Discrimination & Identity: How Engineering Graduate Students Navigate Pathways to Persistence

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Introduction

Traditionally underserved students, namely racially minoritized students and women, remain underrepresented among engineering doctoral degree holders [1, 2, 3]. Retention and degree completion rates are consistently low, even as more racially minoritized students and women are recruited into engineering graduate programs [1, 2]. A consistent reason that students leave engineering graduate programs is racism and sexism embedded in interpersonal interactions and institutional policies [4, 5, 6, 7]. Engineering identity—an individual’s sense of belonging to engineers and engineering—may be one factor that can help explain why traditionally underserved students persist and remain in engineering graduate education.

Discrimination in Engineering Graduate Education

Discrimination is inequitable and differential treatment based on social identities such as gender, race, or sexual identity [8]. Discrimination is when individuals and institutions enact bias and prejudice on the individual and is rooted in systematic oppression. In engineering graduate education, discrimination is reflective of discipline culture, institutional policies, and interpersonal relationships [9, 10]. This discrimination is the result of and results in disparities in graduate engineering degree holders [11]. Discrimination experiences that traditionally underserved students face in STEM is also detrimental to psychosocial and educational outcomes including mental and physical health [12]; and continued participation in their chosen field following graduation [13].

In this study, we focus on racial and gendered discrimination, which are rooted racism and sexism. Engineering graduate students regularly experience discrimination which undermines their racial and gender identities, which in turn denies students of identity related social, emotional, personal, and academic recourses that facilitate success [4, 5, 6, 7]. The denial of identity related resources reinforces stereotypical gendered roles and systematically isolates racially minoritized students by reinforcing white patriarchal heterosexual behavior norms as an inherent part of engineering development [10, 14, 15, 16, 17]. For example, Black men in graduate engineering programs experience racial microaggressions and report that faculty and peers do not value their identities and communities that are a necessary aspect for successful degree completion, thus leaving students feeling isolated [6, 7]. Similarly, women in graduate engineering programs reported less support from peers and faculty while being required to perform tasks not required of men, such as coordinating social events, cooking, cleaning, and ordering beverages or food [4].

Engineering Identity in Graduate Education

Engineering identity is the degree to which individuals see themselves as a part of a wider engineering community, including feelings of belonging in engineering and connectedness
to the qualities and skills of engineers [18, 19]. Engineering identity was used to better understand the pathways students follow into the engineering profession including attrition in undergraduate engineering, persistence to degree completion, and career choice [20, 21]. Scholars found that undergraduate engineering identity, where sense of self was connected to being an engineer, was positively related to undergraduate degree completion and intention to choose engineering as a career [19, 20]. Researchers also found that, for undergraduate engineering majors, strong engineering identity buffered feelings of isolation and not belonging for first generation college students [21]. For engineering students, feeling like an engineer is one interpersonal factor that supports success in engineering graduate education and post-education career decisions.

At the graduate level, scholars conceptualized a multidimensional framework of engineering identity to capture the varied and unique ways that graduate students integrate engineering into their sense of self [22, 23]. In this framework, graduate engineering identity (GEI) includes recognition, interest, and performance/competence. Recognition represents ways faculty and peers recognize the student as being an engineer. Interest indicates the students’ desire to participate in aspects of engineering. The ability to complete tasks and confidence in one’s ability to complete tasks is represented by the sub-construct performance/competence [24]. Further, at the doctoral level, each component of graduate engineering identity can be specific to engineering or research [24]. GEI represents how students see themselves as part of an engineering community with advanced degrees, knowledge, skills, and research ability to solve complex engineering problems [22, 23].

Engineering identity develops from factors that signal membership in the engineering community: research advisor and peer relationships [25], research experience [26], and research lab experiences and peers [27, 28]. These experiences in graduate school can support or inhibit feelings of belonging and GEI development. Peer and research advisor attitudes, research lab composition and communication influence the development of engineering identity providing opportunities for intervention to improve belongingness in engineering communities [26, 27, 29]. Similarly, research experience and belonging to a research lab give students an opportunity to develop their engineering identity and sense of belonging within engineering [30]. Courses, internships, and research in graduate education directly contribute to specific engineering identity constructs by supporting student development in interest, competence, and recognition which are all key components of graduate engineering in-group identification [31].

**Goals of the Current Project**

Researchers have proposed that strong engineering identity is a predictor of persistence and success in engineering. Research on engineering identity, recruitment, and retention has largely focused on undergraduate students and demonstrates that experienced bias affects undergraduate students’ decision to choose engineering or to leave engineering. The paucity of research on marginalized graduate students leaves the engineering community with little empirical evidence for improving the state of graduate education. Similarly, research on bias has been largely limited to undergraduate student experiences, resulting in bias measures that do not capture the unique context and experiences of graduate education. In addition, bias research studies STEM fields collectively, whereas we plan to focus specifically on engineering and
individual disciplines within engineering. By applying an intersectionality lens to our research, we will address these gaps through the investigation of graduate engineering students’ experiences of perceived bias and the effect of bias experiences on engineering identity development.

The goal of this project is to understand experiences of bias and discrimination in engineering graduate education and their effect on graduate engineering identity and degree persistence. Through a mixed-methods approach, we are investigating the following research questions:

1. How do engineering graduate students conceptualize their own identities and experience bias and discrimination based on those identities?
2. How does existing as a marginalized person in a graduate engineering program and experiencing bias and discrimination affect engineering identity?
3. How does engineering identity mitigate the effects of experiencing discrimination and bias?
4. How can racial, gendered, and other identities support engineering identity development? How can identity be leveraged to support student persistence, performance, and participation in graduate engineering?

A mapping of the research questions (RQ) to the study design can be found in Figure 1.

Phase 1 Methods and Findings

This project is a multi-method longitudinal investigation. In Phase 1, 30 graduate engineering students participated in 60-minute qualitative semi-structured interviews about their
experiences and relationships in graduate school. Participants were Asian women (n = 5), African American woman (n = 1), Hispanic/Latina/White-Hispanic Women (n = 5), North African woman (n = 1), white women (n = 10), Asian men (n = 3), Hispanic/Latino men (n = 2), and Middle Eastern men (n = 3) who all attended graduate school in the U.S. Participants represented twenty-one (21) universities and seventeen (17) distinct engineering disciplines. Fifteen identified as international students. Five participants identified as bisexual, and all others as heterosexual. Most participants were in their second year of graduate school (n = 19) with others ranging from year three to seven. Participants were recruited through an email invitation that described the interview as being about experiences in engineering graduate education and included a link to a participation survey that included participation information and demographic survey items. Pseudonyms are used throughout to protect confidentiality. Participants were offered the opportunity to select a pseudonym; for those that declined, the authors randomly assigned pseudonyms.

A social constructivist approach guided the development of the interview protocol and analysis of interviews [32]. The interview protocol began with day-to-day experiences to allow participants to describe their experiences without priming them to discuss discrimination or bias experiences. Participants described their typical day, and the interviewer asked follow-up questions to clarify relationships and to seek additional examples or narratives about the participant’s experiences. The data-making process combines the construction of participant narratives in interaction with the interviewer and compares and interprets narratives by the research team to uncover meaning to identify ruling relations embedded in sexist and racist power distortions within engineering. Students’ perceptions of their experiences shape their interpretations of behavior and responses to others. We used comparative analysis to highlight, situate, and specify the ruling relations that inform traditionally underserved students’ experiences within engineering graduate education.

We have completed Phase 1, a qualitative analysis of semi-structured interviews with graduate engineering students. Results from this phase have provided some answers to RQs 1 and 2. Graduate engineering students experience discrimination based on race and gender throughout their graduate programs, primarily from peers and faculty. These experiences of discrimination detract from a positive engineering identity and contribute to mental health concerns. Graduate engineering students who experience discrimination seem to accept that these experiences are part of the graduate education experience and unavoidable. Women and Men of Color and white Women experienced being treated differently by peers, faculty, and advisors in settings such as classrooms, offices, and labs. Five themes emerged from participant narratives: Talking Matters, Faux Allies, Privileging Practices, Self-Reflections, Affirmation. A superordinate theme illustrates the interaction of the themes in student experience: Recognizing and Resisting Ruling Relations. Three significant findings can be distilled from the themes and the ruling relations they highlight: (1) marginalized students recognize some of the norms and systems that marginalize them; (2) interactions that marginalize students are set into the social fabric of engineering and include excluding some students while including others; and (3) everyday interactions sustain and reproduce the oppressive norms.
Phase 2 Methods and Findings

Following the qualitative interviews of Phase 1, we launched a national survey of graduate engineering students to understand discrimination experiences and identity in relation to degree persistence. Engineering graduate students from across the U.S. were recruited through a survey emailed to graduate program directors or department chairs. We chose to target a subset of graduate programs from a list of 1,374 doctoral degree granting engineering programs across 244 institutions that was compiled from three years of data from the National Science Foundation’s Survey of Earned Doctorates [33]. Use of three years of data allowed for inclusion of smaller programs that did not have graduates every year. We sampled graduate engineering programs based on population proportion in four criteria: 1) U.S. state, 2) engineering discipline (i.e., biomedical, industrial), 3) engineering college, and 4) program size. We used the number of doctorates awarded between 2014 and 2017 as our measure of program and college size. We created categories to represent one-third of the sample for program size by number of doctorates awarded by that program: small (1-6), medium (7-19), or large (19-225). Similarly, based on number of doctorates awarded, three groups for engineering college represented one-third of the sample: small (1-26), medium (27-114), and large (115-992).

Using a random number generator, programs were selected into the sample to match the population proportion criteria. We then compared the sample to the population descriptive statistics to identify and correct an under or over-representation in the sample. Across the four criteria, none were allowed to be over or underrepresented by more than one program. In addition, purposive sampling targeted Hispanic Serving Institutions, Historically Black Colleges and Universities, and Pacific-Islander serving institutions to increase representation of historically marginalized student voices. The program chair or graduate program director for each selected program was identified from university websites. The program representative received up to three email requests to distribute the survey to their graduate students. If we received no reply from the representative and no responses from that program were recorded, the program was replaced with a matched program.

A total of 913 engineering doctoral students participated representing 113 universities and 23 engineering disciplines. These participants completed at least 50% of the survey items. Regarding gender, 36% of the sample identified as men, 53% identified as women, 1% identified as another gender identity (e.g., non-binary, genderqueer), and 10% did not indicate their gender. For race/ethnicity, 0.7% of the sample identified as American Indian or Alaska Native, 28.9% as Asian, 2.6% as Black or African American, 7.8% as Hispanic, Latino/Latina/Latinx, or Spanish origin, 3.4% as Middle Eastern or North African, 0% as Native Hawaiian or Other Pacific Islander, 41.7% as white, 1.2% as another race or ethnicity not listed above or more than one option, and 13.7% did not identify a race/ethnicity. For demographics by race/ethnicity and gender see Table 1. Other demographic characteristics of the sample demonstrate representation of a wide range of students: sexual minorities (20%), students originating outside of the U.S. (40%) and students living with a disability (29%). With regard to representation across engineering disciplines, the largest disciplines were 30.9% of participants from Mechanical Engineering, 10.4% from Biomedical Engineering while the smallest were Engineering Physics (0.2%), Nuclear Engineering (0.3%), and Ocean Engineering (0.4%).
Table 1. Participant Reported Gender and Race/Ethnicity (n = 913)

<table>
<thead>
<tr>
<th>Race/Ethnicity</th>
<th>Women</th>
<th>Men</th>
<th>Another Gender Identity</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Indian or Alaska Native</td>
<td>1</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Asian</td>
<td>99</td>
<td>174</td>
<td>0</td>
</tr>
<tr>
<td>Black or African American</td>
<td>5</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>Hispanic, Latino, or Spanish origin</td>
<td>24</td>
<td>16</td>
<td>3</td>
</tr>
<tr>
<td>Middle Eastern or North African</td>
<td>40</td>
<td>46</td>
<td>3</td>
</tr>
<tr>
<td>Native Hawaiian or Pacific Islander</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>White</td>
<td>152</td>
<td>202</td>
<td>4</td>
</tr>
<tr>
<td>Multiracial/multiethnic or another race/ethnicity not listed</td>
<td>1</td>
<td>11</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: Participants could select multiple gender identities, races, or ethnicities. 104 participants did not respond to either or both race/ethnicity or gender identity questions.

From the data in Phase 2, we developed and validated the Discrimination in Engineering Graduate Education (DEGrE) Scale to identify and measure gender and race/ethnicity-based discrimination experiences specific to engineering graduate education [34]. Through exploratory factor analysis, we identified a 27-item scale that measures racial and gendered discrimination in engineering graduate education across six dimensions: Participation, Class Faculty, Lab Faculty, Sexism, Lab Peers, and Advisor Racism. Confirmatory factor analysis provided additional evidence to support the six-factor structure, particularly in comparison to a single-factor solution. Each dimension covers specific areas of graduate student experience. The Participation dimension measures lack of participation and belongingness due to racism and sexism. Class Faculty focuses on interactions with faculty, including advisors, within a classroom setting while Lab Faculty focuses on interactions with advisors and faculty within a research lab. The Sexism dimension measures sexism experiences and belongingness related to sexism. The Lab Peers dimension specifically covers interactions with peer graduate students within the lab setting. Finally, the Advisor Racism dimension specifically focuses on differential treatment of racial and ethnic groups by research advisors.

We also found evidence of convergent and concurrent validity, where the DEGrE subscales related to graduate students reports of their relationships with advisors and peers, unfair treatment, and consideration for changing labs, advisors, or leaving the program. Altogether, our findings provide strong preliminary evidence that the items and factor structure of the DEGrE scale are appropriate to use in research on the experiences of students who pursue graduate education in engineering. Evidence suggests that degree completion in graduate engineering is low, and particularly low for students from minoritized race and gender groups [1]. The DEGrE scale provides a tool to assess the discrimination experiences that students have and can help improve decision-makers’ ability to provide structural changes to support retention and graduation.
With the newly developed DEGrE scale, we then investigated the associations between discrimination experiences, engineering identity, and doctoral degree completion intentions among a national sample of doctoral engineering students (RQ3). Using structural equation modeling, we examined whether discrimination experiences in engineering graduate education have a negative association with graduate engineering identity and degree completion intentions for racially marginalized graduate engineering students. We included engineering and researcher domains of engineering identity, as well as sub-constructs of each in our model (recognition, interest, performance/competence). We found that the type of discrimination students endured and their own positionality with regard to race/ethnicity and gender are important determinants to both graduate engineering identity and intentions to complete the graduate degree. We also tested mediation, investigating whether the association between discrimination in graduate engineering and degree completion intentions is mediated by graduate engineering identity. We found support for a mediation model, wherein discrimination in engineering graduate education threatens graduate engineering identity, which then undermines intentions to complete the graduate degree. This mediational path varies depending on the minoritized or privileged status of students in terms of their race/ethnicity and gender. The predominance of unsupportive white environments isolate students, and then students are more likely to leave and consider leaving their doctoral education programs.

**Phase 3 Methods and Findings**

In Phase 3, we conducted follow up semi-structured interviews with the participants from Phase 1 to understand how their experiences have changed over time, and how their racial and gendered identities have influenced their decisions to persist in their original degree program, change programs, or leave the original program. We conducted interviews with twenty participants from Phase 1. Participants were Asian women (n = 5), Hispanic/Latino woman (n = 1), white women (n = 9), Asian men (n = 2), Hispanic/Latino man (n = 1), and Middle Eastern men (n = 2) who all attended graduate school in the U.S. Participants represented twelve (12) distinct engineering disciplines. In our semi-structured interview protocol, we asked about their experiences in graduate school since we last spoke. We focused on milestones (e.g., preliminary or comprehensive exams), relationships with advisors and peers, engineering identity, discrimination experiences, and graduate school during the dual pandemic of COVID-19 and racial reckoning during 2020. After conducting interviews, we conducted post-interview memos and reviewed each interview with the research team. In our next steps, we are conducting phenomenological analysis with a focus on 1) How Traditionally Underserved Students with varying engineering & social identities experience racism and sexism in graduate engineering programs?; 2) How do Traditionally Underserved Students manage, cope with, and navigate the racism and sexism experiences in engineering graduate education? Preliminary findings suggest that graduate engineering students navigate experiences of racism and sexism by leaving their program (e.g., graduating with a Master’s degree instead of a PhD), finding a new formal or informal advisor within their university, and switching fields or institutions. Further, our findings suggest that these experiences of racism and sexism are embedded in the culture of graduate engineering and will require structural changes to policies and procedures (rather than an emphasis on bias training and interpersonal relationships) for systematic and lasting change.
Conclusion & Next Steps

Graduate engineering students leave doctoral programs without their intended degrees at high rates with students from minoritized groups leaving at higher rates than their peers. Altogether, findings from this project highlight the prevalence of racism and sexism in graduate engineering and the potential of engineering identity as a protective interpersonal factor that can help sustain students through unconscionable and demoralizing experiences. Our findings also suggest that engineering identity is not enough to redress the pervasive impact of discrimination. The culture of engineering graduate education must be restructured to minimize racism and sexism to support and retain the next generation of engineers.

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Figure 2: Summary of findings to date mapped to project phases
References


