in that they needed meaningful engineering-related experiences to feel like engineers in the present. As a result of their perceived lack of experience, they could not see themselves as an engineer in the present moment. Nevertheless, their reality did not limit their ability to perceive themselves as an engineer in the future due to a motivational disposition to foresee opportunities to step into practicing engineering roles.

Theme 3: Aspirations, confidence, and past experiences allowed some students to see themselves as engineers through a present and future perspective.

When asked to clarify the time perspective for which they saw themselves as engineers, four participants described both present and future-oriented views. Alexander, Diego, Jack, and Fernando saw their current selves in alignment with their ability to become engineers in the future, supporting both a current and future-oriented identity. For example, Alexander's identification was driven by his passion for improving the world through engineering, specifically renewable energy. He is studying electrical engineering, and his goal to create a better environment for the future contributed to his pathway into and through engineering. When asked to provide examples of past experiences that have helped him feel like an engineer, Alexander mentioned his volunteer efforts in planting trees. Although it may not be "the traditional engineering path," Alexander emphasized how his tree-planting experience allowed him to create a positive impact on the environment. He said:

> "Because currently working as an electrical, I feel like I can work to basically advance the world later with the whole trying to create a better electrical production means, production of electricity. Like once I finally get to learn how the electrical engineer. And then also just using the example I used earlier with just the tree plantings I did earlier, it's not something that would be considered the traditional engineering path, but it is something that would better the environment in the future ..."

Alexander embraced how his past experiences aligned with the part of engineering focused on bettering society. He used this understanding to validate his identity as an engineer in the present. Although Alexander did not mention a stereotypical engineering experience (i.e., tree planting), he understood that the experiences he accumulated aligned with the altruism of an engineer, specifically with the desire to make a lasting impact on society. Alexander also mentioned that his brother is an electrical engineer, which may have contributed to his understanding of what an engineer is and how engineers can enact change, allowing him to vicariously see himself in that role. Alexander's experiences foreshadow the way he can currently make a change in the environment as a student and the difference he can make in the future as an engineer. As such, Alexander perceived an alignment between who he is and who he wanted to become through his experiences planting trees and his goal of creating renewable energy. In the present, he demonstrated indicators of feeling like an engineer but ultimately used that goal as a foundation to bolster his ability to see himself as an engineer in the future.

Jack had understood the process of becoming an engineer in terms of career milestones. Until now, Jack had been thriving with his coursework by learning the material in all his classes. His ability to persist through his challenging coursework built his confidence as an engineer, which led him to feel like an engineer in the present. However, he noted the need to successfully complete the Fundamentals of Engineering (FE) exam as the last milestone needed to be considered an "actual" engineer:

> "So, I think to be a complete engineer, an actual engineer, we have to understand everything in mechanical engineering. So, when we do take the FE exam, then, and passing it, that's

> when it's become a true engineer. By just passing courses, and having diploma, does not... For me, it would not be actual engineer yet."

Although Jack continues to gain engineering knowledge throughout his academic pathway, he felt that he still needed to acquire formal certifications to be distinguished as an engineer. Jack felt on track to fulfill career milestones (e.g., graduating with an engineering degree and passing the FE exam), facilitating his ability to feel like an engineer in the present moment. However, his current identity as an engineer was related to his perceived future experiences, accumulated knowledge, skills, and accomplishments. Jack's anticipation of his ability to fulfill his perception of an engineer solidified his future-oriented engineering identity. That is, his present engineering identity is heavily tied to his future possible self: a version of himself that satisfies his standards of a "complete" engineer. As a student, he is laying the foundation necessary to achieve his definition of an engineer. His present self is laying the groundwork to propel his future self toward the successful completion of engineering milestones and the activation of being a "complete" engineer.

Unlike Alexander and Jack, Fernando focused on the quality of hands-on experiences within his institution to define how he saw himself as an engineer. Within his coursework, Fernando worked on small projects like a submarine and flashlight. He was also a Formula One race team member where he intended to gain more hands-on experience. Fernando's course projects were the first time he felt like an engineer. He said, "So far, I'm starting to think of feeling myself as an engineer… the more I work on stuff with my hands, I feel like I'm a start feeling confident that I'm an engineer." However, by the end of the term, Fernando's experiences with his course projects did not sustain a present identification as an engineer due to a lack of meaningfulness. Fernando described his experiences in the following way:

> "My first year, the first semester we had a group project to build a submarine. It was cool because we actually cut part, we added all the waters and stuff and actually worked. But for some reason, the pool was reserved on that day and since it was December, it was going to be a few days before a winter break. We didn't get to test our submarines in a little race. So I think that kind of brought me down as feeling as myself as an engineer, because we built a submarine that actually worked, it goes up and down…we put all the waters and stuff. And I think my team's design was very good, we worked on it really hard, but I feel that since we didn't really test it out, I'd never see myself as engineer because I'm supposed to feel myself as an engineer if I don't know if it works or not.
>
> So even though [the submarine project] was the first time I felt as an engineer, that kind of brought me down because we didn't actually see in action. And then for my second semester, we didn't really do that much building. It was just math and physics. So, it didn't really... So that kind of brought me down as seeing myself less of an engineer ..."

Although Fernando's submarine project helped activate his self-perception as an engineer, the inability to test the design did not fully validate his ability to continue to see himself as an engineer at present. Although he gained pride in his capability and design, he was unable to prove the innovativeness or functionality of his ideas, thus rendering the experience less than meaningful. Fernando continued into his second semester, not feeling like an engineer at present due to minimal

quality hands-on experiences. Nevertheless, Fernando was optimistic that his experiences as a second-year student would help him feel more like an engineer:

> "… at the beginning of my second-year, I've been learning much more. Right now we're going to make flashlights and we're going to use machinery to cut them and we're also... You know how I said that I'm in a club where they make Formula One cars? … So far, I'm starting to think of feeling myself as an engineer, but I have to... Kind of, not yet, but the more I work on stuff with my hands, I feel like I'm start feeling confident that I'm an engineer."

> "I say, I kind of see myself as an engineer, but not yet because I still don't have the experience, but once I get more experience and I am more knowledgeable on how they actually do bigger projects, how to get machinery to 3D print, laser cut, cut metal, throw a hold of metal, all that, then I'll feel more as an engineer. But so far I say maybe half percent sure I'm an engineer."

Fernando maintains a future-oriented identification as an engineer; however, he acknowledges that having more hands-on, meaningful experiences will help him solidify a present-oriented engineering identity. His value toward seeing himself as an engineer is related to his ability to design and build projects that work. His past experiences and knowledge provided the foundation for him to feel like an engineer to the extent that he claimed he was "half percent sure I'm an engineer." His drive to obtain more meaningful hands-on experiences is required to reinforce his established confidence as an engineer and fulfill his vision of seeing himself as an engineer. As Fernando continues his studies, he is conscious of how he could gain quality engineering experiences to help him identify more as an engineer. By being better equipped with the technical skills of an engineer, he is confident of his ability to see himself more like an engineer in the future.

Diego's trajectory into engineering differs from all other participants in that he transferred to the institution and engineering major. He was previously a physics major and saw himself as a physicist then. As he switched pathways, his transition to an engineering major highlighted his newfound alignment with feeling like an engineer in the present. His confidence in his ability to be successful in engineering coursework helped inform his future-oriented identification as an engineer. His newfound interest in engineering helped realign his academic journey in a way that aligned with his future goals and motivations. When asked if he saw himself as an engineer, Diego responded:

> "I think I can do it. Like I said, I just transferred. I just changed my major, so I used to view myself more as a physicist before, but so far with the classes that I'm taking and everything, I liked it so far so I could see myself as an engineer."

When asked to elaborate on what led him to consider himself as an engineer, Diego emphasized his perception of his future as an engineer:

> "I guess it means that if I'm able to see myself 10, 20 years in the future, being able to work as an engineer and doing a good job, I guess, do my job well, or if I believe that in 20 years I'll be upset about being an engineer or if I'm going to be having regrets about

becoming an engineer, or whether or not if I think I'm capable of doing the work as an engineer."

Diego used his current position as an engineering student to understand if what he is "doing right now is helping [*him*] achieve [*his*] goal of becoming an engineer in the future." That is, his response to the question "Do you see yourself as an engineer?" was based on a reflection of the ways his present actions were helping him become the person he wishes to be in the future. While Diego did not point to a specific engineering experience, he described his confidence in his ability to be successful in engineering, which helped him feel like an engineer in the present but mostly drove his ability to see himself as an engineer in the future.

Alexander, Jack, Fernando, and Diego hold a unique perspective on their engineering identity. They all hold some level of certainty of feeling like engineers in the present but have more confidence in their ability to feel like an engineer in the future. These four students foresee being on track to becoming engineers in the future through the alignment of their current actions or acquired knowledge. The contrast of when they saw themselves as engineers highlights the tension within developing an identification as an engineer and how variations between students' self-perceptions are influenced by the quality of experiences and their perceived alignment with their aspirational engineering self.

Discussion

The aim of this study was to obtain a better understanding of students' identity development trajectories, specifically *when* they start to identify as engineers. Synthesizing the descriptive statistics with the qualitative findings, we can gain a nuanced understanding of *when* students identify as engineers and, most importantly, *why*. On average, students had lower levels of endorsement on the present-oriented survey statement (e.g., "I see myself as an engineer now"), and the qualitative findings help shed light on why students might not see themselves as engineers *now*. Based on our interview data, few students' engineering role identity was actualized through meaningful, engineering-relevant experiences; thus, most of our participants could not fully embrace that identity in the present. Conversely, our survey respondents were more inclined to "feel like an engineer in the future," which aligned with our qualitative findings. Specifically, from our interview data, students saw themselves progressing toward one day fulfilling the expectations of the role (e.g., obtaining meaningful real hands-on engineering experiences), resulting in a future-oriented identity. A subset of our interviewed participants were ambivalent about *when* they saw themselves as engineers, oscillating between identifying as engineers in the present and the future, a pattern consistent with the correlation values outlined in Table 2. Based on our qualitative results, it is evident that students' varying levels of experience with engineering impact the degree to which they feel like engineers in the present or future. Students' social positioning and exposure to engineering culture cannot be ignored when considering how they develop their engineering identity.

A key part of being an engineering student is the *student* component of their identity. Expectations are different between working engineers and engineering students because of their social positioning. Engineering students, for example, are in a place of learning and are in the process of acquiring the knowledge necessary to be skillful engineers. Our qualitative findings confirmed that most students saw themselves as students who were learning and gaining new skills every

semester. For example, Jack noted that he felt like an engineer because he was performing well in his engineering class but felt that he needed to pass the Fundamentals of Engineering (FE) exam before being considered a "true engineer." Likewise, Diego who was performing well in his engineering classes, still felt like he lacked engineering-related experiences. As a result, his ability to see himself thriving in the long-term as an engineer is what allowed him to feel like he's capable of *becoming* an engineer. While these students were academically achieving in their engineering coursework, they recognized that they still had gaps in their knowledge, skills, and experiences that inhibited their ability to confidently say they are engineers in the present. Perhaps their social position as students placed them in a position of "learners," whereas engineers are perceived as "knowers."

In addition to reconciling who students are now and who they want to become in the future, they are subject to the hidden curriculum of engineering (i.e., "the unwritten, unofficial, unintended values, lessons, and perspectives that are present in academic settings and work environments" [28]). Within engineering, students are exposed to messages regarding the importance of hands-on experiences for becoming an engineer, particularly internships and co-ops. These messages provide students with unwritten rules for being an engineer that extend beyond the traditional obligations of a student (e.g., learning in the classroom and completing their degree). However, when students cannot meet these expectations, their engineering identity is affected. In Nicole's case, her lack of engineering experience was a significant factor inhibiting her ability to feel like an engineer in the present. Additionally, obtaining real-world, hands-on engineering experiences can be a matter of having the privilege to allocate time during the summer and knowing how to apply those experiences. Studies have highlighted that students struggle to access hands-on engineering opportunities due to various reasons like external responsibilities and commitments [29] and a lack of knowledge about the internship search and recruitment process [30]. Given our predominantly first-generation population (76%), it may be that students are experiencing the aforementioned struggles, which affect their ability to apply for and pursue internships and co-ops. As such, the inherent inaccessibility of hands-on experiences may be why our participants aligned more with a future, aspiration-oriented engineering identity rather than a present-oriented identity.

Access to *meaningful* engineering-related experiences is vital to supporting present-oriented engineering identities. The interviews uncovered how the time perspective of *when* students saw themselves as engineers was contingent on their level of meaningfulness in their past experiences. Our qualitative findings underscored this for individuals who viewed hands-on engineering experiences as a criterion for identifying as engineers at the current moment. Specifically, Andres and Amy were the only participants who presented a clear, present-oriented engineering identity. Both students had engineering-related experiences that allowed them to work in an engineering role and be recognized as engineering people by other engineers. That is, their experiences satisfied two conditions for a meaningful experience: 1) having the ability to engage with hands-on engineering tasks and 2) receiving validation of their engineering skills from meaningful individuals. Not only were hands-on experiences essential to Andres and Amy's present-oriented engineering identity, but those experiences were made meaningful through the external recognition they received. Studies have found that receiving recognition serves as a catalyst toward converting the simple engineering experience to a meaningful engineering experience [29], [31]. However, not all recognition is valued equally [19], [30]. Studies have found that engineering students value external recognition when it comes from meaningful others [19], [29] and when it is aligned with

their internalized level of competence [32]. When students' internalized sense of self aligns with the feedback they receive from a meaningful other, they accept the recognition. When that condition is not met, students do not find the recognition meaningful, thus not supporting their engineering identity [32]. Said differently, not all hands-on engineering experiences can be deemed meaningful due to a lack of meaningful recognition. Therefore, not all engineering experiences hold the weight to support students' present-oriented engineering identities.

Privileges Associated with Accessing Hands-on Engineering Experiences

The identities of some of our participants facilitated their access to engineering-related experiences. Andres, for example, is a continuing-generation college student who benefited from his father being a practicing mechanical engineer. Andres' familial connection allowed him to engage with engineering in ways that afforded him recognition for his engineering skills and mindset by a meaningful other, his father, which further fostered a meaningful experience. As a result, his sense of self aligned with the expectations of his environment, thus affirming his present-oriented engineering identity. Andres' father's career was integral to his access to hands-on engineering experiences. Similarly, studies have reported on how engineering students have leveraged their parents [29], [33], [34], [35], [36], [37] and their networks [29], [36], [37] to obtain engineering-related experiences. Hands-on engineering experiences can be more readily accessed when students are able to connect with practicing engineers. Unfortunately, access to practicing engineers is less feasible for individuals whose community networks are outside engineering or broadly STEM. A disparity in students' ability to connect with engineers leads to inequity within engineering because it affects their opportunities to engage in valued engineering experiences and connect with potential sources for meaningful recognition. Additionally, the need to have hands-on engineering experiences creates an inequitable expectation affecting students' ability to see themselves as engineers due to a lack of access. Critical work must be done to redefine what it means to have "experience" and "knowledge" in engineering, particularly to embrace non-traditional engineering experiences that can supplement students' classroom experiences and support their engineering identity.

Limitations and Future Work

Our study did not come without limitations. First, the interview protocol was not *exclusively* focused on understanding students' identity; therefore, substantial time was not given to the topic. More interview questions need to be asked about how students receive messaging about what it means to be an engineer, particularly from peers and faculty. Additional questions could explore the key personnel providing students with messaging on what it means to be an engineer and how it affects students' internalized identity feedback loop. Also, additional questions about how students' personal and social identities interact with their engineering identities were warranted. Future work will continue to explore how students' experiences at the intersection of their multiple identities influence their ability to fulfill a present-oriented engineering identity.

Implications

The purpose of this study was to understand how students were interpreting a widely used survey measure: "I see myself as an engineer." Specifically, the research team sought to understand the time perspective related to the survey measure: were students aspiring to see themselves as engineers, or did they already hold that identity? Recognizing the variability in how students interpret the survey measure is crucial as the data we collect and our interpretations can be

significantly affected. When students interpret a scale differently, that introduces bias or error in survey analyses and results [14], [38]. The resulting bias was evident in the qualitative data showing how students' different experiences led them to identify as engineers at different time points. As researchers, we rely on the accuracy of our data to help inform policies, interventions, and recommendations. Additionally, the accuracy of our instruments allows us to evaluate the efficacy of proposed recommendations. The varied interpretations observed in both datasets underscores the importance of unambiguous survey design. Using a clear time-focused survey scale can help minimize misinterpretations and clarify the results produced in various modeling approaches (e.g., structural equation modeling).

Researchers studying engineering identity development can tailor their investigations based on when students identify as engineers. This knowledge can guide research questions, methodologies, and interventions to understand and support students across different trajectories of their engineering identity development. The time point at which students identify as engineers may necessitate using different retention strategies. Students who identify as engineers at present may require efforts to maintain interest and motivation. In contrast, students with aspirational future-oriented identities may benefit from efforts that help solidify their place and sense of belonging within the engineering community of practice. Curricular adjustments can be made to engage students who do not, at present, see themselves as engineers. For example, instructors who already integrate hands-on, real-world learning experiences into their courses need to build an environment that fosters meaningful experiences within the classroom. Instructors can facilitate meaningful experiences by connecting class projects to students' values and backgrounds, allotting enough time for students to undergo the entire engineering design process, and validating students' unique ways of knowing that may influence their approach to their projects.

Conclusion

This study disentangled the interpretations undergraduate students were making when responding to the survey measure "*I see myself as an engineer*." The responses of the participants bring to light how students are coming to see their identities as engineers and what experiences they value to verify and confirm those identities. Particularly, their responses highlight the weight students put on meaningful hands-on experiences to verify and confirm their identities as engineers. As such, the greatest gap in students' ability to see themselves as engineers in the present moment was linked to their ability to recall meaningful experiences within engineering.

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