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# Developing Engineering Identity in an Introductory Engineering Course: A Multi-Case Analysis

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**Abstract:** Research in engineering education has identified several factors relevant to the development of students' identity as engineers. Here we examine the engineering identity of undergraduate engineering students after an introductory engineering course. The specific research question explored here is: "How do engineering students in an introductory engineering course interpret competence, performance, and recognition in relation to their identities as engineers?" We used a modified engineering identity framework to explore the development of engineering identity within the undergraduate engineering context through a multiple case study approach. Six students majoring in engineering participated in the study. The students had divergent perspectives on what it meant to be competent as an engineer. In all cases, students connected both competence and performance as an engineer with persistence. At this introductory stage, self-recognition as an engineering person took center stage for each student. All were able to identify themselves strongly as an engineering person. The findings add to the current understandings about the development of engineering identity, and suggest that engineering identity may be critically important in conversations about the steps faculty may take in working with students to promote increased retention of undergraduate students in engineering.

**Keywords**: *Engineering Identity; Multi-case study; Undergraduate.*

## Introduction

STEM fields are historically known for their support of a meritocracy and for grading practices based primarily on high-stakes multiple choice assessments (Blickenstaff, 2005; Seymour & Hewitt, 1997; Tonso, 2014), reflecting a traditionalist view of education. Seymour and Hewitt (1997) described the competitive nature of this context: students are expected to sink or swim while navigating courses designed to "weed out" students. This context makes a sense of belonging challenging for students who do not fit in with the dominant norms and values (Carlone & Johnson, 2007) or whose ways of thinking may differ. Meanwhile, students in engineering majors have a high attrition and engineering remains a STEM field still unable to achieve gender parity (Bastalich et al., 2007; National Center for Science and Engineering Statistics, 2021). Although high academic standards are often blamed for this high attrition in the engineering major, the culture and tradition found within engineering classrooms may be a significant factor (Seymour & Hewitt, 1997; Tonso, 2014). Recent research in engineering education has suggested the importance of examining constructs, such as students' sense of identity to better understand how the culture of engineering education influences student outcomes.

Research has demonstrated that identification of oneself as an engineer, or not, has an impact on the persistence of an individual in the field – whether as a professional or as a student (Patrick et al., 2018;

Pierrakos et al., 2009; Seymour & Hewitt, 1997; Tonso, 2006). Thus, the formation of an engineering identity is critical for retention. The impact of engineering contexts on students' engineering identities has become recognized on a larger scale in recent decades, and a body of research has grown in attempts to understand what professional identity means for engineering students, how it forms, and to develop measures for studying the construct in this particular context.

In this study, we explore students' engineering identity after an introductory engineering course (a 200-level Statics course). Part of a larger study (Gray et al., 2017; Tuchscherer et al., 2017), this exploration includes descriptions of cases, as well as comparisons between cases, to explore frequent themes that may transcend each individual case and provide the additional perspective of cross-commonalities. This research is informed by the following research question: *How do engineering students in an introductory engineering course interpret competence, performance, and recognition in relation to their identities as engineers?*

## Literature Review

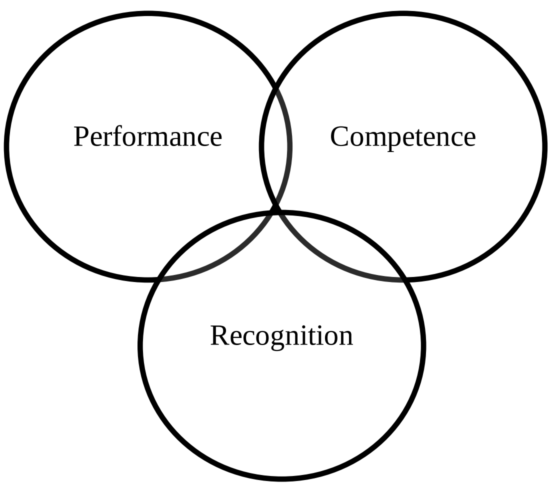
Here we make the case for exploring first year students' engineering identity. First, we discuss the current understandings about science and engineering identity (see Gray et al., 2018 for a review). We include science identity as it is foundational to recent work in engineering identity. We then move to the engineering context and outline the current understandings about the influence of the context on students as they move through the pre-professional program, and demonstrate a need for further identity study within the engineering context. Finally, we provide a framework for this study.

Early work on identity resulted in two distinct views of the construct. A psychological orientation to identity saw it as something that was stable and consistent (Freud, 1961; Kuhn & McPartland, 1954) while a sociological orientation described identity as dynamic and situated (Erikson, 1968; Goffman, 1963). Building on these early ideas, more contemporary views of identity have led to the conclusion that an individual's identity is dynamic and may have many facets that are relevant in different situations (Beauchamp & Thomas, 2009; Gee, 2000; Stryker & Burke, 2000; Tajfel & Turner, 1986; Wenger, 1998). These views of identity as multi-faceted and dynamic informed the understanding of science and engineering identity.

### Science Identity

Science as a profession offers a unique lens for viewing identity, as it is a context that comes with a distinctive set of historical norms, values, and beliefs. The historical culture of science includes an emphasis on meritocracy (Blickenstaff, 2005; Seymour & Hewitt, 1997), and science departments at the university level, which serve to train pre-professionals in the science content, reflect this culture. Carlone and Johnson (2007) pointed out that the existing literature offers little explanation for how students experience and succeed in the context of scientific disciplines, and they proposed identity as an analytic lens for exploring these issues. They drew on previous literature around identity role theory (e.g., Stets & Burke, 2000) to create a model for exploring identity development in the sciences. The Carlone and Johnson framework comprises three dimensions – competence, performance, and recognition – that interconnect to form a professional identity. Figure 1 provides a visual model of how these dimensions interconnect. Competence involves the individual's knowledge and understanding of science content and the ability to apply this knowledge to scientific contexts. Performance is the way that an individual makes visible their knowledge of scientific practices; a social context that includes an audience is necessary for performance. Recognition involves the acknowledgement from the self, and others, that an individual is a "science person" (p. 1191); this often occurs through the performance of knowledge and skills in a social context. These dimensions, together, influence a person's professional identity.

**Figure 1**




*Carlone & Johnson (2007) identity model*

The dimensions of this model overlap in significant ways, emphasizing the interconnected nature of identity, and all three are required for high levels of science identity. The Carlone and Johnson model offers an important analytic tool that accounts for the interconnected dimensions and contextual influences that comprise an identity.

**Engineering Identity**

A body of research has grown in attempts to understand what professional identity means for engineering students, and to develop quantitative measures for studying the construct in this context (Meyers et al., 2012; Godwin & Lee 2017; Jones et al., 2014; Patrick et al., 2018). These quantitative measures have been used to look at factors that influence the development of an engineering identity with large groups of students. While these large-scale studies have offered valuable insights into which factors influence engineering identity development, more research is needed to examine the influence of these factors in more depth.

A recent study of engineering identity based partly in Carlone and Johnson's model involved a subject-related role identity framework. This framework posited that individuals attach meanings to social and cultural roles, and that "an individual has as many selves or identities as he or she has groups of people with which he or she interacts" (Godwin, 2016, p. 2). Engineering students negotiate the various roles (identities) that they play within the different contexts of their lives; some of these roles may add or detract from their ability to identify as engineers. Godwin's first study in this area (2016) focused on the development of an instrument to measure the engineering identity of introductory-level undergraduates. These measures were used in several large-scale quantitative studies, and included three constructs: performance/competence belief; interest in the subject; and feelings of recognition (i.e., feeling that others see them as the type of person that can do the work) (Godwin, 2016). Godwin concluded that the results provide strong validity evidence for the developed instrument to measure the identity constructs of performance/competence, interest, and recognition. A follow-up study (Godwin & Lee, 2017) investigating engineering students' identity development across the four (or more) years of undergraduate education found that the same subject-related role identity instrument can measure identity among students in different years of their undergraduate education, not just the introductory level. Their study showed significant differences across years in college for all constructs except interest with the highest measures of recognition and performance/competence in year four. While the constructs of Godwin's (2016) instrument are relevant to this study, the instrument itself was not designed to provide understandings about how engineering students described their performance, competence, and feelings of recognition which were the focus of this study.

In a review of factors impacting engineering identity, Morelock (2017) identified three categories of factors: constructive - those which contributed to identity development; destructive - those which detracted from identity development; and directional - those which influenced the type of identity that was developed. Among the factors identified, engineering-related experiences were found in all three categories of factors. One set of these factors, professional aspects of engineering, has been shown to be predictive of undergraduates' engineering identity (Choe et al., 2019). In particular, three aspects of the profession: tinkering, design, and analysis were shown to be predictive of engineering identity (Choe et al., 2019). Further research into the professional aspects of engineering showed that there is a gender gap in affinity related to five out of six of these aspects (Patrick et al., 2021). The three aspects shown to be predictive of engineering identity were rated significantly higher by men while two aspects (project management and framing/solving problems) were more highly rated by women (Patrick et al., 2021). Collaboration, the sixth professional aspect, did not show a significant affinity difference between men and women (Patrick et al., 2021). These differences may help to explain the gender gap in engineering identity (Patrick et al., 2021). In that same study, Patrick et al. found that, unlike gender, race was not a significant predictor of engineering identity.

Additional studies have examined the role of mathematics and science identities on engineering identity (Cass et al., 2011; Patrick et al., 2018) and persistence in engineering (Pierrakos, 2009). In a comparison between students who persisted in engineering and those who switched majors, Perrakos et al. (2009) found that both groups expressed similar strong ability and interest in mathematics and science. Cass et al. (2011) found that mathematics interest and recognition were positive predictors of engineering career choice for both men and women although the effect of recognition was greater for women than for men. Interestingly, in that same study performance/competence had a negative effect on engineering career choice. A combined model for predicting engineering identity that examined the three domains of mathematics, science, and engineering found that each of the three domains, when considered individually, accounted for a significant portion of the variation in engineering identity (Patrick et al., 2018). While the combined model accounted for 29.1% of the variance in engineering identity, Patrick, Borrego, and Seepersad also found that the addition of the mathematics and science factors did not significantly add to the model and concluded that the engineering factors alone were sufficient predictors of engineering identity. Our qualitative study of these engineering factors addresses the recommendation by Patrick, Borrego, and Seepersad that further insights into students' perceptions of engineering may offer valuable insights about how they contribute to engineering identity.

### Framework Guiding This Research

In this research we utilized the Carlone and Johnson (2007) identity framework on which Godwin based her instrument. This framework utilizes three constructs to measure identity -- performance, competence, and recognition. In this study we chose to use Carlone and Johnson's original framework to understand participants' engineering identity. a. The focus on performance, competence, and recognition offered an opportunity to explore this issue through its components' external orientation (performance, recognition, and -- to a lesser degree -- competence, require validation from others). Given our focus on providing a qualitative understanding of these dimensions, we kept the three dimensions separate for our analysis rather than combining performance and competence as has been done in some previous quantitative work. We used these three components to guide the thematic coding process of the qualitative data.

## Methods

### Context

This study occurred at a mid-size, public university in the southwestern United States. Data collection took place near the end of an introductory 200-level Statics course taught in the engineering department. Statics is widely considered by students to be a "weed-out" course: a rigorous class with high rates of low grades and failures that drives large numbers of students out of the major. It is the first engineering course required by all civil, mechanical, and environmental engineering majors at the university.

### Participants

We identify as middle-class, cis-gender white men and women. Four of us have graduate training as educational researchers, one as a civil engineer, and we all share research interests and perform scholarly work in STEM education and gender. Three of us are mid-career researchers and scholars, one of us is in our early career, and one is a doctoral student. We all have experience teaching undergraduates, and one of us has taught in undergraduate engineering programs.

### Research Design

This study involved a qualitative multi-case study (Stake, 2006) that investigated more than one case of students' engineering identity. Each case was constructed based on the experiences of an individual student. These cases were investigated to create deep understandings about the students' emerging engineering identity through descriptive case study. A comparison of these cases explores common themes that transcend each individual case and provides the benefit of an "understanding of the aggregate" (Stake, 2006, p. 39).

### Data Collection

Individual interviews were conducted with the six participants at the end of the semester. The questions driving the interviews emerged from the Carlone and Johnson's (2007) identity framework (Appendix A). As the purpose of these interviews was to explore students' perceptions and feelings about their experiences, the question format was semi-structured, with the moderator serving to keep the discussions on topic while allowing students to offer additional information and perspectives. The questions changed sequence slightly during the interviews, depending on the responses of the participants, and unscripted follow-up questions were posed during the process.

### Data Analysis

#### *Coding*

The data from the interviews was analyzed through an iterative coding process. The data was first analyzed using themes from the modified Carlone and Johnson (2007) identity framework to code data into the three domains: competence, performance, recognition. During the coding process there were a group of statements that did not fit into any of the framework domains, but seemed important to all participants in relation to how they saw themselves and others as engineers. This group of statements was coded with a fourth code: persistence. Through a process of constant comparative analysis (Marshall & Rossman, 2010) these four codes were used to analyze the transcripts from the interviews. In Table 1 we provide examples of the four codes.

A process of inter-coder agreement occurred with two additional researchers to improve the consistency and trustworthiness of the data. During this process, the rate of agreement was greater than 95% across the three coders. Finally, we created a data matrix that organized the data by code. This permitted the first comprehensive examination of the data. A second data matrix organized the data by participant and codes, which permitted the first glimpse of the types of themes and relationships that might be specific to each individual case.

### Case Construction

To construct the cases, we utilized a descriptive case study framework (Stake, 2006). All data were first considered comprehensively to explore students' emerging engineering identities. Then the data were coded and examined by theme. Finally, the data were organized into cases to tell the story about each individual experience with engineering identity. We created the cases using the analytic lens of the identity framework, harnessing its components to describe the students' emerging engineering identity.

## Findings

Here we discuss the six case studies focused on the students' engineering identity. Each case is organized around the codes of competence, performance, and recognition. Statements about the fourth code, persistence, are highlighted across the sections as they were most often intertwined with the other constructs in the interview data.

### Dyan

Dyan was a 20-year-old African-American female student majoring in Civil Engineering. At the time of her enrollment in Applied Mechanic Statics, Dyan was a sophomore taking Statics for the first time.

**Table 1**

*Coded data examples*

| Initial code | Definition | Example from this research study |
|---|---|---|
| Competence | Knowledge/understanding of engineering; can apply knowledge/understanding to engineering contexts. | "I'm always one to forget to draw free body diagrams, and that would've totally helped me on this. I did not get this one. Instead of breaking it up and times it by 2, I just broke it up because I thought I remembered it in the web work, where it was divided by 1, 2, 3, 4. I just did 800 divided by 4, and that was not correct." |
| Performance | Makes knowledge of engineering practices visible; needs social context with audience. | "Classes like my design process class where you're building a tennis ball launcher, so when I actually bring the actual device home it's like we built this out of scratch, basically wood and plastic and a couple of motors, and at the beginning of the semester I probably would never have built it. But actually showing people what I'm doing outside of my homework, they can see me doing engineering design and breaking things down and figuring out how it works and how to make it better." |
| Recognition | Acknowledgement from self/others that individual is an "engineering person" (this may occur through performance of knowledge in a social setting). | "I think it's more of like a levels thing. An upperclassman isn't going to see me as more of an engineer than them. Whereas outside, you say engineering, and everyone's amazed, and it's not actually that difficult, like it's challenging, but it's not as amazing as other people make it sound." |
| Persistence | Demonstrates belief that success results from perseverance despite difficulty/obstacles. | "…When I do stumble or mess up it's like, just take a deep breath, and as long as I want to get through this, I'm going to get through this. That's basically what it comes down to. I can't see myself doing anything other than engineering." |

**Competence**

Dyan discussed her competence with engineering in terms of her problem-solving abilities. She connected competence in engineering with painstaking attention to detail, and understood that a misstep in the problem-solving process can lead to incorrect answers. She viewed her own competence as dependent upon an ability to break down engineering problems and attend to the minutiae with focus and precision. She also tied her competence to an ability to understand what is important within engineering problems, and what is not. Dyan valued these aspects of engineering competence and was able to discern these abilities within herself. She was able to reflect on the ways that her own competence has developed, and on the areas she needs to improve upon in order to grow her competence.

Dyan saw gaps in her competence existing in the spaces between her engineering classes, and placed the burden of filling in those gaps upon herself to figure out. Her ability to accomplish this was where her uncertainty about her competence creeps in. However, she understood that she has agency to overcome this challenge in becoming an engineer and took action to develop her competence further through persistence. She also suggested that her growth mindset will benefit her as an engineer, and cited her ability to communicate as an asset.

Although Dyan acknowledged gaps in her competence, her sense of self as an engineer was tied to developing understandings. Within her undergraduate peer group, she saw a divide between “that separation of people that just want to get the answer, and the people that want to understand it,” and placed herself squarely within the group that persisted at developing deep knowledge through understandings. Her identity as an engineer depended upon her ability to maintain membership in this group.

**Performance**

While Dyan’s primary concern was with developing understandings, she was very concerned with her performance in her courses, and this element of her identity as an engineer was weaker as a result. Dyan struggled with her own grades, noting that she was below the required average on exams in the Statics course, and cited her performance anxiety with exams as a primary reason her sense of competence and her grades did not align well. But she maintained confidence that, when she is an engineer, her values around performance that reflects competence will eventually make her a stronger professional.

> I'm goal-oriented and I want to get stuff done, but I want to do it the right way. I'm not just someone who would be okay with something just slapped together… Because this is practice, and if you practice a certain way, that's how you're going to perform.

**Recognition**

Dyan understood that there is a difference between the way that those outside of engineering recognize engineers, and the way that those within engineering understand the profession. She believed that those outside of engineering “don't even know what to picture” when discussing the profession, and she cited the misperception that those in engineering need to be very “smart” as an idea that exists primarily outside of engineering. Dyan discounted these superficial perspectives about engineers in favor of the ways she believed engineers are recognized within the profession as dedicated problem-solvers.

Dyan recognized herself as an engineer within this framework of commitment to the work and strong affinity for building. “I'm an engineer because I like to build things, and I like to think about the things that go within that.” However, Dyan’s recognition of herself as an engineer was challenged by the lack of recognition she sometimes experienced from others, both inside and outside of engineering. She understood these experiences of dis-recognition as connected to the other areas of her identity outside of engineering:

> There are assumptions about me being an athlete. There are assumptions about me being African American. There are assumptions about being a girl. There are assumptions about being in classes when you're younger than everyone else.

Dyan discussed the university's status as a PWI (Predominantly White Institution) as an environment where others might find it difficult to recognize her as a developing engineer, and noted that within this context "I don't look like an engineering major." She also recognized herself as different from other engineering students in terms of socio-economic status.

> I am a first-generation student… I feel like a lot of the people around me [in engineering] are more well off, and stuff like that. I do have two jobs, and I have to juggle other things. When people are talking about their weekends, or going [skiing], and stuff like that, I'm like, "that's not what I do on the weekends."

Finally, Dyan understood herself as different from other engineering students in terms of the opportunities she had to develop prior knowledge before entering the engineering major. The effect of these differences within the undergraduate engineering context impacted the way others recognize her as an engineering student, and whether others valued her competence outside of these other aspects of her identity that do not fit with what others expect of an engineer. Despite these experiences, Dyan made efforts to focus on the positive aspects of her differences, and to use these to strengthen her self-recognition as an engineer. "I'm proud of my upbringing. I'm proud that I'm able to figure out how to pay for college on my own, and I'm doing all this stuff. I think that type of resourcefulness would be my best asset [as an engineer]." She was resistant to allowing others to define her as not fitting within engineering.

**Jesse**

Jesse was a 28-year-old male who self-identified as an American Indian/Alaska Native student majoring in Mechanical Engineering. At the time of his enrollment in Applied Mechanic Statics, Jesse was a junior taking Statics for the first time. At 28 years old, Jesse was older than the other undergraduates in this study, and unlike many of his peers, served in the US Marine Corps before enrolling in college.

**Competence**

Jesse was able to articulate his competence in engineering through a step-by-step focus on problem-solving. He felt competent when he could solve engineering problems, and he discussed his understandings about engineering as related to his ability to access prior knowledge, and as a process where he was continuously building upon his knowledge base. Jesse was confident in discussing engineering problems and how he approaches solving them. He expressed his sense of competence as an engineer through his comfort level with the material: "It's like a big puzzle for me and that's how I kind of approach it, especially with math problems."

Privately, Jesse tried to have fun with some of the engineering work as a strategy for maintaining a positive attitude, which helped him to maintain persistence and develop competence with the work. He compared the engineering problems to a “puzzle,” and attempted to lighten the mood for himself when faced with difficult problems to help himself to maintain focus. Jesse understood his competence as directly related to his persistence in pushing through with the work using strategies that were most effective for himself. While he understood that his engineering competence was not developed as easily or as quickly as the competence of others, he credited his persistent attitude with ultimately getting him to the same end-goal as other students.

**Performance**

Jesse was concerned about his performance in the Statics course, and in engineering courses in general, primarily because he understood his ability to make his knowledge visible through passing exams, and his course grades, as another step-by-step process that will lead him to graduating as an engineer. “Just passing the classes I think is a big confidence booster…like I pass my engineering classes and I'm stoked.” He understood completing his major as a big part of solidifying his identity as an engineer, and as a demonstration of his developing proficiency with engineering. He considered his performance in each course important, but he also kept his focus on the end-game performance of completing his degree. His performance in his courses caused him concern, but he was not overly anxious about it if he was passing, and he did not connect top performance with his identity as an engineer.

**Recognition**

Jesse understood engineers as builders, fixers, and problem-solvers, and he recognized himself as an engineering person within that framework. He looked forward to the creative elements inherent in engineering that lead engineers to build something new or better. Jesse understood that his affinity for creative building means that he will need to master a variety of engineering content, and he enjoyed most of this work. However, he struggled with more abstract concepts and content, and looked forward to being able to focus on the kind of work that will allow him to work on concrete types of problems.

> I'm more of a hands-on kind of person. That's what I like to do is work with the hands. But then when I have to sit there and read something and try to memorize a theorem or figure out how an atom works, that's where I struggle the most.

Jesse’s doubts about his identity as an engineer centered around the more abstract content that he recognized as part of being an engineering professional. His strong affinity for building and hands-on projects was a driving force behind his recognition of himself as an engineering person, but he knew that engineers must also understand abstractions, and must do more than simple assembly. Jesse’s self-recognition as an engineering person began to fray when he considered other professions that might also draw on his strengths as a builder, fixer, or problem-solver.

Jesse understood himself as a natural leader within the undergraduate engineering context, which strengthened his self-recognition of himself as an engineering person, at least in comparison to his peers. Between his experiences in the Marines and his older age, he felt he had a leadership edge. He also understood that his responsibility was to make sure that others have opportunities for taking the lead, rather than participating in a dynamic that always left Jesse in charge. “I actually have to tell my [engineering] groups that I'm not going to be the lead on this, because it just naturally comes in my direction.” Jesse’s recognition of himself as an engineer was strengthened by his own, and others’, recognition of himself as a leader in comparison to his undergraduate peers. While he might not perform at the top of his class, the social validation he received in being recognized as an engineering person through leadership strengthened his identity as an engineer. Jesse thought of himself as a person with a strong work ethic rather than someone who was inherently smart and understood engineering concepts easily. He understood engineers as persistent people, and recognized himself within that framework, rather than within others’ framework of inherent intelligence.

### Sara

Sara was a 19-year-old White female student majoring in Environmental Engineering. At the time of her enrollment in Applied Mechanic Statics, Sara was a sophomore taking Statics for the first time.

#### Competence

Sara’s perceptions about her knowledge and understanding of engineering were generally positive, and reflected a critical but pragmatic viewpoint. She discussed other students’ competence frequently as a point of comparison with her own, and seemed comfortable with her self-designated status as an average engineering student within the Statics course. “I feel pretty confident, or competent. I'm not the best person in that class, but I can definitely pass it, and I'm definitely not the worst.” Sara saw her competence with engineering as constructed differently than other students’: she understood step-by-step progressions better than explanations, which she believed sets her apart in terms of her understandings.

Sara built her sense of competence with independent problem-solving. Although she had relationships with peers built around the classroom context, participated in engineering activities with peers, and characterized engineering as “super-collaborative,” she developed her competence primarily outside of those relationships. Sara viewed her involvement in group study sessions as somewhat altruistic: assisting in the competence of others and participating in the community, without the expectation that her own competence would be developed in the process.

#### Performance

Sara’s performance statements were minimal, and were deeply tied to her sense of competence. Sara strongly related her competence in engineering to her performance on exams, and to her grade in the class. She was primarily concerned with her own independent understandings, but she understood that her ability to make this knowledge visible to her professor was an important measure of her proficiency. Her grades, and her standing in the class, were important for developing and maintaining her sense of self as an engineering student.

She also suggested that being able to compare herself with her peers had an influence on her feelings about her performance. Being in better standing than peers after a performance task made Sara feel positive, and she had minimal concerns about performance anxiety in the engineering context. She seemed to accept occasional failure as part of the major, and an expected challenge to overcome: “It's definitely hard. It’s not easy to just sit back and take the fact that you just failed something.”

Although she endeavored to focus on her understandings in engineering, she acknowledged that performances of understanding that demonstrate comprehensive competence might be beyond her abilities, but she characterized these circumstances as a norm, rather than allowing it to chip away at her identity as an engineer.

**Recognition**

Sara demonstrated different viewpoints regarding the value of recognition from individuals outside of engineering versus those within engineering. For Sara, people who were not engineers or engineering students harbored false ideas about the discipline, such as the challenges inherent in the major, or the idea that engineering students needed to be “smarter” than other students. These misperceptions depreciated the value of outsider recognition, or lack of recognition, for Sara as an engineer: “Students who aren’t engineering majors don't understand how difficult it is or what goes into it.”

Sara had mixed feelings about her own recognition of herself as an engineer, and how that recognition will develop. As a student, Sara did not see herself as an engineer yet, but rather as an engineer in development. She understood that her competence in engineering needed to grow before she could recognize herself as an engineer. She also believed that although she will understand that she is an engineer after graduating with an engineering degree, her own recognition of self as a professional in this discipline may be dependent upon the recognition of others first.

Sara recognized her own dedication to something larger than the label of “engineer” as part of her persistence with the degree, and saw the achievement of becoming an engineer as a vehicle for doing something worthwhile. “I definitely want to finish with engineering, not just for the title of engineering, but so I could do something cool, and I can make a difference.” Sara saw herself fitting within engineering because of her philanthropic spirit and her commitment. In comparing her attitude to her peers, Sara expressed bewilderment at others’ lack of persistence at something as valuable as an engineering degree.

Sara’s own persistence colored her viewpoint on others’ lack of it. She believed that becoming an engineer was an attainable and worthwhile goal, and decided that if she can achieve this goal, anyone else could do so as well, if they are willing to persist at it. She recognized persistence as a necessary characteristic of a person developing their competence and performance in engineering.

**Nate**

Nate was a 19-year-old White male student majoring in Environmental Engineering. At the time of his enrollment in Applied Mechanic Statics, Nate was a junior taking Statics for the first time.

**Competence**

Nate discussed competence with the material through the solutions to specific engineering problems and descriptions about the way his competence develops.

When presented with stimulated-recall using an exam problem from the Statics course, Nate focused on the details of what he would need to do to solve the problem. He was comfortable conversing about the content knowledge needed to do engineering, and he was confident in his level of competence with solving problems. Nate understood some areas where he still needs to grow his competence with engineering, and was able to reflect on areas where he still struggled with concepts.

Nate also understood areas of engineering where he was extremely competent in his knowledge, such as his ability to understand engineering processes, and he worked hard to make sure that his higher-level understandings were clear to his professor.

> I always explain every step that I'm doing, write out everything possible that's involved in a problem, just so the [Statics] professor knows that I'm thinking about this logically, not just regurgitating what I remember, because that's probably what you could do for a lot of these since they are homework problems if you were dedicated enough to remember them.

Nate understood that engineering is built upon layers of knowledge, and that prior knowledge is necessary for competence while moving forward as an engineer.

Nate valued his competence in all his engineering courses because he saw his developing competence as a system that will lead him to his goal of becoming a professional engineer, rather than discrete parts that were disconnected from one another. "You're trying to learn this material, not just like you're going for a grade." Nate rarely struggled academically in the past, and he viewed the difficult aspects of his engineering coursework as positive preparation and a challenge to grow his competence, rather than an obstacle.

**Performance**

Nate understood himself as the kind of student who can pass courses more easily than his peers. "I'm a pretty good test-taker." However, he acknowledged that engineering courses require a different level of performance to do well. "In other [non-engineering] classes, I know I can kind of bullshit and get a good grade." Nate understood his performance in engineering as a direct measurement of his competence, and traced the evolution of his performance on Statics exams as evidence of his deepening understandings about engineering concepts.

> So for the first test [in Statics], I believe I got an 81, which, up to this point in college, was the lowest test grade I've ever gotten and I was distraught... And at that point, I knew I had to improve my understanding of the entire process thoroughly. So for the upcoming test, I worked on how I should approach a problem more logically before I actually put in numbers. So I think that helped… So the tests are pretty much a direct reflection of how much you know.

Nate expressed pride in his performance in Statics over the course of the semester, and in his shift in mindset towards deeper understandings that he believed will allow him to perform more proficiently as a developing engineer.

**Recognition**

Nate was recognized as an engineer by others both within, and outside of, the engineering context. He understood himself strongly as an engineering person through his skills as a problem-solver. Recognition from others served to bolster his self-recognition, especially when it came from those within the engineering community. “With the skills that I have and meeting engineers, who have been there, and they're all confident in my abilities, so that gives me confidence in how I'll do outside of the school.” Nate believed that as recognition of himself as an engineer grows, he will be able to understand himself as an engineering person.

Nate understood engineers as problem-solvers, and easily recognized himself as an engineering person through that lens. He understood that recognition by others relies on the understanding of him as a problem-solver, but that his own growing self-recognition may take the place of others’ affirmations in moving him towards an identity as an engineer.

Nate’s strong academic abilities provided him with opportunities for leadership roles within engineering and reinforced his sense of recognition as an engineer among his peers. He understood that his leadership skills will benefit him as an engineer, and constructed part of his understanding of what it means to be an engineering person around this idea of leadership. His opportunities to position himself as a leader during collaborations with peers also allowed him to make comparisons between himself and other students, and he found that he measures up well, both in terms of competence and work ethic. This also supported his self-recognition as an engineering person.

Nate enjoyed his role as a leader, and believed that his position as the person-in-charge is often mutually beneficial for everyone in his engineering groups. For him, it built his confidence and pride in himself as a leader within engineering.

> You can put me in any group. I've always been this way, but you can put me in a group with any kind of people... I think it definitely builds my confidence in myself as a leader when people gravitate towards me and when I can actually direct people.

Similarly, when others outside of engineering recognized the work Nate puts in to become an engineer, he felt a sense of pride. Nate’s sense of recognition as an engineering person was tied primarily to his self-recognition, but it was supported by the way others see him as well.

**Kerri**

Kerri was a 21-year-old White female student majoring in Mechanical Engineering. At the time of her enrollment in Applied Mechanic Statics, Kerri was a sophomore taking Statics for the first time.

**Competence**

Kerri understood competence as a critical component of being an engineer, and viewed her own competence largely as something that she needs to develop as an independent activity. Her ability to problem-solve, and to understand overarching concepts, was developed primarily in isolation. “Organization is a big part of it for me. So I'll write my really gross notes in class, and then I'll go home and fill in extra stuff, and read from the textbook and add in. That seems to help.” She held herself responsible for her own competence, and saw little connection between her learning and the actions of her professor or her peers. “If I don't get it, it's because I'm not practicing.” She understood her own agency over her competence in engineering.

Kerri viewed the math-focused nature of developing competence in engineering as a primary reason for her independent perspective. While she believed some students can pass classes with help from others, she did not believe that this develops true competence as an engineer. Kerri admitted that there are some benefits to developing competence in collaboration with others in engineering, despite her emphasis on independent learning.

> By myself I figure out my way to do things more. But with other people it helps me see, like if I'm struggling with something then it helps me see how they do it, and that might change my approach to it.

While working with others might offer her a fresh perspective while struggling to master a concept, Kerri strongly associated competence with doing engineering in her own individual way.

**Performance**

Kerri’s ideas about performance within an engineering context were centered around anxiety. When considering making her knowledge and understandings about engineering visible to others, Kerri expressed apprehension about her ability to perform engineering tasks, and the worth of her participation within the classroom. While reflecting on a previous exam question during a stimulated-response prompt, Kerry offered comments only related to her unease with the performance task. “I always get scared when a problem gets thrown down in front of me.” She also expressed that she tends to believe that she performs more poorly than she does, suggesting that she harbored doubts about her competence. “I remember I thought I did worse than I actually did, after I left.” Kerri understood that participating in class helps students to build competence. However, her anxiety about making her knowledge visible to other students by participating in discussions prevented her from doing so.

> I generally don't ask questions in class. Outside of class, I'm fine asking questions, like in office hours. Or like after class, going up and talking with the professor. But not during class generally... I just don't like it.

Kerri’s had doubts about the worth of her questions, and she was reluctant to take up class time to strengthen her understandings if it meant possibly being judged by her peers. She was comfortable having conversations with her professor, however, to clarify her understandings.

**Recognition**

Kerri understood engineers as individuals who behave professionally, are project-oriented rather than social, and are very persistent. She recognized herself as an engineering person through these understandings about what it means to be a professional in this discipline. Within the undergraduate engineering context, Kerri saw her professionalism as a strength she will carry forward into her career, and she believed the slovenly behavior of her peers suggests that they may struggle with being an engineer in the future. She believed that engineers avoid allowing themselves to be drawn into the kinds of inappropriate socialization that would detract from their work, and instead focus on the project at hand. She recognized herself as an engineering person through this lens as well. “I tend to be a very focused person, I guess. I like when things are finished.” She understood engineers as socially disinclined in terms of their temperament and as individuals who have developed persistence, rather than possessing inherent qualities that lend themselves to engineering. She saw herself as an engineering person because she was willing to work for it.

Kerri discredited the idea that engineers are inherently smart, and believed that anyone can be an engineer with a persistent attitude and strong work ethic. She exhibited this idea in her own engineering work through both her attitude and her actions, which strengthened her own recognition of herself as an engineering person.

> It definitely makes it so that when I do stumble or mess up it's like, "Just take a deep breath," and as long as I want to get through this, I'm going to get through this. That's basically what it comes down to. I can't see myself doing anything other than engineering.

Kerri was recognized by others as an engineer as well. Within engineering, she understood that there are “levels” to being an engineer, and that as she moved towards graduation, she will be recognized within engineering as more and more of a true engineer. Outside of engineering contexts, Kerri was recognized as an engineer by her family, who she believed uses that recognition as a form of encouragement and pride. Peer groups outside of engineering recognized Kerri as an engineer, particularly in relationship to her strong math abilities. “They'll just say the engineer over here...like if they get a math problem wrong, and you correct them, they'd say ‘Oh, well you would know, you're the engineer.’”

**Steve**

Steve was a 20-year-old Hispanic male majoring in Mechanical Engineering. At the time of his enrollment in Applied Mechanic Statics, Steve was a sophomore taking Statics for the first time.

**Competence**

Steve discussed competence in engineering through the solutions to specific engineering problems and understanding big-picture concepts. When presented with stimulated-recall in the form of an exam problem from the Statics course earlier in the semester, Steve discussed his knowledge and was able to discuss the prior knowledge he believed an engineer would need to know to solve the problem.

Steve was comfortable conversing about the content knowledge needed to complete engineering tasks, and he was also able to articulate his limitations with the content, and his feelings of doubt about his own competence. Steve explained that he believed his strengths within engineering are with understanding concepts, but that solving problems in the Statics course presented him with challenges, and that his ability to solve the problem presented during the stimulated-recall had limitations.

Steve’s explanations for the limitations to his engineering competence were related to the time he felt he had available to work through the problems. “I have to prioritize homework...and this class, I'm not doing that great, to be honest…It’s time. I don't have time to go through everything….I understand the concepts, it's just not enough." Steve characterized his time limitations and sub-optimal grades as being the result of overworking himself, and cited the 20 credits he was taking during the semester under study.

**Recognition**

Many of Steve's statements about recognizing what it means to be an engineer were related to "leadership" and "dedication." He expressed pride in his position at ASME, and noted that he lost his bid for president of the organization by only one vote, making him the runner-up and therefore vice-president. Steve explained that his actions related to influencing the direction of the group led to his achievement of leadership. "I kind of put it on myself to bring the group together, and to actually cooperate and get to the competition, and then they started seeing me as a leader." Steve's pride in this achievement was linked with his ideas about leadership as part of recognizing someone as an engineer. Similarly, he connected viewing dedication as part of being an engineer with his own recognition of himself as a developing engineer.

Steve recognized himself as a developing engineer through attributes that he viewed as integral to success in the profession. "I'm just picturing myself as a practicing engineer and people around me. I would just imagine, again, being good at math. The stereotype for engineers. And then just having the ability to come up with solutions to problems." He viewed open-mindedness and critical thinking skills as important for an engineer to be able to generate "creative ways to fix problems." Steve also recognized engineers as collaborative, and suggested that teams with shared goals are more valuable in engineering than those working in isolation: "Being an engineer is something you need others for."

When others recognize Steve as an engineer, a sense of elevation is created for him. While describing showing an engineering project to others, Steve noted: "Everybody outside of the engineering field is like, 'Oh, my god. How'd you do that?'" He also addresses the misperception that "A lot of people think you have to be like a super genius to be an engineer" – and while he noted this idea as generally incorrect, others' incredulity about his math prowess or his class projects was clearly a source of pride. He enjoyed the sense that his chosen profession elevates him in the eyes of others in terms of his intelligence and abilities, and he appreciated the validation that he receives from others that engineering was the right career path. "I was that person that when I came up here for engineering, [people in my life] were like, you need to stay with that."

While Steve's recognition of himself as an engineer, and the recognition that he felt from others, was strong, he also has had experiences where this recognition was challenged. Steve characterized these experiences as primarily related to his ethnicity, and notes that these experiences tend to occur outside of the primary engineering context of classes and student organizations: "For one, it's the fact that I'm Hispanic. It's not a huge deal, especially when it comes to engineering, but I know that's bias that's come across more than once."

These situations involving bias and others' assumptions about his competence were not positive engineering recognition experiences for Steve. However, Steve's other strong domains of engineering recognition seemed to negate the impact of these types of experiences on his own prospects for becoming a successful engineer.

**Performance**

Steve's sense of his own ability to perform within the engineering context varied. When he was involved with hands-on projects that were collaborative in nature outside of the classroom context, Steve was confident in his ability to perform and to make his knowledge about engineering concepts visible. However, within the classroom context, Steve struggled, particularly when it came to independent work related to solving engineering problems that required competence with the specific content of the course. "When I actually have to do [problems] on tests, I don't know if I overthink it or if my brain just blanks out, but I can't complete them and be confident with my answer." Steve's performance on exams has been an issue throughout the semester, and he noted that his grades were not very good within engineering courses, particularly because he lacked the time availability to complete homework and consistently earn points towards his grade in that way. He also did not feel well-positioned to perform more informally during lectures, such as by engaging verbally in class discussion or in answering questions to see if his ideas about the content were on the right track. "I don't feel comfortable enough with the material to do that." Steve's sense of his own positive performance in engineering tended towards contexts involving collaboration, whereas his ability to independently perform engineering tasks was couched in self-doubt. Steve expressed that doubt about one's ability to perform engineering tasks is a factor in whether a person will become an engineer, and that persistence is critical to the mindset of a successful engineer: "I feel like as long as you stay confident in your abilities, you'll do pretty well."

Steve believed that confidence and an ability to plunge forward with performing engineering, even in the face of obstacles, will lead him to achieving the goal of becoming an engineer. He characterized the coursework in Statics as "hard, but extremely passable," and noted that hard work will lead to competence and success if an individual persists at trying. Steve suggested persistence as a vehicle for both competence and performance. His comments also reflected a mindset of persistence: "I don't know where I'll fit [within engineering]. I will fit, because everyone can fit if you really want to."

## Discussions

The framework used in this study informed the interpretations of engineering identity for the six participating students and was a critical element of the research question: How do first year engineering students interpret competence, performance, and recognition in relation to their identities as engineers? As described above, the focus on confidence, recognition, and performance offered an opportunity to explore engineering identity through its components' external orientation. Here we use these three components to guide the cross-case analysis to uncover patterns across our participants.

In every case, statements around competence frequently bubbled to the surface during discussions about what it means to be an engineer. However, students had divergent perspectives on what it means to have knowledge and understanding about engineering, and several had expressions of competence that differed from that of others. Nate, Dyan, Steve and Kerri discussed competence in terms of their ability to understand big ideas in engineering, as well as to solve engineering problems, and all four of these students harbored some doubts about their understandings of the big picture as they moved through their engineering coursework. Achieving these broad understandings were strongly connected with their identity as an engineer. Meanwhile, Sara and Jesse understood competence in terms of pragmatic knowledge -- step-by-step problem-solving – and showed less concern for big-picture understandings. For Sara and Jesse, being an engineer meant basic competence and discreet understandings. Sara and Jesse also took the most pragmatic view of their performance in engineering courses: while they were concerned about their exam and overall course grades, their sense of identity as an engineering person was not strongly tied to top performance. They understood that if they could graduate with an engineering major, they would have performed adequately to identify as engineers. These students moved beyond simply recognizing shared goals, and actively engaged in behaviors that increased their knowledge/understandings of the subject – competence – and their ability to make the knowledge of subject-related practices visible – performance (Carlone & Johnson, 2007).

In all cases, students connected both competence and performance as an engineer with persistence, and reflected the understanding that engineers are individuals who do not give up in the face of challenges. All students in this study expressed the understanding that competence and performance in engineering is a result of hard work. This mindset suggests a high level of agency in developing competence and improving performance in engineering across all cases in this study. Interestingly, while competence and performance have both been shown to be important to the development of an engineering identity, they were not found to be significant predictors of engineering persistence (Patrick, Borrego, & Prybutok, 2018). Additional research is necessary to understand the connection that students made between competence and performance as an engineer with persistence and the relationship, if any, to engineering persistence.

Recognition is understood as a critical element of identity development. “A student’s perception of how others view him or her is vitally important to how that student sees himself or herself. These recognition messages are important early on in students’ careers from parents and teachers, but also during engineering identity development in college through instructors and peers” (Godwin, 2016, p. 3). However, defining engineering identity is very complex, and there are a range of viewpoints on what it means to be an engineering person from a variety of perspectives within the profession (Meyers et al., 2012). In this study, recognition of the self as an engineer depended upon the students’ individual ideas about what it meant to be an engineering person. We do not seek to define what it means to be an engineer, but rather seek to understand students’ own perceptions, and how students believed those perceptions fit with their individual selves as engineers. From the open-ended probe of students’ ideas around recognition of the self as an engineer, and how others recognize them as engineers, several themes emerged that relate to modern ideas about engineering identity.

Self-recognition as an engineering person took center stage for each student. All identified themselves strongly as an engineering person, and all understood engineers as persistent problem-solvers. An ability to collaborate was also noted by all students as an important part of being an engineer, although students expressed various degrees of willingness to work collaboratively as engineering students.

Nate, Jesse and Steve – the three male students – associated identity as an engineer with leadership, and their self-recognition as engineers, and the recognition they perceived from others, was strengthened by their own leadership abilities. For Steve, self-recognition as a leader within engineering came from his position as an officer in an engineering student group outside of the classroom. For Nate and Jesse, self-recognition as a leader within engineering came from collaborations that emerge from the classroom context. In contrast, the female students – Dyan, Sara and Kerri – did not discuss leadership in association with being an engineering person, or in association with themselves.

This recognition by others that they were a leader in an engineering context bolstered their self-recognition as an engineering person, in alignment with Godwin's (2016) discussions highlighting the idea that recognition by others influences students' self-recognition. These gender differences are particularly interesting given that prior work showed that engineering practices that align with gendered stereotypes also predicted engineering identity along gendered lines (Patrick et al, 2021). Further research focused on gender differences related to recognition as an engineer would be helpful especially given the greater effect mathematics recognition had on engineering career choice for women (Cass et al, 2011). This finding suggests one possible difference between the way male and female students recognize themselves as engineers, and further research may be needed to establish this difference as a more generalizable idea.

The students perceived those outside of engineering as holding misunderstandings about the profession, and especially about what it meant to be an engineering person: they perceived that outsiders tended to believe that engineers possessed above-average intelligence, and that this allowed them to master the tough content necessary for being an engineer. All students discredited this idea in favor of persistence as a key factor in whether someone is an engineering person. Recent attention to smartness in engineering culture (Dringenberg et al, 2019) and our participants' rejection of this stereotype suggests that this might be an interesting area for future research.

All students in this study experienced some level of recognition from others that they are an engineering person. However, two of the three non-White students have also perceived dis-recognition from others that they were an engineering person based on their race/ethnicity, which created tension around their self-recognition as an engineer. Steve, who is Hispanic, and Dyan, who is African-American, experienced situations where they felt that others outside or within engineering have not been able to recognize them as an engineering person because of their race/ethnicity. While both expressed strong self-recognition of themselves as an engineering person in other areas, the biases of others worked against this self-recognition that they fit within engineering. As shown by Tonso's (2006) ethnographic study, a lack of recognition by peers and professors can weaken identities as engineers. This finding related to dis-recognition and its perceived connection to race and Patrick et al.'s

(2021) finding that race was not a significant predictor of engineering identity suggests that additional research is necessary to clarify the relationship, if any, between race and aspects of engineering identity.

Looking across the six cases, we see that the constructs of competence, performance, recognition, and persistence highly overlaped. This intersection of performance and competence in our qualitative results, for example, supports the way in which Godwin (2016) combined these two aspects of the framework in her quantitative instrument. The interconnectivity of the constructs, as well as the importance of persistence, are important findings relevant to future studies in this area. Additionally, the connections between gender and racial identities and students' engineering identity require further research to fully understand how these factors may influence aspects of engineering identity.

## Limitations

Unlike the large quantitative studies of engineering identity in the past, the small sample size in this study limits the generalizability of the findings to the larger population of novice engineering students. However, the in-depth analysis provided by the case study methodology allowed us to illustrate the findings of previous studies at the individual level in ways not possible in large scale studies. In addition, this study was situated after an introductory level engineering course so these findings should be viewed through the lens that these are novice engineering students and the relative influence of the three aspects of identity may shift as students advance in their coursework towards more specialized courses.

## Conclusion

Recent research on trends in undergraduate engineering, and on the experiences of students, has illuminated a variety of patterns related to when students decide to stay or go within the engineering major, and which students are most likely to persist (Meyers et al., 2012). As colleges and universities invest more effort into the retention and graduation rates of undergraduates, studies suggesting insights into the how and why of phenomena like attrition and retention become important for understanding how faculty might better support the students they serve. This study provides a window into the construct of engineering identity that may be critically important in conversations about the steps faculty may take in working with students to promote increased retention of undergraduate students in engineering. For example, our findings suggest one way an engineering program could provide opportunities for students to engage in meaningful engineering leadership, which might support an engineering identity through self-recognition for some students. Additionally, our findings supported previous claims that there may be differences in the factors which support the development of engineering identities depending on students' gender and racial/ethnic identities. Given this, engineering programs should consider that interventions designed to support engineering identity development are not one-size fits all and should offer opportunities to meet the needs of diverse students.

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## Appendix

1. Please describe your future self as an engineer. How do you see this career as a fit for you?
2. What do you enjoy about engineering? Why? What don't you enjoy? Why?
3. How do you believe you will do in engineering outside of a classroom? What leads you to that belief?
4. Do you fully understand the concepts you have learned in engineering? Why do you think that?
5. Do you think other people see you as an engineer? How?
6. How do you know when others see you as an engineer? Why do you think they see you as an engineer?
7. When you think about yourself as an engineer, how do you think you fit into the profession? What experiences have you had that lead you to believe you will fit, or not fit?
8. How have your experiences in engineering been so far? What challenges have you had in engineering?
9. How do you feel about the other students in the Statics class? About the professor? Why do you feel this way? Can you provide an example?
10. How has the Statics course affected your sense of identity as an engineer?

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