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A Mixed-Methods Approach to Compare General and Discipline-Specific Engineering Role Identity Development in Upper-Division Students

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WIP: A Mixed-Methods Approach to Compare General and Discipline-Specific Engineering Role Identity Development in Upper-Division Students

Introduction

In this work-in-progress empirical research paper, we explore disciplinary differences in engineering role identity. Many studies have demonstrated that the development of engineering identity and a sense of belonging in engineering is important for retention and degree persistence [1]-[9]. Though some studies have reported cross-sectional data that includes upper-division students, most of this work has focused on first-year engineering students. These studies provide important insight into early identity development and factors that influence engineering career choice but offer limited nuance between engineering disciplines, which vary widely in enrollment and demographic composition [10]. Importantly, while first-year engineering students across disciplines generally take very similar courses, the junior and senior years of engineering programs feature distinct disciplinary contexts, which emphasizes the need to study the identity development of upper-division students. A cross-sectional study by Godwin and Lee [11] demonstrated that engineering identity increases with academic level and is highest in the fourth year, indicating that upper-division students are distinct from first-year students. Other qualitative longitudinal work by Scalaro et al. [12] examined the role of disciplinary interest, a subconstruct of identity, in guiding enrollment decisions. Furthermore, as students become more deeply socialized into their disciplines over time, the types of experiences that shape identity and the value placed on various sources of recognition change [13]. Together, this prior research points to differences in upper-division students' engineering identities, which have been understudied.

Potential differences in engineering identity development across engineering fields may arise from distinctions in how disciplines are developed and perceived. For example, disciplines like chemical, electrical, and mechanical engineering have long been established in higher education and have achieved relative homogeneity across universities. In this work, we refer to such fields as "high consensus," a term from organizational theory that encapsulates methodological, theoretical, and topical uniformity within a field of study [14], [15]. In contrast, disciplines like environmental and biomedical engineering are more emergent fields and can vary widely in content and scope across institutions—we refer to such fields as "low consensus." These classifications are not to be interpreted according to Kuhn's theory of consensus, wherein "low consensus" may suggest a lack of scientific rigor or maturity [16]. Importantly, high consensus disciplines may be more strongly represented in the social narrative of what it means to be an engineer. These differences indicate that the broad measures of engineering identity used in previous studies may not capture disciplinary nuances. For example, biomedical engineering students in a case study of capstone design reported a stronger science identity than an engineering identity, in contrast to previous work in which engineering identity was the strongest role identity in the fourth year for engineering students in various disciplines [11], [17]. Taken together, previous work demonstrating the potential nuance of engineering role identity development as a function of academic year and engineering discipline underscore the need for studies that probe these differences using discipline-specific identity measures.

In this work, we describe the first steps in a study to investigate differences in discipline-specific and general engineering identity development and socialization of upper-division engineering students. This study answers the following research question: How do general and discipline-specific engineering role identity and belonging compare as a function of engineering discipline among upper-division students?

Theoretical Framework

The concept of engineering role identity is founded in Gee's multiple identity theory, which posits that individuals hold as many identities as they do social roles [18]. Within an educational context, STEM role identities have emerged as an informative framework for better understanding students' experiences and development. Pioneering work with science professionals established three sub-constructs of science identity: recognition, performance, and competence [19]. Studies in physics and mathematics education established interest as an additional sub-construct for undergraduate students and demonstrated the theoretical equivalency of performance and competence, resulting in their combination into a single construct [20], [21]. Godwin demonstrated that this framework could be used to describe engineering identity and that engineering major choice is predicted by mathematics and physics identities [1], [4], [21], [22]. Similar work corroborated the use of these three constructs to describe engineering identity development in undergraduates [23], [24].

The sub-constructs of recognition, interest, and performance/competence describe both internal and external factors that shape the development of engineering identity. The recognition sub-construct encompasses a student's beliefs that meaningful others see them as the type of person who can do engineering, as well as their own sense of self-recognition. The interest construct captures a student's desire to learn engineering and has been shown to play a key role in engineering students' persistence. Finally, performance/competence beliefs refer to a student's beliefs in their ability to understand and do well in their role as a STEM student [6], [9]. Crucial to this study, recognition is an important factor that drives engineering career choice and, when lacking, can weaken engineering identity, particularly for underrepresented students [4], [25], [26]. Recognition beliefs may thus play a role in disciplinary differences in enrollment in engineering, as they could relate to cultural and social beliefs about what engineers do and who participates in engineering [27], [28]. This is closely related to sense of belonging in engineering, defined as "the experience of mattering or feeling cared about, accepted, respected, valued by, and important to the group," [29] which is important for engineering degree persistence [8], [30] and academic achievement [31].

In this work, we employ Godwin's engineering identity framework, with the sub-constructs of recognition, interest, and performance/competence, to investigate disciplinary differences in engineering identity development among upper-division students. While previous work has primarily measured general engineering identity (e.g., "I feel like an engineer"), this study also measures discipline-specific engineering identity using adapted survey items (e.g., "I feel like a biomedical engineer") to compare general and disciplinary identity. We also include general and discipline-specific sense of belonging, gender, and race/ethnicity as important related variables to evaluate relationships between engineering identity and other aspects of students' experiences.

Methods

We developed a survey instrument to measure engineering students' general and discipline-specific engineering identity by adapting Godwin's survey items using a 5-point anchored

numeric scale. Students are asked to respond to both general (e.g., “I feel like an engineer”) and discipline-specific (e.g., “I feel like a biomedical engineer”) survey items (13 items for each) based on their self-selected engineering discipline from a provided list of 21 common disciplines. Because belonging and engineering identity are closely related, we included six belonging items reported in a previously developed survey of undergraduate engineering students [32], [33]. Similarly, we adapted these items to measure students’ sense of belonging both within engineering as a broad field (e.g., “I belong in engineering”) and within their specific discipline (e.g., “I belong in biomedical engineering”). All engineering identity and belonging measures can be found in Tables 1-4 in the Appendix. Additionally, we included measures of turnover intentions and career commitment (13 items), using discipline-specific language to capture persistence beliefs, adapted from studies by Singh and Meyer [34], [35], [36]. We also asked students to provide demographic information, including gender, race/ethnicity, international/domestic status, parents’ education, and year of enrollment.

To pilot this survey, we distributed it to upper-division engineering students at a large, private university in the Northeast (IRB # 0150072). Of the 32 respondents, 21.9% were men and 78.1% were women. Only 3.1% of respondents were international students. Fifty percent of respondents were Asian, 46.9% were White, 6.3% were Black or African American, 6.3% were Latiné, 3.1% were Middle Eastern or North African, and 3.1% identified as a write-in option. Seven engineering disciplines were represented—chemical (37.5%), biomedical (15.6%), electrical (15.6%), software (12.5%), biological (9.4%), materials (6.3%), and mechanical (3.1%). All participants were enrolled in their junior or senior year of study.

Preliminary Results

While the number of responses to the pilot study was insufficient for inferential statistics, several insightful points arose from this phase of data collection. All data is summarized in Table 5 in the Appendix. For both recognition and interest, most respondents scored the general engineering items higher than their discipline-specific counterparts. This trend might suggest that students perceive their identities as engineers to be more salient in these contexts than their identities as a particular type of engineer. For performance/competence, students on average scored the discipline-specific items higher (e.g., “I can do well on exams in engineering” versus “I can do well on exams in biomedical engineering”). While we cannot determine causality with these data, one explanation may reflect the specificity of upper-division coursework; alternatively, students who persist in their degree pathways may hold higher disciplinary engineering identities. For belonging, students in all disciplines except biological and biomedical engineering reported a greater sense of belonging in general engineering than in their disciplines, while students in biological and biomedical engineering reported a stronger sense of belonging in their disciplines. This trend may represent potential discrepancies between students’ lived experiences and societal perceptions of what it means to be an engineer—notably, both biomedical and biological engineering are newer disciplines that we categorize as low-consensus.

Two students wrote that they wished they had selected a different engineering discipline. These feelings were reflected in their recognition beliefs, interest, and belonging, which were significantly lower for discipline-specific measures than for general engineering measures. One student provided equivalent rankings of their general and disciplinary performance/competence beliefs, whereas the other reported notably higher performance/competence in general engineering than in their discipline, in contrast to the trend observed for the total group of respondents. These observations suggest that engineering field choice satisfaction is an important

consideration for the national survey distribution, as students' feelings towards their discipline may significantly impact identity and belonging measures.

Next Steps

In the next phase of this study, the survey will be distributed to doctoral-granting institutions across the United States with a target of 2000 responses. Institutions will be stratified by enrollment size, and some engineering disciplines will be oversampled to collect comparable responses from the largest engineering disciplines, as listed in the annual ASEE report, "Profiles of Engineering and Engineering Technology" [10]. A subset of volunteers will be interviewed using a semi-structured protocol to better understand their disciplinary experiences and the nuances of their engineering identity development. Survey data will be analyzed for disciplinary trends in general and discipline-specific engineering identity and belonging measures. Interview transcripts will be coded using thematic analysis to identify underlying beliefs and experiences that may contextualize students' experiences within their engineering disciplines. Nuances between disciplines may be more apparent in recognition from certain meaningful others, such as professors, other engineers, or oneself, than from individuals like parents, who may not fully appreciate the distinctions among types of engineers. This possible explanation aligns with prior work about how recognition sources shift throughout undergraduate education [37]. Students' sense of belonging may also vary across disciplines, particularly for low-consensus fields of engineering that are less represented in the social narrative surrounding what it means to be an engineer. In the context of this larger study, we will also seek to answer an additional research question: How do demographic enrollment trends and engineering role identity development relate across engineering disciplines? The interview responses will provide crucial insight into why these differences may arise and how we can use the results of this work to impact educational practice through discipline-specific targeted curricular and programmatic interventions that address challenges in engineering education with greater nuance.

Conclusions

In this work-in-progress empirical research paper, we describe the development of a study to investigate disciplinary differences in engineering students' general and discipline-specific engineering role identity and sense of belonging. In future work, we will examine if students in low-consensus disciplines, many of which are characterized by relatively high enrollment by women, hold different general and discipline-specific identity and belonging beliefs relative to students in high-consensus disciplines. A pilot study of 32 students suggests that differences between general and discipline-specific measures may exist, and students' degree of satisfaction with their engineering field choice may offer crucial insights for contextualizing responses. Our goal is to offer nuanced insight into disciplinary experiences of engineering students to inform targeted educational reform that seeks to broaden participation across all engineering fields in the service of a more diverse engineering workforce.

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Appendix

Table 1: Survey items used to measure general engineering role identity.

Construct	Question	Item
	Q 1.1	I see myself as an engineer.
Recognition	Q 1.2	My parents see me as an engineer.
	Q 1.3	My instructors see me as an engineer.
	Q 1.4	My peers see me as an engineer.
	Q 1.5	I have had experiences in which I was recognized as an engineer.
Interest	Q 1.6	I am interested in learning more about engineering.
	Q 1.7	I enjoy learning engineering.
	Q 1.8	I find fulfillment in doing engineering.
Performance/ Competence	Q 1.9	I am confident that I can understand engineering in class.
	Q 1.10	I am confident that I can understand engineering outside of class.
	Q 1.11	I can do well on exams in engineering.
	Q 1.12	Others as me for help in this subject.
	Q 1.13	I can overcome setbacks in engineering.

Table 2: Survey items used to measure discipline-specific engineering role identity. The "X" variable was replaced with students' self-selected engineering major.

Construct	Question	Item
	Q 2.1	I see myself as an X engineer.
Recognition	Q 2.2	My parents see me as an X engineer.
	Q 2.3	My instructors see me as an X engineer.
	Q 2.4	My peers see me as an X engineer.
	Q 2.5	I have had experiences in which I was recognized as an X engineer.
Interest	Q 2.6	I am interested in learning more about X engineering.
	Q 2.7	I enjoy learning X engineering.
	Q 2.8	I find fulfillment in doing X engineering.
Performance/ Competence	Q 2.9	I am confident that I can understand X engineering in class.
	Q 2.10	I am confident that I can understand X engineering outside of class.
	Q 2.11	I can do well on exams in X engineering.
	Q 2.12	Others as me for help in this subject.
	Q 2.13	I can overcome setbacks in X engineering.

Table 3: Survey items used to measure general sense of belonging in engineering.

Question	Item
Q 3.1	I feel comfortable in engineering.
Q 3.2	I feel I belong in engineering.
Q 3.3	I enjoy being in engineering.
Q 3.4	I feel comfortable in my engineering classes.
Q 3.5	I feel supported in my engineering classes.
Q 3.6	I feel that I am part of my engineering classes.

Table 4: Survey items used to measure discipline-specific sense of belonging in engineering. The "X" variable was replaced with students' self-selected engineering major.

Question	Item
Q 4.1	I feel comfortable in X engineering.
Q 4.2	I feel I belong in X engineering.
Q 4.3	I enjoy being in X engineering.
Q 4.4	I feel comfortable in my X engineering classes.
Q 4.5	I feel supported in my X engineering classes.
Q 4.6	I feel that I am part of my X engineering classes.

Table 5: Summary and descriptive statistics of pilot study results. "R" stands for "Recognition," "I" for "Interest," "PC" for "Performance/Competence," "B" for "Belonging," "G" for "General engineering," and "DS" for "Discipline-specific." Numbers represent mean ± standard deviation.

Discipline	N	R-G	I-G	PC-G	R-DS	I-DS	PC-DS	B-G	B-DS
Biological	3	3.73 ± 1.10	3.33 ± 1.41	3.27 ± 1.22	3.53 ± 0.92	3.89 ± 1.05	3.67 ± 1.05	3.28 ± 1.23	3.78 ± 0.94
Biomedical	5	3.88 ± 1.01	4.13 ± 1.30	3.72 ± 0.79	3.72 ± 1.17	3.73 ± 1.28	4.04 ± 0.79	3.33 ± 0.84	3.60 ± 0.89
Chemical	12	4.23 ± 0.98	4.22 ± 0.90	3.77 ± 1.13	4.05 ± 0.98	4.06 ± 0.92	3.83 ± 1.17	4.03 ± 1.17	3.96 ± 1.37
Electrical	5	4.04 ± 0.89	4.07 ± 0.96	3.80 ± 0.91	4.08 ± 0.91	4.13 ± 0.92	3.84 ± 0.94	3.87 ± 0.90	3.83 ± 0.76
Materials	2	4.60 ± 0.70	4.83 ± 0.41	3.70 ± 1.16	3.78 ± 1.30	4.17 ± 0.98	3.60 ± 1.07	4.67 ± 0.65	3.92 ± 1.38
Mechanical	1	3.20 ± 1.10	4.67 ± 0.58	2.80 ± 0.84	3.00 ± 1.00	4.67 ± 0.58	2.60 ± 0.89	3.17 ± 0.75	3.17 ± 0.98
Software	4	4.17 ± 0.70	4.47 ± 0.83	3.56 ± 0.92	3.96 ± 0.73	4.20 ± 0.77	3.56 ± 0.51	3.79 ± 1.02	3.75 ± 0.74

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