The Role of Engineering Identity in Engineering Doctoral Students' Experiences

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The Role of Engineering Identity in Doctoral-Level Engineering Students' Experiences

Introduction

This research paper explores the role of engineering identity in graduate student success. Identity and belonging have been consistently linked to student success and retention in engineering, but the majority of studies focus on undergraduate students [1–3]. Graduate school presents unique challenges to students' development of engineering identities and is both a key element of the STEM pipeline and a point at which many students leave academia [4]. To improve retention among engineering doctoral students (EDS), this paper explores how students develop and modify their engineering identities throughout their studies. This is accomplished through analysis of regular practices and cultural definitions and an exploration of how these factors impact performance and retention.

Theoretical Foundations

We used two theories to interpret identity among graduate level engineers, *social identity theory* and *identity theory* (sometimes called *role identity theory*). Identity is used to refer to the ways that students view themselves as being recognized by others. These similarly named frameworks both grapple with issues of identity but take different approaches and operate at different levels of analysis. *Social identity theory* is often used in social psychology and focuses primarily on group processes and relationships, as well as their impact on the social self. This framework proposes that social categories, such as race, nationality, or gender, are manifested in prototypes that, when activated, help individuals affirm their membership within an in-group and categorize others into out-groups. Categorization plays a strong role in social identity theory, as does depersonalization (the act of identifying more with a group than as an individual), both of which work to clarify group boundaries and provide (or erode) belonging[5].

Identity theory also has a strong social component, but arises from the sociological literature rather than social psychology. It is primarily used to predict individual behavior as influenced by social roles and self-schemas that are defined through interpersonal interaction. For instance, the role 'engineer' has no clear definition on its own; it acquires meaning only when performed in context and alongside other roles, such as *scientist, programmer,* or *student.* This means that roles are not only defined socially, but through an individual's daily activities and interactions. Identity theory also emphasizes a hierarchy of roles, proposing that the self is not only dialogical and multi-faceted, but that some roles (and the correct performance thereof) are valued more than others (often tied to ideas of *salience* and *commitment*)[6].

Key differences between the two theories include the levels at which their explanatory power is strongest. Social identity theory is often used to examine prejudice and discrimination, exploring

the ways that culturally-defined constructs influence intergroup behavior. Role identity theory is often used to explore how individuals define themselves in their daily lives, and how their self-perceived adequacy is influenced by their interpersonal interactions. It is possible to define social identity theory as operating in a 'top-down' fashion, in which social constructs are imposed on individuals, and role identity theory as operating in a 'bottom-up' fashion, in which individuals construct their identity through experiences.

The two theories are not always well-reconciled, and so there is some overlap and divide within the literature. For instance, social identity theory often speaks about the influence of constructs like race, socioeconomic status, gender, or other broadly defined social characteristics. Identity theory also discusses these constructs, but refers to them as *master statuses,* and disagrees as to their handling and their importance[7, 8]. However, there is a space for the two theories to work together, particularly when it comes to studying identities that are defined socially and performed daily, e.g., engineering.

For this paper, we use these theories to clarify differences between the two types of engineer identity and address the ways that cultural definitions of engineering impact students in the daily performance of their identities. This approach is anchored in existing work that explores the impact of social identities on student success, as seen in studies of belonging among undergraduate students[9, 10]. While we agree that social identity is still important to success in graduate programs, we also theorize that engineering doctoral students (EDS) are called upon to enact their engineer identities in new ways (consistent with role identity theory) that uniquely influence their performance. Consistent with this theory, we explore how they use the feedback they receive from their interpersonal environments to assess their role performance and their in-group belonging.

Current Project and Paper

As mentioned previously, the current paper is exploring EDS' engineer identities. This article is one part of a larger project that is divided into stages. The first is a qualitative examination of students' experiences, grounded in the identity theories listed here, as well as future time perspective[11] and identity-based motivation[12]. The second stage will require the development of a quantitative survey instrument that will be used with a representative national population of EDS. The third stage will involve detailed analysis of the results as well as follow-up interviews and analysis. This paper draws from early results of the first stage of the project, in which Interpretive Phenomenological Analysis (IPA)[13] was used to examine participants' statements and then generate connections (superordinate themes) between individuals. In the course of this analysis, the themes of secure and transitional identities have emerged, which are combined and described together here. The current results are interpreted in light of the theories detailed above, as well as their potential applications in graduate level programmatic decisions.

Methods

Participants **–** An initial pool of doctoral-level participants (*n* = 46) from two large land grant institutions (one in the Southeast and one in the West) were randomly assigned to four separate interview conditions. The final sample for this paper (*n* = 8) was made up of participants from both institutions (see Table 1 for an overview of the sample's demographics). It was reasonably diverse, with 50% of the participants identifying as female, 50% indicating international status, and a variety of racial/ethnic backgrounds reported: Asian (37.5%), Black (12.5%), North African/Southeast Asian (25%), and White (25%). Three of the participants were interviewed alone, and the remaining five were interviewed in a focus-group setting. All participants were assigned pseudonyms for use in transcripts and in this paper.

Interviews & Focus Groups – We created four protocols, each focusing on either a theoretical perspective (future time perspective, identity-based motivation, and engineering identity) or on a broader informational target (general experiences of engineering doctoral students). For the purposes of this paper, we focused on the interviews that use the Engineering Identity protocol (see Appendix A for the full protocol). These questions were developed from earlier research that explored undergraduates' engineering identities, based around three constructs of interest, recognition, and performance/competence[14]. A semi-structured protocol was utilized so that researchers could explore themes and topics unique to participants' graduate experiences as they emerged.

Four participants were recruited via email and offered a $25 electronic gift card in exchange for participation in solo interviews; five participants were also contacted for participation in a focus group for similar compensation. Solo interviews and focus groups were used in order to derive insights from both one-on-one and group conversations, as different environments provoke different discussions and interactions. One participant was dropped from analyses due to a data copying error resulting in the loss of his data. Interviews were conducted in isolated, on-campus rooms set apart from students' usual lab spaces. Participants were reminded that their information was protected and would be kept anonymous, that they could withdraw their consent to participate at any time, and in the case of focus group participants, they were reminded to maintain one another's confidentiality. All protocols and procedures were IRB approved.

Interpretive Phenomenological Analysis – The tenets of an IPA approach were used to analyze the transcribed data collected from the focus groups and interviews[13]. In a typical IPA, the sample size ranges from three to six homogeneous participants for each analyst. Two analysts worked with the Engineering Identity participants' data; one primary analyst (the lead author), who conducted the bulk of the qualitative analysis and cultivated a deep familiarity with the participants and the subject matter, and one secondary analyst who provided feedback and checked for comprehensiveness, clarity, and cohesion.

For the solo interviews, the procedures laid out by Smith, Flowers, and Larkin[13] were utilized, focusing on an iterative process in which data were analyzed descriptively, linguistically, and then interpretatively (described in more detail below). This enables both close, unbiased analysis of participants' statements, as well as wider connections to the existing literature. The use of IPA as a method of analysis for focus groups is still emerging, although there have been some papers published using this approach[15, 16]. Tomkins and Eatough[17] discuss strategies for use of IPA in focus group settings, highlighting the need for a sensitive approach that acknowledges the differences of group-based interactions. Themes from both individual and group interviews are reported in this paper.

Positioning and methodological rigor – A key aspect of all qualitative research is the analyst's role as researcher and research tool, as their understanding and interpretation are central to the project's success. To clarify those roles and enact boundaries, IPA calls for a reflective dialogue between analyst and participant[13]. Throughout the process of analysis, the researcher 'brackets' their existing views and theories into a separate strand of analysis, acknowledging but carefully demarcating them from participants' statements. In later stages of the analysis, these personalized reflections are referred back to and expanded upon interpretively[18]. This allows the researcher to inform their analysis with references to existing theory and literature systematically and transparently, preventing bias.

Analysis for this paper was conducted in four steps, as per recommendations from Smith and colleagues[13]. The first step involved careful reading and listening of interview transcripts and audio recordings to develop a clear sense of participants' words and voices. Individual interviews were reviewed three to five times before analysis began, as researchers familiarized themselves with the speaker and the text as a whole. The second step required researchers to make detailed descriptive, linguistic, and conceptual notes throughout the interview. Descriptive notes focused on clarifying understanding of the participants' statements, a way for researchers to review and revise their assumptions about what participants were trying to communicate at every stage throughout the interview. For instance, the following statement from the participant Xena had several descriptive notes attached to it:

> *"I think conservation and environmentalism has always been important in my life. It's still engineering [laugh], so it wasn't too far from where I started. I thought also having worked mechanical engineering and in manufacturing, I have a different perspective than people going in from chemistry or something like that." - Xena*

In this quote, Xena described her current research topic and her past experiences in engineering. However, she also described her understanding of others' perspectives, and she compared herself to this imagined other. She also communicated messages about her values -- her lifelong appreciation for conservation and environmentalism, and her desire to be consistently involved

in engineering and to provide new perspectives -- that are not as overtly stated, but still important aspects of her statement.

Linguistic commentary involved reflecting on word choices and patterns in speech and tone. Smith and colleagues[13] provide a list of linguistic elements that researchers can focus on, such as "pronoun use, pauses, laughter, functional aspects of language, repetition, tone, degree of fluency … [and] metaphor" (p. 88). This level of annotation adds richness to the analyst's interpretation of participants' meanings. For instance, in the above quote, Xena laughed after commenting that "it's still engineering", which provides some potential insight into her feelings, although determining the nature that insight requires further analysis. This leads to the final stage, conceptual comments, in which the analyst becomes most involved as an individual in the process of analysis and interpretation. For instance, when viewing the above quote in the context of Xena's statements throughout the interview and her recent experiences, her laughter can be interpreted as rueful and wry. The statement emphasized her long-term engagement with engineering and her continued identification with the role, while also acknowledging the view that her current research is not considered 'real' engineering when compared to more traditional and stereotypical fields. This ties into the literature around women's involvement in engineering and how it is often seen as illegitimate due to an interpersonal or applied focus[19, 20].

The third step of the analysis requires the careful review of comments and codes for each individual interview as well as notes and observations regarding the emergence of categories and themes. For instance, the quotes from Xena's interview above were included in categories such as 'industry experience', 'values', 'multidisciplinary research', 'applied work', 'engineering definition', and 'peers'. Themes emerged across categories, such as themes of feeling isolated, social and cultural definitions of engineering, and the importance of significant and meaningful work. The fourth and final step is very similar to the third; however, it calls for these comparisons and connections to be made across individuals and is often referred to as the identification of 'superordinate themes'. It is this level of thematic analysis that is presented in this paper, focusing on discussions that appear in the interviews of multiple participants and are supported by existing literature.

Results and Discussion

This paper will focus on the superordinate theme of 'Permanent and Transitional Identities', which focuses on students' identities as engineers. The characteristics of these two groups' engineer identities can be summarized thusly:

(1) Transitional: students with conflicting self-concepts view their identities in graduate school as temporary and transitional, delaying their full engagement with the engineer role and identity until the conflict is reconciled. In other words, they have strong 'role' engineer identities but weak 'social' engineer identities. Although their present identity is

oriented towards engineering, they often report that they did not feel like an engineer in the past, or that they may not consider themselves an engineer in the future. They do not view themselves holistically – instead, they report feeling as if they are existing only partially in various spaces.

(2) Permanent: students who are able to reconcile disparate aspects of their self-concept identify strongly and permanently as engineers and show indications of higher performance and greater persistence. Like the previous group, these participants also have strong 'role' engineer identities, but unlike the previous group, they also have strong 'social' engineer identities. Their past, present, and future identities are all oriented toward engineering; even when reflecting on identities that occur outside the engineering sphere (e.g., sister, daughter, English-language learner), they are able to draw connections to engineering and take a gestalt view of themselves as larger than the sum of their parts.

Interviewees who were most positive about their progress and place in their program were those who discussed their engineering identity holistically and permanently – that is, their understanding of their 'engineer' identity was linked to their understanding of themselves as individuals, citizens, and members of their communities. This discursive process of negotiation and unification is not novel: it has been observed in previous work in undergraduate classrooms, where integrating social identities and engineering work was found to promote student success[21]. However, these processes are rarely observed and described as they occur in graduate settings. Ultimately, the extension of these findings to graduate students highlights the ongoing importance of shaping engineering culture to be an inclusive, diverse, and welcoming space.

Permanent and Transitional Identities – The interviewed students identified as engineers to varying degrees. Sean, an international student from Iraq, was an example of a student with a permanent engineer identity. He displayed a great deal of confidence in his engineering skills, and was eager and excited about his research and teaching. He had transferred from a Master's program in Iran to a doctoral program in America and was under great pressure to develop his mastery of the English language as he earned his Ph.D. in engineering. Ultimately, he spent more time discussing his struggles with language than he did discussing his struggles with advanced engineering and mathematical concepts. He said:

> *"I don't feel so confident about my English right now. About my knowledge I feel completely confident. I know that my knowledge is done [chuckle], but about my English, because I'm in a new place, and new people…. It's pretty hard, but I'm getting used to it." - Sean*

Sean's struggle with language could have caused him to disengage from his program, but it did not. Instead, Sean drew upon his experience of learning a new language and culture to clarify and describe his identity as an engineering doctoral student (EDS). In the following quote, he drew

on the double meanings of words to explain why he valued a scientific approach to engineering, a view that he felt set him apart from his peers:

> *"In your language, for example, you say a student for the high school, and you say a student for those guys in college, and for the grad student, right, but we don't use the same word. For example, we say ... science learner for the high school, before high school. You just learn the science. For the student in college and university, we use ... science seeker. You've got to seek science."* - Sean

Sean also viewed teaching as an essential part of being an engineer, after being inspired by his father, who taught physics. *"When I was a kid my father took me to the physics lab.... When you're a kid it ha[s] a great influence on you, because ... your dad just looked like an Einstein."* For Sean, being a good son was tied up in being a good teacher and a good engineer, as success in one indicates success in the others. He also drew on his experiences and identity as a non-native speaker when talking about his work teaching engineering, as demonstrated in the following quote:

> *"One of my students asked me, 'Oh my god. I got a minus work, a negative work.' ... Don't feel bad about the negative work.... This negative means that this is work out of your system, not into your system. For example, the pump work, and the rankine cycle is positive, because you did that work into your system. That [other] work is negative because it's out of your system."* - Sean

These quotes illustrated that Sean's identity as a student of the English language was not segregated from his identity as an engineer nor his identity as a son; instead, he used the insight provided by all of his experiences to inform and enrich his engineering identity. Although learning English was a challenge, he drew on that experience to make himself a better teacher and to improve his understanding of his engineer identity. Ultimately, success as a teacher and as an engineer let him live up to his father's example, a goal he imprinted on early in life. Thus, he is an example of a secure engineering identity -- both his belonging to the engineer in-group (i.e., socially-determined definitions of engineering) and the daily performance of his role (his lived experiences as an international student and language learner) cement his identity as an engineer.

Sean's experience was positive, but that was not the case for all participants. Xena was a domestic student who transferred to her current program after completing her Master's, following her advisor as he moved to a new position at their current institution. Xena also changed her field from mechanical engineering (as an undergraduate) to environmental engineering (as a graduate student) and became increasingly multidisciplinary as she focused on her research in water infrastructure and allocations. In this paper, Xena exemplifies the student with a transitional engineer identity -- she was not fully rooted in her role or work, and experienced detachment and ambivalence as a result. As quoted below, she talked about the

challenge in learning advanced concepts from another field and integrating them into her engineering work:

> *"Right now I'm trying to learn some economic models. Because economists have a lot of very sophisticated tools that they use, it's way over my head and I'm trying to understand.... The math doesn't seem too complicated, that's true, but it's more so understanding.... It's very different than what most engineers maybe even think about." - Xena*

This transition into specialization led her to push the boundaries of what it meant to be an engineer, an act that created distance between herself and her peers and required additional effort to maintain connections within engineering while making new ones outside it. Unlike Sean, Xena did not derive positive meaning from these experiences; instead, she experienced uncertainty, isolation, a consistent sense of being underprepared, and the belief that she not functioning successfully as an engineer:

> *"My advisor is not really knowledgeable about [research topic], it's just, yeah, I have a lot of control over what direction it goes in.... It's a little terrifying. Especially because I would hopefully get involved with some students from outside of engineering, because I don't know that much about economics, even though I'm taking the class.... It would be easier for me if I had someone else right now from economics." - Xena*

> *"I am definitely, I feel pretty behind in terms of planning out my academic [career].... I have my transfer credits, they haven't all been aligned or something like that. The other negative is that I'm going to have to take the qualifying exam here…. Different teachers, different textbooks, different emphasis. I'm pretty worried about that….I usually rely on students to tell me about [opportunities], and I don't know too many people here…. I haven't done much preparing, honestly. I don't have a very clear plan." - Xena*

The number of hurdles she faced were intimidating, and as she had little guidance or information about where to start, she delayed beginning. At the same time, she alternately castigated herself for her procrastination or disengaged from her responsibilities: *"I should probably reach out to one of the other professors to get a better idea, maybe. I have and I'm not super concerned with it, obviously. 'I'll do it when you tell me to do it.' I don't know."*

On this note, one of Xena's most frequently uttered statements was the phrase 'I don't know', which she used in versatile ways. Sometimes it was a straightforward statement about a lack of knowledge, whereas other times its use, alongside other minimizing phrases, reflected a deeper

lack of confidence. For instance, Xena made a statement about her academic reading, where she used the phrase 'I don't know' to demonstrate her indecision and discomfort:

> *"I read journals and I read like, WEF, the big conference, they have monthly publication that they put out, so I read their news and then I just follow some other random news stories, I don't know. I don't really page through, like the major publication journals. Maybe I should, I don't know." - Xena*

This discomfort and uncertainty was a common theme throughout Xena's interview, and reflected her lack of belonging with the socially defined identity of engineer. This lack of social belonging manifested as daily, lived experiences of physical distance and isolation, as seen in Xena's statement about her lab:

> *"I don't have classes with other engineering students, really? Our lab, our workspace, for me and Lisa [her labmate], it's separate from most the rest of them. Just in my little corner working…. You feel so isolated, everyone's in their little spaces, and when you're there all day, you can feel really claustrophobic." - Xena*

The distance between Xena and her peers was not merely an artifact of the physical space she was working in, but also of the constraints imposed by shared definitions of what engineers do. When asked what would help her feel that she belongs more in her program, she answered, *"If I could work in the lab for some of my research, that would probably take me away from my computer and take me away from my little isolated environment [laugh]."* However, she did not see that it was likely this would happen: *"It's hard to imagine how. Only if I help someone else out with their stuff, not for my own projects, it's all modeling."* The incongruence between her work and that of other engineers is what produced her isolation and alienation, although she attributed it to the environment or her own choices. Within the literature, similar experiences are often referred to as 'identity interference', e.g. when the performance of one identity (water infrastructure researcher) interferes with the performance of another (engineer). Like the individuals in these studies, Xena's inability to unify her activities and experiences beneath a single, permanent identity is reflected in her poor performance and low belonging[22, 23].

As detailed above, Sean's work learning a second language was utilized to strengthen his identification as an engineer. He relied upon his language experiences to inform his socially defined identity of engineer (as seen in the discussion about being a science seeker) and integrated them into the teaching and performance of his engineer role (as seen when he used the double meanings of words to communicate concepts to a student). While Sean's experiences were utilized to strengthen his engineering identity, Xena's experiences weakened hers. Like Sean, she was learning a new skill (economics rather than English) but unlike Sean, this skill caused her to view herself as part of the out-group (unlike other engineers) instead of the in-

group (like other engineers). This is a prime demonstration of the differences between students with permanent engineer identities and transitional engineer identities.

Ned, an international student from China, also experienced difficulty after switching majors to study in the U.S., and also fits within the transitional identity category. His transfer required him to 'start over' in many ways, invalidating his previous engineering identity as established by his academic and professional accomplishments. In his own words:

> *"I transferred my major so I'm a baby in my field now [laughing]. I think in the future I can make some achievements. Now I have no published paper in my project, in my field…. I have to keep going. I have to." - Ned*

With this statement, Ned framed the identity of an 'engineering doctoral student' as something to be gotten through on the way to the amorphous 'true engineer' identity available after degree completion. This gap provided Ned the freedom to practice the behaviors of an engineer in a relatively safe space, but also resulted in delayed collaboration and networking opportunities. When asked if he would like to work with the people he meets at conferences, Ned said yes, but only later:

> *"Oh, yes…. I think it's not easy. Maybe after I graduate, maybe they can help me in my job…. I think, maybe I'm working on my PhD I don't have so much time. I have to focus on my own project and my advisor also need some success, so I have to work harder." - Ned*

Like Xena, Ned took personal responsibility for his lack of identification as an engineer. While Xena acknowledged the barriers that resulted in her disidentification, such as her difficulty in bridging disciplines and her office space, Ned approached it as a personal failing that should be resolved by working harder. Ned also reported experiencing a great deal of isolation and loneliness, and consistent with the literature around international students, many of his social connections were focused around engineering[24]:

> *"Outside of school activity, not so much. Maybe play computer game and go out with my friends…. Not so much, I think…. I just come here and I don't have a car. I have no place to play, I just stay in the university and work on my project…. Sometime it's boring to stay in university all time." - Ned*

Unlike Sean, Ned's connection to engineering did not have positive consequences for his family roles and identities. He did not discuss his family of origin as much as he talked about his wife and their newborn daughter, who was just four months old. When asked about what it meant to be a doctoral student, his response was immediate and uncharacteristically negative:

"[It means] I will have done my PhD and my wife didn't apply for visa after I applied for my PhD, so I was later homesick. It's not easy to stay here alone and we can't see each other, and my child. Yeah. This is a big problem." - Ned

All of this contributed to Ned's delayed identification as an engineer. When asked if he is recognized as an engineer, Ned says that he used to be, but when pressed about his current identification, he deflected the question with humor:

"You know, my major, when I was working on my Bachelor degree, was civil engineering, so I was recognized as engineer. Definitely. Now…. As an engineer.... I belong to college of engineering, so I think I'm an engineer. Both my parents and my peers, they don't know so much about my major. They don't know much about pavement and transportation, so definitely I'm an engineer [laughing]." - Ned

Although Ned was laughing when he made this comment, it reflected the theme established throughout his interview: being an engineering doctoral student meant being socially isolated and poorly understood. This highlighted a central difference between permanently-identified (Sean) and transitionally-identified (Xena and Ned) students: connectedness. The ability to connect seemingly disparate identities to each other (as in Sean's example) and to connect and communicate with other engineers (or not, for Xena and Ned), is key to the ability to identify as an engineer. This finding is supported within the literature: previous studies indicate that narratives constructed from individual experiences are important sources of identity, and that professional connections are important sources of recognition and identity reinforcement[1, 25]. This interpersonal back-and-forth is the process by which socially-determined definitions of engineering are modified to fit students' diverse topics and goals. Without that communication, students are left to conclude that their work doesn't 'fit' as engineering and that they aren't true engineers.

Grant, a domestic student near the end of his doctoral degree, echoed the significance of this theme when discussing what it was like to witness such struggles from the outside. Although he reported experiencing a strong sense of belonging, he acknowledged that some students did not, and he was sensitive to how it left others feeling aimless and disconnected:

"One of the biggest factors for the people … that felt like they couldn't [finish] was basically the ones with the least communicative professors. [They] have been the ones that usually have that feeling of, 'I'm never going to finish'." - Grant

For these students, Grant said, their stalled student progress eclipsed interest, motivation, and ability to continue in the program. Eventually, Grant said, "some of them just had to transfer out ... or the funding of the department runs out and they just have to start applying to jobs." Grant

linked their uncertain identities to depressed belonging as an engineer and to worsened academic performance and mental health. As Grant said:

> *"I think it makes people feel isolated…. Especially if you moved here from somewhere else, like some students in our department are also from China, come all the way over here [and] have no support system. I think it's pretty crucial to the mental health of grad students to have that…. Which is something I wish the university and departments themselves had spent more resources on … I think it's a bigger problem than the university recognizes." - Grant*

Angel, another domestic student near completion of her degree, agreed with Grant and echoed the connection between progress, belonging, and marginalized identities: "I think that's what makes people drop out, the sense of belonging. I'm one of the two Black women in [my department].... I feel like my identity has changed." Angel was a successful student, but described struggling with belonging and representation in the past for multiple reasons – first, as a Black woman in a predominantly White and male field, second, as a former student athlete who saw her social networks evaporate as she graduated and became ineligible, and third, as an undergraduate who continued in the same program as doctoral student. As she said:

> *"I'm here, same building, different friends … track was my community and I don't have any of that. That was a really interesting transition for me.... I don't feel like being here as much…. I think I get less work done sometimes…. [You] never really realize something is a part of you until it's gone." - Angel*

However, like Sean, Angel was able to view her struggles positively and integrate them with her engineering identity. Much of her research came to focus on women in computing, in which she explored what caused women and other marginalized groups to pursue careers in programming and software engineering. She described how she derived personal and professional meaning from her research:

> *"I think it's a[n] interesting blend of, what you said, personal and research stuff…. I like to do outreach activities…. It's fulfilling and it makes me excited about, okay, I'm here to do research, and I'm going to encourage the next wave of people to do the same." - Angel*

As a result of this integration, Angel reported strong, permanent identification as an engineer, in spite of multiple sources of social pressure to do otherwise: "I do see myself as an engineer…. A lot of people in computer science have this interesting debate whether or not they're engineers or not, [but]…. I myself consider myself an engineer." Ultimately, she discussed how she challenged and refined her understanding of engineering to incorporate the work that she did, and with support and understanding from her advisor and peers, she put-forth a definition of

engineering that included her work and lived experiences while also fitting the socially-determined definition of what an engineer 'did'. Once again, this taps into the idea of connectedness that Sean was able to muster, to his benefit, and that Xena and Ned have not tapped into. This suggests that the success these EDS have experienced is not due exclusively to their coursework or research activities, but their ability to fully engage with all aspects of their identity and feel connected, as an engineer, to their own past, present, and future – a finding supported by previous studies that highlight the importance of integrated identities and discursive practices in engineering environments[21, 22].

Conclusion

Engineering graduate students face a number of challenges including transferring to new spaces, learning and working in new spoken and disciplinary languages, and shaping new research topics that challenge the boundaries of existing engineering definitions. The types of transitions that students experience do not reliably predict their belonging or success in their program; instead, it is the ability to build connections and to integrate disparate or contradictory elements of the self into a holistic, stable whole that does this. Consistent with social identity theory and role identity theory, this integration requires positive interpersonal relationships and feedback about daily performance of engineer roles (e.g., messages from valued others that one is attaining the desired milestones and doing the required work successfully) and fit between individualized and social/cultural definitions of engineering (e.g., the work done or topics studied are recognized widely as being engineering, and the individual as a member of the in-group). For students who are unable to make those connections and reconcile potentially negative experiences, they remain in a state of transition, searching for a solution to their depressed feelings of belonging or, ultimately, leave the program entirely. Students who successfully navigate their way to a secure engineer identity, however, are able engage positively in their programs and redefine engineering to be more innovative and inclusive, thereby driving the field forward.

Implications for Understanding and Practice – The findings reported here support the need for identity support in engineering Ph.D. programs. This includes the acknowledgement of students' diverse backgrounds and approaches, but more than that, it emphasizes the need for active reconstruction and processing of what 'engineer identity' means, both at the individual level (as manifested in students' work) and at the social level (as manifested in belonging). The students who struggle the most with their engineer identity do so because they experience identity interference in which their multiple identities and roles are discrepant and at-odds with one another. However, as demonstrated by Angel and Sean, it is possible to rework these incompatible identities into a holistic whole. Although McAlpine's identity-trajectory work was not utilized as a foundational theory, this conclusion closely mirrors its findings[26]. This suggests that longitudinal work drawing from an identity-trajectory approach might help untangle some of the processes underlying students ability to integrate – or not – their disparate parts into a permanent engineer identity.

Future Studies and Applications

The primary limitation of this work is the small sample size and heterogeneity of the sample. IPA, as an approach, generally recommends small samples that are homogenous, and while all of the participants in this study are similar in their status as engineering doctoral students, they differ on other characteristics. It's impossible to rule out other, potential confounding factors at this stage, and these themes should be explored in more depth through qualitative and quantitative projects. Additionally, although the conclusions reached here are supported by the literature, further study should be done to confirm the specific significance of secure and integrated identities among EDS and career engineers. This work will be most immediately applied to the ongoing study of EDS identity and motivation profiles in a national survey of graduate student engineers. However, it can also be used by advisors, faculty, and administrators who work with EDS to identify struggles and strengthen student identification and performance in engineering. As seen in the comments from Ned and Grant, international students are often isolated, and their performance and mental health suffer. Angel and Sean provide examples of how students with unique or diverse experiences can be helped to thrive. Xena's negative experiences highlight the importance of clearly articulated maps of student progression so that they have concrete measures with which to assess themselves. Overall, the strongest conclusion from these findings is the importance of identity and the realization of engineers as individuals with widely varying interests, experiences, and background. It may be that this will challenge many traditional perspectives and approaches in the field, but the evidence suggests that the benefits are worth it.

Acknowledgements

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Appendix A
Engineering Identity Interview Protocol

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Proposal Research Questions
- What are the identity and motivation profiles of engineering doctoral students which are based on previous academic and research experiences in STEM?
- How does STEM community influence identity formation and motivational goal setting processes of engineering doctoral students?
- How do these processes related to identity formation and motivation influence engineering graduate student retention, productivity, and pursuit of doctoral level engineering careers?

Focusing on Engineering Identity

Competence and Performance
1. Do you feel like you can finish your degree?
2. Do you feel like you can contribute to conversations in your field? Do you feel like you can understand the concepts inside and outside of the conversations?

Interest
3. What types of academic activities do you enjoy participating in?
   a. Do you find fulfillment in the activities you participate in? (program and academics)
4. What types of activities do you participate in outside of academic activities?
5. Are you interested in learning more about your field?
   a. Do you enjoy learning about your field?
   b. Do you find fulfillment in learning about your field?

Recognition and Belongingness
6. Do you feel like you belong in your graduate program? Why or why not?
   a. What experiences make you feel like you belong?
   b. Is there anything that would help you feel like you belong more?
7. Are you recognized as an engineer by your peers? family? others?
8. What causes them to recognize you this way?

Table 1

Demographics of Study Participants

Name	Program of Study	Race/Ethnicity	Nationality	Gender
Ned	Transportation Engineering	Chinese	China	Male
Sean	Mechanical Engineering	Persian	Iran	Male
Xena	Environmental Engineering	N/A	U.S.	Female
Angel	Software Engineering	Black	U.S.	Female
Grant	Biological and Agricultural Engineering	White	U.S.	Male
Marina	Industrial Engineering	Asian	China	Female
Miles	Industrial Engineering	Asian	India	Male
Zoey	Industrial Engineering	Asian	China	Female