Normative and Non-Normative Engineering Student Experiences in Navigating the Cultures of Engineering

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Introduction

Promoting diversity within the culture of engineering has been of great importance to the field of engineering education. With greater diversity also comes a need for the understanding of how students with different identities and beliefs navigate their pathways through engineering. To begin to identify these different pathways, this paper presents current data from our project, Intersectionality of Non-normative Identities in the Cultures of Engineering (InIce; NSF EEC-1428689/1428523). This project explores how students with normative and near-normative attitudes and beliefs in engineering position themselves as engineers (i.e., their identities), develop throughout their undergraduate career, and navigate the culture of engineering. Within engineering culture, the formation of identity has been shown to be important in the retention of students [1]. The past decade of engineering education has focused heavily on improving students' development of an engineering identity, which has been shown to affect both students path into college and how they proceed through college [2]–[6]. These results illustrate the importance of developing an identity; however, this development process can be difficult. For example, having a metric for comparison to what constitutes an engineer is important and yet Tonso [7] described how students view engineers as, "a mythic persona that transcended the mundane." This quote not only illustrates that the role of an engineer is not typical or static, but that students lack a role model to relate to. Since students must first define what it means to be an engineer this makes incorporating the role of an engineer into their existing identity difficult.

Another facet of students' development of an engineering identity is believing that they can understand the material and do well in their coursework [8], [9]. Students define success in engineering in many ways including passing a test, attaining an engineering degree, and/or getting a "real world" engineering job. This myriad of ways of defining success means that students feeling recognized or like an engineer can be a moving target. Without recognition, students struggle to develop confidence in knowing the material or doing well as an engineer.

The prior literature on engineering identity development highlights that taking on an engineering role identity is a complex and multifaceted process. While there are particular kinds of experiences that promote engineering identity development, in general, each student must author their own identity as an engineer. In our study we expand this body of literature, by investigating how students underlying attitudes and beliefs shape how they see themselves as engineers and position themselves within the world in that role. We ask the question, "What are normative and near-normative students' perceptions of who can succeed in the culture of engineering?" This paper will report our work to date for this ongoing study.

Engineering Identity Shapes Student Experiences

Multiple factors have been shown to shape the development of an engineering identity. These are performance competence, recognition, and interest [3]. The importance of these underlying constructs in developing an engineering identity can be found across engineering education literature [7], [10], [11]. One narrative in particular that focuses on identity development by Foor et al. [12], focuses on the story of Inez. Despite her team winning a design competition, against all expectations by her peers, she still did not identify herself as one of the "top people in the class" [12, p. 110]. This case illustrates the importance of feeling that one can see themselves as an engineer and successfully understand engineering material. Additionally, this type of experience along with interest in engineering and beliefs that others see you as the type of person that can do engineering are significant shaping forces in students' development as engineers [3], [8], [9].

An Overview of this Project

If students are unable to develop a strong engineering identity, they are unlikely to persist, further impacting the range of individuals in both the academic and industrial engineering culture. The Intersectionality of Non-Normative Identities in the Cultures of Engineering (InIce) project was conducted to explore concerns about students' ability to form engineering identities and persist in their degree pathways. Consisting of two phases, the first stage was a quantitative analysis of data from 2,916 first semester engineering students across four institutions representing research intensive, land grant, undergraduate serving and minority serving foci. The goal of the survey was to measure multiple attitudinal constructs and from that data, identify groupings of students that are present within the current engineering student population. In developing the groups of students within engineering, the project team wanted to identify students based solely on their underlying attitudes rather than demographic characteristics. This approach was taken to determine if a core cluster of "normative" engineering attitudes existed and if those attitudes made navigating an engineering degree pathway easier for those students compared to those with near-normative identities. Constructs include mathematics, science and engineering identities, belongingness, grit, motivation, and personality amongst several others. A full description of items administered and their rationale for selection can be found in our prior work [13].

Using Topological Data Analysis (TDA) and the Mapper algorithm, the project was able to cluster individuals based on similar responses across the measured constructs [14]. Resulting from this analysis were nine groupings of participants, made of one "normative," seven "near-normative," and the "disparate" group (individuals who were not clustered with anyone else). The normative group had a dense cluster of attitudes that were similar to other studies of students attitudes and beliefs in engineering [1], [15]. The analysis was described further in prior work [13].

Taking these groupings, the second phase of InIce involved recruiting 24 participants, with representatives from each group, who took part in longitudinal semi-structured interviews. Each interview lasted approximately 45-60 minutes. Students were given the option of choosing their own pseudonym, and those that did not were assigned one by the research team. The goal of this phase of the project was to track how initial attitudes mapped in the first phase later translated

into how students experienced engineering culture and persisted (or did not persist) in their engineering degree pathway. IRB authorities approved all data collection and analysis procedures.

Current work

This paper focuses on the pathways and experiences of six participants from four different groups at two institutions to understand how students from different attitudinal groups navigated through engineering. Brief descriptions of each attitudinal groups defining characteristics can be found in Table 1, with full descriptions in Kirn et al. [13]. This paper presents on all of the near-normative identifying students that participated in multiple interviews. Additionally, these participants were chosen to illustrate similarities and differences between the normative and near-normative groups

Table 1-Group and Participant Information

Group	Group Description	Participant Pseudonyms
Normative	Scores high in connectedness, belongingness, perceptions of the future, and instrumentality.	Keyla Sean Tranlin
Near-Normative Group 3	Lower construct scores in grit and performance approach.	Shey
Near-Normative Group 5	Scores higher in extroversion compared to the normative group.	John Smith
Near-Normative Group 7	Lower construct scores in work avoidance and recognition.	Christian

Qualitative analysis

During the qualitative interview phase, semi-structured interviews with each participant were conducted approximately every six months. The goal of the interviews was to track the students' progress and investigate their beliefs of belonging in engineering, experiences in engineering, and obstacles encountered and how they dealt with them. In this paper, we present data from the first two sets of these longitudinal interviews conducted during the 2016 Spring and Fall semesters. To analyze this interview data, thematic analysis was chosen as the analytical approach [16]. This method was chosen due to its flexibility to examine general trends both inductively and deductively. This approach allowed for a quick data analysis to determine the most salient themes for each student. This ability to quickly analyze the data between interviews allowed for modification of interview protocol between rounds of interviews.

There were multiple considerations when thinking about the quality of the qualitative analysis. Walther et al. [17] recommends that data should have theoretical, procedural, communicative, pragmatic validation as well as process reliability. In compliance with this standard of quality in interpretive research, the research team conducted coding by multiple individuals who communicated difficult or abstract codes. Coding was done to consensus through weekly coding meetings. Additionally, the research team focused on using *in vivo* codes of students' own words and connecting larger themes to explicit quotations to discourage misinterpretation of students' interview responses. Transcripts were iteratively examined as more themes became evident to ensure procedural and theoretical validation [17].

Results

Examining both the normative and near-normative groups within this study, there were two results that came out of the data. First, both normative and near-normative students communicated that they believed anyone could do engineering, if the individual has willpower, endurance, and enjoyment then they can succeed in engineering. Second, there was a distinct difference between the normative and near-normative students in how they discussed why they pursued an engineering degree. This discussion had components that related to students' agency, identity, and motivation. Students who experienced high agency felt that they chose engineering, while students who had low agency felt that they were "pushed" into choosing engineering. Students' levels of perceived agency influenced their motivation in engineering as well as their development of an engineering identity.

Anyone Can Do Engineering

Engineering students across the normative and near-normative groups discussed that anyone could do engineering when prompted. This result is counter to many of the published findings on the lack of access and equity of engineering degree pathways for minoritized students [18]–[20]. Students leaned on a meritocratic view of who could do engineering in stating particular requirements for students to succeed in engineering. Quotes from several participants when asked, "Who can do engineering?" are presented below. Emphasis added by the researchers.

> **Anyone** that has the mindset going into college that **it's not going to be easy** and has the endurance to stick with it regardless of the grades you get and to not be scared by a challenge. (Christian, Near-normative, Interview 1)
>
> I feel like **anyone** could do engineering. I feel like you need to be **really determined, and want to do it.** (Keyla, Normative, Interview 1)
>
> I think **anybody** can if they really want to. Some people just don't really enjoy things that go into doing it like math. (Sean, Normative, Interview 1)
>
> It definitely takes **a lot of willpower** to get through programs and whatnot. Aside from that, I think **most people** could pull it off. (Shey, Near-normative, Interview 2)

Participants responded that engineering was available to anyone, yet also qualified this stance by discussing how willpower, endurance, and enjoyment of engineering were necessary. These quotes exemplify a view of engineering that is paradoxically both welcoming and exclusive. This narrative by students shows that the doors are open to anyone passing by, but without certain traits the original welcoming atmosphere shifts, leading students to feel out of place. This conditional treatment of success in engineering is indicative of engineering students' beliefs in their own abilities and intelligence. Additionally, the frequency of this type of response from students both within and outside of the normative group suggests that such an attitude may be pervasive in engineering students.

Agency

The other theme that emerged from data was students' linguistic patterns in how they described who and/or what influenced them to pursue an engineering degree. Students in the normative attitudinal group talked about how engineering was their choice. Students who were in the near-normative groups focused on how their parents encouraged them to pursue an engineering career. Sean, a normative student, described how he enjoyed engineering and that he chose engineering himself but was encouraged by his father.

> **I enjoyed it, so I kept at it…** As much as my dad has pushed me to do my best, he really leaves me up to make my own choices, so my parents are very supportive in the things I choose to do, but **they don't push me** in any one direction. (Sean, Normative, Interview 2)

Conversely, the near-normative group talked about how they felt pushed into pursuing engineering by someone important to them, be that a teacher or a parent.

> I guess my engineering teacher [in] high school… He kind of **pushed me** just seeing I was doing well in those classes. He kind of **pushed me** towards that and my parents both my mom and my dad kind of **pushed me towards it** too because they wanted to see me succeed and do well. (John Smith, Near-normative, Interview 1)

In the case of Sean, the decision to "keep at it," in conjunction with saying that his parents did not push him to choose engineering was the key distinction between these quotes. Listening to Sean speak about his influences, he spoke more often as the actor in his decision-making process using "I" and "me," which illustrates his own perceived agency over his choice of engineering. In contrast, John Smith spoke about his teacher as the actor in his throughout his description of why he chose engineering, using words like "he" and "they." John Smith discussed how his teacher and parents pushed him. The use of the word "push" repeatedly throughout his interview illustrated a limited agency in his choice of engineering, and that engineering was chosen for him by other influences in his life. This pattern is illustrated in another quote by John Smith where he talked about his parents wanting him to have a planned path in case of failure or a change of degree by applying into an engineering program over a tech program.

> [My parents] were like it would be easier to fall back to [engineering] than start in like that poly[technic] school and then try to go up within engineering, into the engineering school. (John Smith, Near-normative, Interview 2)

This quote further highlights that the driving "push" by John Smith's parents was more influential in his engineering career pathway than his own interests. John Smith shared that he was more interested in pursuing a hands on agricultural career, but that his parents felt that

engineering was a better pathway for him. These results may highlight particular challenges that students who do not feel that they have agency over their choice of degree pathway.

Discussion

The results to date of our work show that engineering students' beliefs about who can become an engineer, along with how students talk about their own identities in pursuing engineering can dramatically shape who belongs in engineering and how they succeed. By saying anyone can do engineering these students have implied that there are no barriers to becoming an engineer and that they believed all students needed was to be interested in the field or strongly motivated to earn an engineering degree. Yet, prior literature emphasizes multiple cases in which students do not feel recognized as an engineer, causing them to lose momentum and leave engineering at varying stages [2], [12]. Tonso [7] showed that a weak engineering identity can have dire effects on students' paths through engineering. In Tonso's study, Marianne, who was described as "a bona fide engineer… at the end of her senior year, had no job offers, agreed to work for her department as a teaching assistant in the summer, and seemed likely to become a high school math teacher" [7, p. 294]. Despite her success in the engineering team, her lack of identity from not being recognized by others as an engineer appears to have derailed her future as an engineer.

Anyone Can Do Engineering

Another emergent theme, paralleled findings by Godfrey and Parker [1], where they stated that diversity is not an important factor in the consideration of who can do engineering. This is not to say that everyone will feel welcome, but that when describing that hard work and interest are needed the participants are not considering obstacles faced by their peers, but the skills that they see their successful peers utilizing. To support this, the cases outlined by Godfrey and Parker [1] placed emphasis on teammates working hard and doing their part. This lack of consideration of obstacles can correlate to peer support being available up to the point that a student no longer provides benefit to their teammates.

To further support this conclusion, Cech [21] speaks of meritocracy within engineering. Particularly, the idea of meritocracy or governing or the holding of power by those with skill or ability resonates strongly within engineering culture. This focus on skills can result in turning a blind eye in many cases to factors such as race/ethnicity, gender, and socio-economic status. Engineering students tend to focus more on the passion and interest that other students present rather than differences among them. This result does not dispute that students may not create in and out groups based on visible demographic characteristics, like race and gender, but in discussing what it means to be an engineer, students do not recognize structural barriers that exist for diverse students. By perpetuating this cultural trait, the obstacles that students are encountering in becoming a part of the engineering culture are not being worn down.

Agency in Engineering

When examining students' agency and their development of an engineering identity, we found that parental influence can serve to build or undermine these constructs. Godwin et al. [3] discusses how students agency influences their choices in engineering. This agency or how empowered they feel to make decisions or changes draws parallels with identities discussed by Perez, Cromley and Kaplan in their 2014 paper [22]. In this paper achieved and foreclosed

identities are outlined, where the main distinction is the amount of exploration that students take in making decisions. An example of lacking agency and having a foreclosed identity, would be with John Smith's acceptance of pursuing engineering because he was pushed. This was not his own decision, and there was little exploration taken by the participant. Whereas having agency and thus an acquired identity comes from exploration and a decision by the individual, which is exemplified in the quotes by Sean. While his father wanted him to be an engineer, having sufficient agency led Sean to explore it, giving him an acquired identity and he chose to stick with engineering. From these identities, there is evidence that students' own agency in their decision to pursue engineering is an important factor in their success as an engineering student and potentially as an engineer in their future career.

In both cases, the malformation or breaking down of an engineering identity will have impacts on the retention of students within engineering. To improve students' formation of an engineering identity and thus increase interest and retention within the field of engineering, the recognition and reasonable support of students is of the utmost importance, particularly in the case of diversity.

Future Work

Based on this paper there are two important considerations to be made. First, students communicating that anyone can do engineering is due to their beliefs in their own abilities and what they expect from other engineers. Second, the fine line between encouragement and pushing of students to pursue engineering is an important consideration in the development of engineering identities.

Moving forward this work will continue to focus on the development of engineering identities, and how students talk about belonging in engineering. By comparing the different groups and the trajectories of the students within different groups, researchers can better understand the types of students in engineering and how they navigate through engineering cultures. One example is studying agency and how students with low agency navigate engineering when simply being good at math and science is not enough to support their efforts.

Furthermore, these results have multiple implications for how students choose and navigate engineering cultures. We should reconsider the effect of saying "anyone can do engineering" while upholding the ideal that certain traits are necessary to do engineering. This could lead to a broader discussion on diversity by eliminating the "don't ask, don't tell" culture in which students' backgrounds are not considered. Those conversations will hopefully open students' eyes to the variety of individuals in engineering, and possibly finding others with similarities to build community.

Conclusions

Through the explicit exploration of the variation in engineering student attitudes, we have begun to unpack how these attitudes may shape student experiences. In addition to establishing different attitudinal profiles in engineering, this project highlights how these attitudinal profiles manifest as students navigate engineering experiences. Here we have shown that all students,

regardless of group, believe anyone can be an engineer if they are willing to put in the work. Differences emerged across groups when examining how students selected engineering, with normative groups self-selecting and near-normative groups being pushed into engineering. These perceptions serve to guide how engineering students propagate engineering culture and provide grounding for how we support students in engineering.

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