2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION
Paper ID #51888

Development of a Survey to Investigate Graduate Student Engineering Identity Development Across Disciplines

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WIP: Development of a Survey to Investigate Graduate Student Engineering Identity Development Across Disciplines

Introduction

Women and Black, Latiné, and Indigenous populations remain significantly underrepresented in engineering graduate programs—in 2023, women comprised only 27% of engineering doctoral students, Latiné students only 10.6%, and Black or African American students a meager 5.6% [1]. Despite national calls to reform graduate engineering education to address structural issues that affect graduate degree attainment, minoritized populations continue to be underrepresented in the STEM workforce [2], [3]. Enrollment of women students in particular varies widely by engineering discipline—for example, women represented 41.6% of doctoral students in biomedical engineering in 2023, but only 16.7% of doctoral students in aerospace engineering [4]. These stark differences highlight the importance of developing discipline-specific insights into graduate engineering education to better design educational reforms. Importantly, attrition from engineering graduate programs remains high; early work suggests that the overall ten-year engineering Ph.D. completion rate is only 57% [5]. Women not only depart engineering graduate programs at higher rates than men [5], [6] but also report significantly higher attrition considerations than men, suggesting experiential differences during graduate engineering education [7]. These data underscore the importance of studying disciplinary experiences of engineering graduate students to understand how developing identities as engineers within disciplines, feelings of belonging within their chosen field, and intentions to persist may be addressed to broaden participation.

Numerous studies have demonstrated that the development of engineering role identity and feeling a sense of belonging impact degree retention and persistence in undergraduate engineering students [8], [9], [10], [11], [12], [13], [14], [15]. Engineering role identity has been defined as "an individual's sense of belonging to engineers and engineering" [16] and includes how students see themselves as engineers, researchers, and contributors within their field. While significantly fewer studies have been conducted on graduate students, some work suggests that completion intentions for graduate education are positively correlated with engineering identity [17], [18]. A strong engineering identity (especially researcher identity) reduces perceived task difficulty and fosters persistence, whereas indicators of discrimination and lack of socialization lead to identity disruption and attrition intentions [19].

Bahnson and colleagues [20] demonstrated that graduate engineering identity varies by discipline, underscoring the need for further work to describe the development of disciplinary engineering identity. Additionally, current graduate engineering identity work has not explored the impact of students' undergraduate engineering field on overall identity development. Because some students undergo a disciplinary transition between undergraduate and graduate education, engineering identity formation may be more complex and nuanced at the graduate level than undergraduate. Furthermore, previous work has shown that STEM identity factors may influence how women select their undergraduate engineering fields, suggesting that engineering identity could differentially inform graduate field selection [21]. This work-in-progress study develops a survey to explore factors that inform graduate engineering field selection through the lens of disciplinary engineering role identity, sense of belonging, and turnover intentions.

Theoretical Frameworks

Identity Theory

Multiple identity theory posits that individuals hold a multiplicity of identities, including role (social relational position; e.g., engineer, mother, etc.), social (membership of a group; e.g., white, woman, etc.), and personal (unique traits, choices, and experiences; e.g., hiker, introvert, etc.), as a function of their roles in society [22]. These multiple identities are more or less salient in different contexts and shape how students perceive themselves in specific roles. This saliency is important to consider in how individuals experience different engineering disciplines and may more or less strongly identify with a particular social role [23].

Engineering identity—seeing oneself as an engineer—has been established as a key framework for understanding engineering students' educational experiences. This framing was initially established in undergraduate education research and has more recently been taken up in graduate education research. In this work, engineering role identity is comprised of three constructs: 1) interest in the subject area, 2) recognition beliefs that meaningful others see one as the kind of person that can do the role, and 3) performance/competence beliefs that one can both do well and understand key concepts in the domain associated with the role [8], [11], [24], [25]. Prior research has connected engineering identity to numerous important student outcomes, including persistence in engineering degree programs, motivation, belonging, and well-being [11], [21], [22]. Additionally, this work has found that identities in other STEM domains, such as mathematics and physics, are important predictors of engineering major choice at the transition from high school to college, underscoring the value of this framework for understanding engineering career pathways through education systems [11], [24].

Several studies have sought to adapt this framework for graduate engineering students. Choe and Borrego proposed the addition of a researcher sub-domain to better describe engineering role identity in graduate students and emphasized the importance of interpersonal communication skills competence as a part of this role [26], [27], [28]. Additional work pioneered by Kirn and colleagues utilized a mixed-methods approach to further develop a quantitative measure of graduate engineering identity through qualitative interviews, focus groups, and surveys, establishing three crucial identity domains of engineer, researcher, and scientist [29], [30], [31], [32]. Each of these identity domains uses separate measures of performance/competence, interest, and recognition specific to each role, like the well-established undergraduate engineering role identity framing. The addition of the researcher and scientist identity domains reflects the unique nature of graduate engineering education, which emphasizes students' research progress and individual development more than disciplinary coursework, which is the focus of undergraduate engineering education. This framework was further developed to uncover nuances in the recognition sub-construct, highlighting the importance of the advisor relationship, research experience, and peer interactions as graduate students develop identities as researchers and scientists [33], [34].

Belonging

Feeling a sense of belonging is a basic human need that is important for degree persistence [15], [35] and academic achievement [36], and a lack of belonging remains a chief cause for attrition of women and underrepresented minorities from engineering [37]. Previous work produced the Measures of Belonging in Higher Education (MBHE) instrument [38], which was adapted to

measure undergraduate students' beliefs in an engineering context [39]. Belonging, defined by Strayhorn as "the experience of mattering or feeling cared about, accepted, respected, valued by, and important to the group" [40] is related to engineering role identity (particularly recognition beliefs) and is an important dimension to understand graduate students' disciplinary experiences.

In this work, we leverage the engineering role identity framework to investigate students' disciplinary role identities in both their undergraduate and graduate degree fields. We include sense of belonging, turnover intentions, graduate program type, gender, and race/ethnicity as important related variables to better capture students' experiences in their graduate engineering programs and the factors that drive graduate field selection.

Methods

We developed a survey instrument to measure graduate students' disciplinary engineering identity in their undergraduate and graduate engineering fields, decision-making, and attrition. We adapted the engineering measure from Kirn and colleagues' work [20] to include students' specific engineering disciplines. For students who remained in the same engineering field between undergraduate and graduate study, both general and disciplinary engineering identity were measured (Table 1), while for students who transitioned between fields, disciplinary engineering identity measures were presented for both their undergraduate and graduate degree fields. We also asked students to describe their disciplinary identity in an open-response question. Additionally, we asked students to rate the importance of several factors to their graduate degree selection, combining previously reported career satisfaction factors with specific question items, and we included an open-response question asking students to describe the factors that had the greatest influence on their decision to pursue their graduate degree field.

To measure students' sense of belonging, we included items from the previously described instrument used in an undergraduate engineering context [39], [41], [42]. To adapt this measure to the graduate setting, which usually de-emphasizes classroom learning in favor of research activities, we removed class-specific items (i.e., "I feel comfortable in my engineering classes"). Students who did not transition between engineering fields were asked to report both their general and discipline-specific sense of belonging in engineering, while students who did transition fields were asked to report their sense of belonging in both their undergraduate and graduate fields of engineering. We also included a measure of students' turnover intentions and career commitment using a set of reported survey items, adapted from previous works by Singh and Meyer [43], [44], [45]. For these items, we included students' graduate engineering field choice. Finally, we included demographic items, including age, gender, race/ethnicity, and international/domestic status, and programmatic features, including type of degree program, year of enrollment, and undergraduate and graduate engineering fields, offering a list of 21 common disciplines from which to choose.

To pilot this survey, we distributed it at a large, private university in the Northeast (IRB # 0150072) and included open-ended questions to solicit respondents' feedback on each section. Recruitment of participants was limited to individuals who had completed an undergraduate degree in engineering and were currently pursuing or had recently completed a graduate degree in engineering. Of the 14 respondents, six evaluated the survey items and provided preliminary feedback in the open-response sections, while eight both completed the survey measures and

offered feedback. For the respondents who completed the survey, 71% were male, 29% were female, 42.8% were White, 42.8% were Latiné, and 14.3% were Black or African American. All participants were domestic students. Finally, 75% of respondents remained in the same degree field between undergraduate and graduate school.

Table 1: Survey constructs and example items

Construct	Number of Items	Example Item
Engineering identity (general)	15	"I see myself as an engineer."
Engineering identity (discipline-specific)	15	"I see myself as a chemical engineer."
Scientist identity	15	"I see myself as a scientist."
Researcher identity	16	"I see myself as a researcher."
Advisor relationship	8	"My advisor values my work."
Degree selection factors	16	"Offered research opportunities I was interested in"
Belonging (general)	3	"I feel I belong in engineering."
Belonging (discipline-specific)	3	"I feel I belong in chemical engineering."
Turnover intentions	3	"I often think about quitting chemical engineering."
Career commitment	10	"I am enthusiastic about chemical engineering."

Preliminary Results

Participants offered several insightful points of feedback in the open-response sections of the pilot survey, some of which were addressed in early revisions as responses were received. For example, several participants suggested including additional demographic items in order to better understand respondents' individual contexts, such as the types of institutions attended for undergraduate and graduate study (i.e., R1, R2, primarily undergraduate institution), the type of work experiences acquired prior to graduate study, whether or not participants matriculated directly into graduate school or worked prior to entry, and what type of research they conduct. These factors may be important to understand more nuanced reasons for respondents' graduate school decision making—for example, if a respondent places the most value on proximity to family, they may select an in-state graduate program, offering less consideration to the research opportunities afforded by the program than a respondent who places the most value on the opportunity to work with a specific PI. Additionally, respondents preferred a 5-point anchored numeric scale over a 7-point scale, citing the ease of response. The survey will be revised to reflect these changes, both to improve accessibility and to better capture respondents' holistic experiences throughout their academic careers.

Respondents ranked several factors as most important for their selection of a graduate program. Overall, the most important factor was "offered research opportunities I was interested in," with an average score of 4.4/5. Another crucial factor was "opportunity to work with a specific PI,"

which scored 4.1/5. In the “other” factors field, one participant noted “internal fellowships” as highly important for their program selection. Of the career satisfaction items, “developing new knowledge and skills” and “working with people” were the most important factors. When asked to describe the reasons for their graduate field selection, respondents who remained in the same engineering field for both undergraduate and graduate study frequently cited research opportunities and the ability to apply their existing knowledge to new contexts as important drivers.

For the respondents who transitioned between engineering fields, both noted that their undergraduate institutions did not offer their desired engineering discipline as a major, and they selected the undergraduate major that was most aligned with their long-term career goals. These students reported increases in their disciplinary engineering identity and sense of belonging in graduate school as the field aligned better with their career goals. For participants who stayed in the same engineering field during undergraduate and graduate study, their general engineering identity and belonging responses were similar to their disciplinary identity and belonging responses. Overall, participants indicated a strong sense of commitment to their graduate engineering fields, with statements like “I am proud to be a chemical engineer” or “I think I will be working in chemical engineering 5 years from now” consistently scoring above the median.

Conclusions and Next Steps

In this study, a pilot survey instrument was developed and distributed to a small sample of participants to gather feedback on how well it captured factors that inform graduate field choice, with a focus on discipline-specific engineering identity development among graduate engineering students. Participant feedback offers insight into additional measures that could be added to better understand students’ experiences and decision-making considerations. Additionally, the pilot results successfully captured nuances in the educational experiences of individuals who transitioned between engineering fields during graduate study, compared with those who stayed in the same field, suggesting that this survey will generate rich data when deployed nationally. In the next phase of this study, the survey will be revised in alignment with participants’ feedback and distributed to students at Ph.D.-granting institutions across the United States, stratified by graduate enrollment. To better contextualize participants’ survey responses, semi-structured interviews will be conducted with a subset of volunteers, offering deeper insight into holistic disciplinary engineering identity development. Data collected will also undergo factor analysis procedures associated with Classical Test Theory to generate evidence for fair use across contexts. This study adds to our current understanding of engineering identity in graduate students by offering discipline-specific insights and considering the impact of undergraduate engineering study on holistic engineering identity development throughout an academic career.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant Number 2430496. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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