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Exploring the Critical Incidents and Sociocultural Dynamics that Initiate and Anchor Engineering Identity Formation

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Abstract

Engineering education scholars have identified a wide range of factors that influence the growth of an undergraduate student's professional identity as an engineer, including internship experience, club participation, grades or other academic achievements, social interactions with peers, and family tradition. These experiences contribute to students viewing themselves as engineers prior to graduating and entering the workforce. At the same time, several factors have been known to discourage students from pursuing or continuing to study engineering. These factors, which include cultural and socioeconomic background, race, gender, and sexual orientation, can affect a student's sense of community and belonging in engineering and other STEM fields. In this paper, we discuss the pivotal moments, significant relationships, and social interactions that participants used to anchor their engineering identities. These anchors serve as foundational reference points on which engineering identity is iteratively built and assessed. Our findings offer valuable insights into the commencement of engineering identity development, contributing to our understanding of this important, complex, and dynamic process.

Introduction

Several factors have been shown to influence an engineering student's ability to recognize and identify themselves as an engineer, including personal academic achievement, experience in the engineering field, acceptance of family legacies, or a combination of other factors [1], [2], [3]. As an engineering student experiences and accepts these factors, they can better envision and realize their potential as an engineer. However, due to their diverse backgrounds and prior knowledge, we know that students have differing definitions of what it means to be a 'successful engineer' [4], [5]. While some students base their definitions on academic prowess and professional stage-gates, others draw their definitions from individuals they view as 'being' engineers and the positive traits and characteristics they associate with them [3].

The diversity in defining what it means to be an engineer has made it particularly challenging for scholars to identify exactly how and when undergraduate students actively begin their outward identifications as engineers. To address this issue, we conducted a qualitative study that asked the research question: When does one become an engineer? To answer this question, we conducted semi-structured interviews with four undergraduate engineering students at Utah State University. Our research unveiled pivotal moments, significant relationships, and social interactions that participants used to anchor their engineering identities. These findings offer valuable insights into the initiation of engineering identity development, which can be used to inform the design of engineering outreach and recruitment programs as well as university- and college-level support structures that promote the success and retention of students pursuing engineering degrees.

Researcher Positionalities

Kaitlyn Pope, Senior Mechanical Engineering Student, Utah State University. I have spent over four years striving to receive my engineering degree. Throughout my experience, I struggled to understand how I fit into the engineer stereotype. Despite being a high performing student academically, I spent much of my time trying to become an engineer in the social sense. I became discouraged when interacting with other engineering students because I rarely found common interests with others outside of coursework. It wasn't until I pivoted into a unique career path that I felt I had the potential to become an engineer, despite not fitting the social mold of a stereotypical engineer. As I achieved milestones that were important to my personal beliefs about engineering, I began to recognize my abilities. I placed more emphasis on academic milestones, which were most important to me, and found that I was achieving just as much as any other student. This logic led me to believe in myself as an engineer, despite my social status. I continue to consider myself as an engineering student, as I have yet to graduate with an engineering degree. However, I see my potential to become an engineer grow as I continue to challenge my own social perceptions of engineers. While talking to other students, I found that each engineering student had their own list of requirements to achieve in order to consider themselves engineers. Studying engineering identity formation allowed me to see professional potential in myself and other students. My journey to acceptance and excitement about engineering inspired this study.

Cassandra McCall, Assistant Professor, Engineering Education, Utah State University. My experiences as an undergraduate student has significantly influenced my research interest in engineering identity formation. As an undergraduate student, I performed well enough to pass my courses and obtain my degree. However, while walking across the stage at graduation, I felt like I was an impostor, both academically and socially. Academically, I had not achieved the same success in college as I had in high school, which was a big reason why I was initially encouraged to go into engineering. Socially, I was constantly reminded of the highly, and sometimes toxic, masculine culture associated with going to an engineering-focused institution. At the same time, I was repeatedly told by people inside and outside of engineering that I was too social and too outgoing to be an engineer. I had hoped that graduating with my undergraduate degree would ease my anxieties, but it did not. I did not feel like an engineer, and the thought of pursuing an engineering career was very intimidating. As I continued into graduate school and into engineering education research, I found myself fascinated by student career pathways and professional formation. I conduct this work to gain a better understanding of this process and how to help facilitate it in others so they can enter the engineering workforce as confident engineers.

Theoretical Framework

This study is grounded in social identity theory (SIT), which implies that membership in a group – in this context, in engineering – is constructed through comparisons of values and behaviors that members make between themselves and members of other groups [6], [7], [8]. Group members use these comparisons to partially define who they are by ascribing or choosing not to ascribe to the meanings and regulatory influences of the group [8], [9]. SIT is further delineated into two sub-theories: (1) SIT of intergroup relations, and (2) self-categorization theory [8], [10], [11]. These sub-theories approach social identity, or group identity [10], from two perspectives. SIT of intergroup relations considers the comparisons, agreements, and tensions within a larger social structure [6], [8]. Some engineering students may struggle to perceive themselves or be perceived by others as an engineer based on characteristics that are not traditionally associated with engineering (e.g., see researcher positionalities above) [12], [13], [14], [15], [16]. Self-categorization theory (SCT) is essentially the inverse of SIT of intergroup relations. It considers social systems as a defining framework from which an individual's place in society is determined [6]; social identity is constructed as an individual interacts with multiple groups and maintains positive values from some groups while distancing themselves from others [10]. As a research lens, social identity theory is useful for gaining a greater understanding of when and how students begin to identify with engineering individually and socially. As a result, these concepts influenced all aspects of our research design including participant recruitment as well as data collection and analysis, as discussed in the next section.

Methods

To address our research question, we conducted an exploratory qualitative study designed to gain deep insights into student backgrounds and understandings of engineering with the purpose of identifying critical incidents or key anchor points that initiated students' formation of engineering identities. The first author led the design and implementation of data collection and analysis techniques.

To recruit study participants, a recruitment survey was disseminated via email to all undergraduate students enrolled in the College of Engineering at Utah State University. Questions on the recruitment survey included topics related to the perceived difficulty of their program, intentions to stay in their program, and how they would "grade" themselves as an engineer, in addition to general demographic information. Due to time constraints of the study, conducted during Summer 2023 as part of the Research Experience for Undergraduates (REU) program, four students were invited to participate in a semi-structured interview via Zoom. A summary of the participants selected for participation in this study is shown in Table 1.

Table 1: Summary of interview participants (using pseudonyms)

Characteristic	Connie	Tony	Gabby	Max
Gender	Female	Male	Female	Male
Grade Level	3rd Year	3rd Year	3rd Year	4th Year
Discipline	Civil	Civil	Mechanical	Mechanical
GPA Range	2.5-3.0	3.5-4.0	3.0-3.5	3.0-3.5
Self-Grade*	6	7	6	9

*Engineering self-grade is a rating by the participant to indicate their current success as an engineering student (1 – Low grade to 10 – High grade)

Interview participants were purposively selected to gather a wide variety of experiences and perceptions related to demographics and background, academic performance, involvement in extra-curricular activities, and perceived difficulty of engineering programs. Recognizing that gender and engineering sub-discipline can significantly impact students' experiences and identity formation as engineers [4], [15], we selected one man and one woman from the civil and mechanical engineering departments to participate in the study. These majors were chosen due to their close alignment with one another, and much of their coursework is taken together. To gather a foundational understanding of each student prior to the interview, we also noted their self-reported GPAs and self-grade as an engineering student. This provided nuanced insights into the dynamic relationship between academic performance and self-perception to facilitate conversation during the interviews.

Interviews lasted approximately one hour and were conducted by the first author. The interview protocol was designed using a semi-structured approach to build rapport with participants and to make the interview more conversational. Participants were asked questions about what inspired them to pursue engineering, the challenges they faced, and what helped them work through the stressors they experienced while in their engineering programs. Sample questions that were discussed during the interview included:

1. From your perspective, what are the traits and skills necessary for being an engineer?
2. Do you think of yourself as an engineer? Why or why not?
3. At what point in your academic career did you begin seeing yourself as an engineer? Please describe that turning point.

These questions allowed participants to identify and share their perspective as engineers. If students described themselves as having all of the necessary skills to consider themselves as engineers, the interviewer asked follow-up questions to elicit descriptions of key events and interactions that fostered their perspectives. In contrast, if students did not consider themselves to be engineers, the interviewer asked follow-up questions to prompt further discussion of key events and interactions that hindered or impeded their identifications with engineering. All interviews were audio-recorded and then transcribed for analysis, and all study procedures were approved by the Utah State University Institutional Review Board (USU IRB).

The results of this study were determined using inductive qualitative analysis techniques [17]. We began analysis by reading the interview transcript to become familiar with the content of each participant's interview. In a second round of analysis, the interviews were again reviewed and then coded by factors that contributed to each participant's engineering identity. In a third round of analysis, we employed constant comparison techniques [18] to refine and reapply codes. Codes were then mapped chronologically using a timeline that captured the critical events, experiences, and people that influenced each participant's engineering identity along their career pathway.

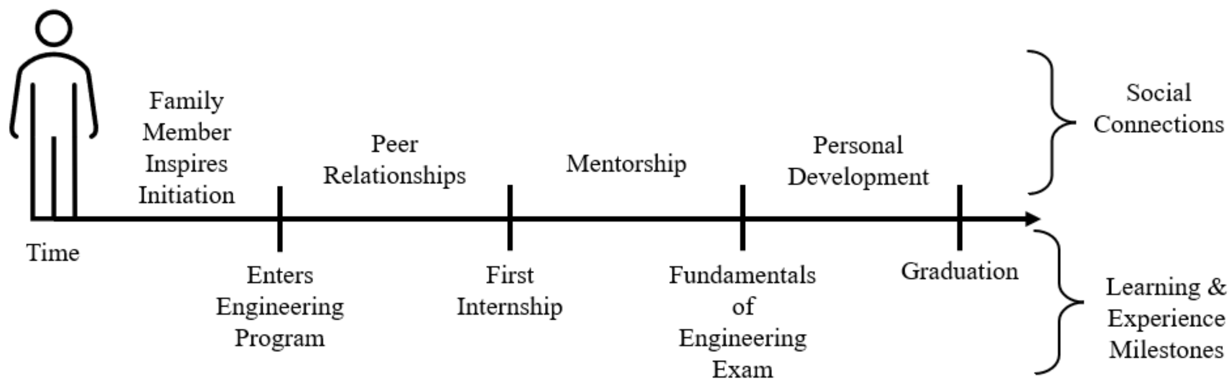
Limitations

This study is focused on understanding the variety of factors that may influence an engineering student's identity as an engineer. Limitations to the study were introduced as only four students from one participating university were included in semi-structured interviews. To mitigate the impact of these study limitations, we provide rich, in-depth descriptions of participant accounts so that other undergraduate students and researchers may translate and apply these findings to their own contexts as they see fit. Notably, we intend to continue data collection, which will likely result in the emergence of additional or different themes than what are discussed in this paper. Other possible contextual factors contributing to engineering identity may be identified when conducting interviews with participants aligning with different traditions and cultures (e.g., post-traditional students, religious backgrounds, etc.) stemming from a wider variety of geographic areas. We do not offer this work as a culminating summary of all undergraduate students' engineering identity formation. Rather, we offer this work as data point in the broader conversation of engineering identity formation across undergraduate students. As research continues in this area, we hope that educators, researchers, and other students find this work useful in furthering their own inquiries into this complex topic.

Results and Discussion

Upon completing the qualitative analysis of interview transcripts, five major themes were identified that were categorized as initiators, anchors, and supplements to engineering identity development: (1) mentorship and legacies (initiator), (2) 'real-world' experience (anchor), (3) learning achievements (anchor), (4) social connections with peers (supplement), and (5) personal characteristics and traits (supplement). To capture the on-going evolution of one's engineering identity, we conceptualize identity formation as a timeline of student experience that begins with identity initiators and is later dotted by the anchors and supplements that constitute engineering identity. This timeline is shown in Figure 1.

Figure 1: Timeline of initiation and impacts to engineering identity



Participants in this study shared that they were inspired to pursue engineering by a relative, initiating their engineering identity. Students were then anchored by learning and experience-based milestones throughout their academic journeys. These milestones served as important experiences that contributed to participants' engineering identities. However, time-based milestones were not the only contributors. Social connections, with peers, mentors, and self, bridged the gaps between major milestones. As students were supported by peers and mentors, they were motivated to continue through their academic career. Social connections also compensated for late and missing academic milestones, allowing students to feel the same sense of engineering identity as peers who had already achieved specific milestones (e.g., obtaining a summer internship). As students further developed their perception of engineering through exposure to industry, they also relied on personal traits they believed were valued and necessary to continue forward in their engineering careers.

Theme 1: Mentorship & Legacies (initiator)

Mentorship and family influence played a role for most study participants, typically to learn and get excited about engineering, and thus initiating their engineering identities. Despite different experiences within engineering education, three of the four students could attribute their engineering identities in part to a mentor or inspirational person. For example, Tony's decision to pursue engineering was due to family connections and supplemented by career placement test results. Tony had a few family members who were engineers, but he was specifically interested in civil engineering because of his uncle, who had a successful career in civil engineering. While Tony did not necessarily consider his uncle to be a mentor per se, his observations of his uncle piqued his interest in becoming a civil engineer, “To be honest, I kind of would hear bits and pieces about what he would say, and kind of like, you know, I’ve seen his lifestyle, and then I would do my own research about it and like, look into, you know, what it all entails.” Tony also chose to attend Utah State University because his uncle attended there. Despite not having a strong relationship with his uncle, their interactions – even at a distance – helped Tony identify key topics that allowed him to research, scope, and determine his career pathway and the resources that were needed to pursue it.

Others chose to pursue engineering as a means to keep a family legacy alive. For example, Gabby originally wanted to pursue a career in the medical field, but chose engineering after being inspired by her grandfather, whom she had never met. “My grandfather was actually an engineer back when you only needed an associate degree, so he was an engineer. And I’ve just apparent[ly] always been really close to him. And so that kind of just pushed me…” Her limited knowledge of her deceased grandfather was enough to see potential in herself as an engineer. The connection between Gabby and her grandfather grew as she continued to study engineering. Learning more about his story motivated her to push through challenges she experienced while in college, “… and if he can do it with just an associate degree, I can do it with my bachelors type of thing.” Gabby’s experience demonstrates that social and family connections can encourage students to pursue and perform well in engineering, even if they have never met them. Gabby still does not know much about her grandfather’s career but continues to find connections to him in learning the same or similar skills that he did when he was in college. Both Gabby and Tony’s stories show that familial connections can be significant in the formation of students’ engineering identity initiation, even if these connections are distant or only passed through family histories.

At the same time, these legacies may influence students in similar, yet opposing ways. Max, for example, did not have any family members in the engineering field. He explained that his family had a general legacy of becoming teachers. However, he was still inspired by this father who taught him about mechanical systems,

> And so I was raised fixing plumbing. I was raised flipping houses. I would go and fix the pipe system for a swimming pool. Just that sort of thing. And so I have some mechanical inclination, and it just kind of as mechanical engineers, we are really good at fixing just general problems. And that’s just something I like to do. And it seems to have been a very good fit.

Max attributed the learning experiences he had with his father as inspiration for pursuing mechanical engineering even though his father did not have formal engineering training. When coupled with hands-on experiences with his father, encouragement from teachers, who recognized his abilities and academic strengths, further solidified his decision to become a mechanical engineer. Max’s story highlights that a pedigree filled with engineering professionals is not necessary for encouraging students to pursue engineering careers and initiating an engineering identity.

The experiences of these students encourage us to further examine the figures that inspire students to pursue engineering careers in the first place. Students can feel linked to family members and ancestors as they choose to pursue the same career path. This link may initiate students’ identities as they see potential in themselves to become engineers.

Theme 2: Real-World Experiences (anchor)

Many engineering professionals and institutions encourage students to participate in as many 'real-world' experiences as possible, including internships, job shadowing, and field-related clubs. These experiences are meant to introduce students to the tasks, environments, and responsibilities they will encounter after a degree is achieved and coursework is completed. Internships are a specific milestone that both students and engineering professionals believe is the gateway to engineering as a career. Tony and Max each described the opportunity to participate in an internship during their undergraduate careers and discussed how these opportunities helped them develop skills that resided outside of academic curricula and course assignments.

When asked about the traits and skills necessary to be an engineer, Tony indicated that engineers need to be thorough and detail-oriented, which he learned while working at a structural engineering internship. He shared that his boss "[did]n't miss any details… He's very thorough with these certain things, and I think there is a difference between like a lazy engineer that misses stuff and then someone who's really thoughtful [and] checks their work [sic]". The opportunity to learn from a current engineer expanded his perspective on the valuable skills necessary to become an engineer in industry. Similarly, Max's experience in an internship emphasized the value of learning course content while also providing him additional insights into how engineering work is continuously changing due to available technologies:

> I feel like there is a lot of value in having engineering intuition that is brought about by us taking those classes, like the heat transfers, the mechanics of materials, the solid mechanics, that sort of thing. But I feel like the way the world is going that more and more of that is automated. You plug in the variables. It comes out, and it's great to know, and you have to be able to tell what a good solution is.

This knowledge gave Max the opportunity to review certain engineering principles and skills that were used more frequently by his employer, bridging the gap between academic and on-the-job competencies. His ability to perform in the role of student and employee contributed to his confidence in his future career. Max indicated that, along with academic achievement, his abundance of job prospects qualified him to be an engineer. These interviews highlight the importance of working in the field during college in preparation for an engineering career after graduation. Both Tony and Max described the importance of internship experiences in gaining an understanding of the technical and professional expectations of future employers.

While internships were considered a turning point in the formation of students' engineering identities, they were not the sole contributor. Connie and Gabby had not yet had the opportunity to participate in an internship prior to interviewing for this study, but both described the development of their engineering identities by having additional experiences and motivations from other areas of their academic careers and personal lives. Connie and Gabby's interviews bring an interesting nuance to the findings of this study that although a student has not yet experienced an internship, there is an expectation that they will participate in one in the future. That is, students continue to develop engineering identities as long as they are experiencing – or anticipate experiencing – the developmental norms established by their fields.

Theme 3: Learning Achievements (anchor)

Learning achievements, such as acceptance into an engineering program, passing the Fundamentals of Engineering exam, and graduation also serve as academic milestones along a student's education career. Grade point average, test scores, and course completion then become measures of success in between these significant milestones. Students may each have their own perception of acceptable academic performance and achievements, which may contribute to or hinder engineering professional identity.

Grades are often viewed as the best measure of a student's progress, but perceptions of successful performance vary across students. When asked if grades reflected their potential to be an engineer, each participant explained that grades play only a minor role in their journeys to becoming successful engineers. Every participant commented that one's understanding of course material is much more important than test scores or final grades, as Connie explained:

> …while grades sometimes reflect [how good of an engineer you are], I also feel like a lot of times, they don't. Particularly for me, because I try and focus more on understanding the material than necessarily getting the assignments turned in properly… my grades may not reflect my understanding.

Connie understood the gap between understanding course content and performing well on course exams. This theme was prevalent throughout interviews as all four students agreed that academic performance was separate from course content retention. Tony further commented, "You can find a solution manual, get through a homework assignment, [and] find out just enough to make it through a test. But if you don't remember anything after that, then you haven't really learned anything." This perspective was prominent regardless of participant GPA, with participants describing grades as only a partial reflection of their understanding of course content.

However, this is not to say that participants did not value grades. For Gabby, grades proved to be a significant financial factor in shaping her educational experience. After losing a scholarship due to low grades, Gabby learned the importance of showing proficiency in course content, "And it's just… I've realized that, hey, I need to get better scholarships and be able to like, improve, and understand what's going on. I need to have better grades." Similarly, Tony and Max, two out of the four students interviewed, agreed that the Fundamentals of Engineering Exam (FE), administered by the National Council of Examiners for Engineering and Survey (NCEES), was an integral part of becoming an engineer. Max, who passed the FE prior to being interviewed, shared that his ability to pass the test and graduate with career options "check[ed] all the boxes for people to consider [him] an engineer." Gabby, who had yet to take the FE, also believed passing it to be the final step in reaching a full engineering identity, including being referred to as an engineer by others, "I feel like that FE exam is going to be like the really big thing [be]cause once I take that and I like pass it, then I feel like I'll be able to call myself an engineer." Within this study context, prioritizing one-time licensure exams over iterative course exams may occur because attempting or sitting for the FE was a requirement for graduation at Utah State University (this requirement has since changed). At the same time, there are no grade requirements to sit for the FE, only that you must be within several months of graduation at an approved program, meaning that no matter one's grades in specific engineering classes, one can still viably pass the FE and be considered part of the engineering community.

Together, these comments demonstrate that academic standing and achievement essentially serve as a checkpoint for determining progress toward the end goal of graduating and eventually passing the FE to become an engineer. These successes and events indicate that engineering identity is anchored in achievement but requires more than a checklist of academic accomplishments. Understanding engineering course content and being able to apply that knowledge in other contexts was the main priority for each student interviewed.

Theme 4: Social Connections with Peers (supplement)

Connie did not attribute engineering inspiration or motivation to family members, but rather to her peers. When asked about the most helpful resource for engineering students, she said,

> For me, the most helpful was the classmate[s] because seeing other people's perspectives and also a lot of my classmates had internships already, and so, being able to talk to them like, hey, what is this like? What do you like about it? What do you not like about it? [It] helped give me a little bit of perspective of what to expect and what my future might look like.

While Connie had not yet experienced an internship herself, she leveraged the relationships with her peers to gain a greater understanding of the internship process and any challenges or benefits that she could anticipate from it. Such interactions have been shown to contribute to a sense of belonging among students [4], [15], [16]. Other shared activities and experiences such as doing homework and sharing hobbies with one another outside of class also bolstered the formation of students' engineering identities. Max made several mentions to his peer community throughout his interview. He stated,

> There are times when I'm in the engineering building that I'll just walk up to someone that I see is working on the same assignment that I am. And say, hey I'm stuck here. Have you made it here yet? And we'll talk it over, and the same things happened to me when people have come up and asked me those same questions. And I think it makes for a very positive environment without taking away from the competition that is healthy when it comes to an [engineering] program like this.

Max further emphasized the role that peers play in student persistence through engineering programs by using the example of paying attention in class; when he is having a hard time paying attention, he makes it a point to sit between two friends who can keep him motivated to focus. Tony similarly described the role of his peers as "comforting" because he had a group of friends who were consistently supportive and, in turn, were those whom he could help support. Community members offered acceptance, validation, and encouragement as they pursued their goals as engineers.

Our findings indicate that community connections can play a variety of roles for individual students. Connie, for example, felt that social connections with peers compensated for her lack of internship experience. This shows that a student's engineering identity may be supplemented by social connections when more concrete, binary achievements are out of reach. Individuals may make additional connections to engineering identity when opportunities for widely accepted milestones are not available. As a result, community does not necessarily anchor the formation of one's engineering identity, but rather, continues to supplement and encourage it.

Theme 5: Personal Character Traits (supplement)

Although engineering is a technical field of study and practice, additional attributes may be needed for a student to identify themselves as an engineer. Each student was asked, "from your perspective, what are the traits and skills necessary for being an engineer?" to understand how students combined learned skills and inherent qualities to form an engineering identity. This question also prompted students to describe a specific event or instance in which they considered themselves to have all of the qualities necessary to be considered an engineer.

Tony expressed that engineers must be tenacious, humble, and detail-oriented, "You have to be able to work hard and push through something even when it is frustrating… being able to kind of realize that you don't know everything… I think you have to be very thorough also." Tony described learning about these qualities as he participated in his internship, where he saw firsthand how engineers benefited themselves and their employers by working hard and contributing quality work. He also explained that being willing and able to learn after obtaining a degree would most likely serve engineers well throughout their careers. Understanding the benefits of these qualities in 'real-world' scenarios taught him the importance of developing these traits as an engineer. While Tony admitted he still had not reached engineering status, he felt he was putting effort into and making good progress toward developing the qualities of the engineer he envisioned becoming.

Gabby shared that successful engineers are effective communicators and problem solvers. Despite working in a job outside of the engineering field, Gabby found herself serving many engineers as customers and was able to identify the advantages of communicating and creating connections with other engineers; however, her experiences also revealed negative traits of engineers, "A lot of engineers have really big egos… they're like, 'we're the ones that everyone goes to, we know we have to know everything.'" Gabby strongly believed she wanted to develop an engineering skillset while discouraging any egotistical traits. This juxtaposition enabled her to identify the engineering traits she wanted to adopt and continue to form as well as those that she wanted to distance herself from.

Engineers are often associated with technical knowledge of math, science, and physics, and are not generally considered to be effective communicators. However, all of the attributes of engineers mentioned by participants were related to professional skills and critical thinking, such as effective communication. These findings indicate that the development of such skills and traits often supplement engineering identity, but are not necessarily considered as anchors; in such instances, participants position engineering as an attitude and a way of doing things rather than fulfilling a list of requirements.

Conclusion

This study introduced initiators, anchors, and supplements that contribute to undergraduates' engineering identity development. Each participant shared defining moments and experiences that helped them understand the purpose and perspectives of engineers, and whether they consider themselves to be one. When asked directly if they or others viewed themselves as successful engineers, most students responded with improvements they needed to make to fully identify as an engineer. Most participants had created self-imposed task lists and learning and experience milestones to complete before they could consider themselves a true engineer. Yet, when asked about other identifying characteristics of engineers, participants talked about supplementary connections and experiences that further defined them as engineers.

The findings from this study lead us to believe that students move through a set of learning and experience milestones throughout their academic career, initiated and supplemented by social connections. As students find themselves going in a different direction than originally planned, they compensate for a lack of experience in one area with additional experience or interpersonal connections in another. Students' perceptions of success stemmed from a culmination of experiences and connections that are valued by them as individuals. While many students followed a prescribed timeline of learning and experiential milestones, success was also found in more unique paths defined by social and personal development.

In future work, we aim to further understand the gap between identifying as an engineer via experiences and achievement and identifying as an engineer via inherent ability, thought, and social grouping. Moving forward, a larger sample of student participants from multiple universities would be helpful in understanding more about engineering identity development as an achievement-based and social phenomenon.

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