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Inequity in graduate engineering identity: Disciplinary differences and opportunity structures

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Abstract
Background: The retention of traditionally underserved students remains a pressing problem across graduate engineering programs. Disciplinary differences in graduate engineering identity provide a lens to investigate students' experiences and can pinpoint potential opportunity structures that support or hinder progress based on social and personal identities.
Purpose: This study investigates the impact of discipline, gender, race/ethnicity, advisor relationship, and years in a program on graduate engineering identity variability.
Methods: Cross-sectional survey data from a national sample of doctoral engineering students were analyzed with multilevel modeling. Multilevel modeling measured the differences at the individual and discipline levels for graduate engineering identity and the domains of engineer, researcher, and scientist. Independent variables included were gender, advisor relationship score, race/ethnicity, and years in a program.
Results: The engineer identity sub-construct of recognition significantly varied among engineering disciplines. Traditionally underserved students (i.e., Women and minoritized racial/ethnic groups) expressed lower engineering recognition levels, with this relationship varying based on discipline. Overall, our model explained 30% of the variation in engineering recognition among disciplines.
Conclusions: The disciplinary variation in graduate engineering identity combined with the significance of gender and race/ethnicity indicates traditionally underserved students do not experience equivalent opportunity structures compared with their well-represented peers. Modifying traditional opportunity structures to serve students better may provide the needed changes to engage and retain traditionally underserved populations.

KEYWORDS
diversity concerns, engineering identity, institutional change, multilevel modeling, PhD students

1 | INTRODUCTION

Despite mild upticks, Women and traditionally underserved groups remain significantly underrepresented and marginalized in engineering at the doctoral level (Barthelemy et al., 2016; National Academies of Sciences, Engineering, and Medicine [NASEM], 2018; Ramirez, 2014; Sallee, 2011; Sowell et al., 2015). In 2015, US citizens and permanent residents of color received 9% of doctoral degrees granted in engineering while representing over 30% of the US population (National Science Board [NSB], 2018; Sowell et al., 2015; United States Census Bureau [USCB], 2019). Further, Women, first-generation college students, and minoritized racial and ethnic groups complete engineering doctoral degrees at lower rates than well-represented group peers (NASEM, 2018; NSB, 2018; National Science Foundation [NSF], 2017, 2019; Sowell et al., 2015). Concerned by this gap in doctoral degree attainment, national agencies have called for significant changes to graduate education to adequately prepare the next generation of engineering problem-solvers (NASEM, 2018; NSB, 2018; NSF, 2017; Sowell et al., 2015). We propose that meaningful change in traditionally underserved student participation first requires investigation of the current systems that serve students differently. We begin with the premise that disciplines engage opportunity structures that support and hinder graduate engineering identity (GEI) development and that strong engineering identity promotes participation in engineering and graduate degree completion.

Opportunity structures consist of systems, policies, practices, and norms that support or hinder students' educational pursuits and engagement with the education system (Gray et al., 2018). Opportunity structures often systematically disadvantage Women and minoritized racial/ethnic identities among other personal and social identity groups (Bancroft, 2018; Burt et al., 2018; Pawley, 2017, 2019; Pawley et al., 2016; Starobin et al., 2010). Further, these structures may begin to explain why a gap in engineering doctoral degree attainment exists (Bancroft, 2018). For this work, we use the term traditionally underserved students rather than "underrepresented minority" to focus on the ways opportunity structures, specifically the educational structures housed within engineering disciplines, departments, and programs, need to be redesigned to equitably serve a broader range of students (Bancroft, 2018; Ramirez, 2014; Sowell et al., 2015). Focusing on disciplines can highlight why some disciplines show higher levels of doctoral degree attainment for traditionally underserved populations, while others have low levels of degree attainment. For example, in 2017, Women earned 48.7% and 39.1% of doctoral degrees in environmental and biomedical engineering, respectively, while only earning 13.6% of doctoral degrees in nuclear engineering (Yoder, 2018).

Traditionally underserved students experience inequity in a variety of ways. Students from underserved groups are less likely to have faculty, mentors, advisors, or peers who share their personal and social identities (Sowell et al., 2015). Peer discrimination, microaggressions, and exclusion isolate and punish already oppressed student groups (Burt et al., 2018; Byars-Winston et al., 2010; McGee, 2016; Robnett, 2016; Wang & Degol, 2017). Finally, underserved students face unique challenges in conforming and participating in the university structure.

In this work, we seek to identify the differences in GEI among engineering disciplines and propose that these differences arise from differences in discipline-specific opportunity structures. Further, we assess if gender and race/ethnicity impact differences in GEI among disciplines. This work uncovers the differences in GEI for Women and underrepresented racial/ethnic groups based on engineering disciplinary cultures that contribute to continued disparities in pursuit of doctoral degrees. The results provide the groundwork for further investigation of disciplinary cultures and opportunity structures to promote support for all students. Further, this work has implications for how graduate education may benefit from evaluating the impact of opportunity structures on traditionally underserved doctoral students. We begin with the premise that disciplines engage opportunity structures that support and hinder GEI development and that a strong engineer identity promotes participation in engineering and graduate degree completion (Bahnson et al., 2019; Bancroft, 2018; Godwin et al., 2016; Gray et al., 2018).

Improvements to the engineering graduate education experience for traditionally underserved students require a widespread systemic change to existing opportunity structures at the discipline level. To generate knowledge on how the design of engineering graduate programs is or is not equitable, we examined differences in engineering identity expression, a contextually responsive marker of students' experiences, across disciplines based on traditionally underserved student groups by gender and race/ethnicity. This approach to studying graduate engineering disciplines elucidates how professional, personal, and social identities of traditionally underserved students are potentially perceived and valued within the opportunity structures of engineering doctoral education while concurrently highlighting potential targets for change.

2 | CONCEPTUAL AND THEORETICAL FRAMING

Opportunity structures are those aspects of educational environments that support or block student success and engagement with educational systems (Gray et al., 2018). The opportunity structures concept enables the investigation of the structural elements of education that support traditionally underserved adolescents' belongingness in schools (Gray et al., 2018). Opportunity structures are similar to the formal and informal aspects of education or “figured worlds” that shape identity and identity expression (Holland et al., 1998; McAlpine & Lucas, 2011). Doctoral degree progress involves identity changes shaped by available opportunity structures (e.g., experiences, relationships, and intentions for the degree; McAlpine & Lucas, 2011). In other words, opportunity structures can help or hinder students' identity development and provide a mechanism to examine the ways identity development occurs within graduate engineering programs, as depicted in Figure 1.

Here, this framework is engaged to conceptualize differences in professional identity among engineering disciplines with attention to differences expressed by gender and race/ethnicity and the implication these differences may have on traditionally underserved student persistence through three interactive levels of opportunity structures: interpersonal, instructional, and institutional (Gray et al., 2018). Interpersonal opportunity structures are facilitated through the social ties actively created by faculty (Gray et al., 2018). Instructional opportunity structures engage students in ways that allow them to express their identities within the performance expectations of an academic setting (Gray et al., 2018). Institutional opportunity structures reflect student experiences of the policies and practices that govern academia, such as admissions, funding, mentorship, lab assignment, evaluation, and degree completion. While institutional structures impact students, this work's focus remains on student identity development and the idea that institutional opportunity structures shape the learning environment that supports or hinders student professional identity development.

Additionally, each level of opportunity structure interacts with the others and has a compounding influence on identity development (Gray et al., 2018; McAlpine & Lucas, 2011). For instance, interpersonal opportunity structures may be influenced by institutional structures that define, limit, or support faculty–student interaction. Similarly, institutional requirements for teaching or service hours may limit faculty interpersonal interactions with students. Within the influence of and interaction among these opportunity structures, students must develop their identities (Pawley, 2019).

However, the implementation of opportunity structures in engineering is often biased or discriminatory, disadvantaging underrepresented populations (Wang & Degol, 2017). Traditionally served students often find these structures more natural to navigate, and the structures reflect sociocultural norms in which traditionally served students are valued and comfortable (Bancroft, 2018; Foor et al., 2007). The inequitable implementation of opportunity structures can limit identity development (McAlpine & Lucas, 2011), exacerbate issues related to representation (Burt et al., 2018),

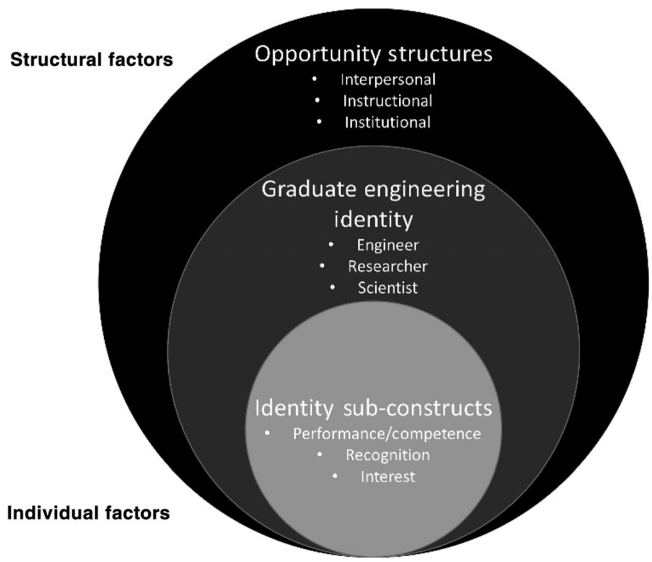

FIGURE 1 Opportunity structures represent structural factors that can positively or negatively influence graduate engineering identity and the individual sub-constructs that shape identity development

and reduce support through challenges for Women and Students of Color (Byars-Winston et al., 2010; McGee, 2016; Robnett, 2016; Wang & Degol, 2017).

Opportunity structures provide a conceptual mechanism to explain differences in GEI expression for traditionally underserved students. Interpreting differences in GEI through this lens points to sources of inequity and provides a mechanism to increase the equity of opportunity structures. Previous works explored aspects of GEI development (Crede & Borrego, 2012; Perkins et al., 2018a). As summarized in Figure 1, we utilized an opportunity structures framework to provide a more holistic understanding of the salient factors for graduate students' development. The following section defines and synthesizes the history of GEI research related to one's professional identity.

2.1 | Graduate engineering identity

Seeing oneself as an engineer or having an engineering identity predicts persistence, motivation, and career choice across multiple engineering contexts (Crede & Borrego, 2013; Godwin, 2016; Godwin et al., 2016; Godwin & Kirn, 2020). Given this framework's importance, researchers have extended and adapted engineering identity frameworks (e.g., Godwin et al., 2016) to study engineering graduate students (Choe & Borrego, 2019; Perkins et al., 2017). Engineering interest, recognition, and competence combined with interpersonal communication skills strongly predict engineering identity in graduate students (Choe & Borrego, 2020). Further, exploratory work examining engineering graduate students who debated leaving the field demonstrates that factors related to identity are vital in their intentions to persist (Berdanier et al., 2020).

Two identity domains (mathematics and physics) comprise undergraduate engineering identity with the sub-constructs of recognition, performance/competence, and interest (Cass et al., 2011; Godwin, 2016; Godwin et al., 2013; Godwin et al., 2016). Performance/competence is an individual's sense of being good at and ability to complete domain-specific tasks (e.g., I am confident that I can understand MATH in class). The interest sub-construct represents the individual's interest in a specific identity domain (e.g.,I enjoy conducting SCIENCE). The recognition sub-construct represents an individual's perception of how others evaluate them (e.g., My peers see me as a PHYSICS PERSON). The recognition sub-construct is highly influential for undergraduate student persistence in engineering (Godwin et al., 2013). See the article by Godwin et al. (2016) for a full review of the developmental history of this framework.

To understand how this framework translates to graduate contexts, Kirn and colleagues utilized a mixed-methods approach, including qualitative interviews, focus groups, and survey testing, when developing the domains of GEI. Intensive qualitative interviews and analyses uncovered three unique domains that influenced graduate conceptions of what it means to be an engineer and belong in engineering (Perkins et al., 2017; Perkins et al., 2018a). Kirn and colleagues validated the identity domains of researcher, scientist, and engineer through focus groups exploring each identity domain and graduate student experiences more generally. Qualitative interviews and focus groups preceded and guided the development of a 15-min survey focused on each of these domains (Cass et al., 2017; Miller et al., 2017; Perkins et al., 2017; Perkins et al., 2018a; Tsugawa-Nieves et al., 2017). The development of a quantitative measure of GEI for each of these domains followed procedures outlined in previous identity work (Godwin, 2016). Subsequent piloting of these measures occurred with students at two geographically diverse institutions (Perkins et al., 2018a). Pilot testing established a satisfactory level of validity and reliability for the survey (Perkins et al., 2018a).

The three identity domains of GEI, researcher, scientist, and engineer, each have the sub-constructs of recognition, performance/competence, and interest (Perkins et al., 2017; Perkins et al., 2018a). The identity domains of GEI reflect the focus of engineering graduate education on research and scientific discovery. This distinction indicates that GEI's role, while similar to undergraduate engineering identity, contributes uniquely to student development at the graduate level. The sub-constructs of recognition, performance/competence, interest remained relevant to graduate students in each domain. However, distinct manifestations of these sub-constructs emerged. For instance, graduate students demonstrated performance/competence as a graduate student in classes, in the lab, and in comprehensive exams. Similarly, recognition from friends and family was less critical for graduate students as their specialization within engineering fields increased. This model of GEI aligns closely with other models of graduate student engineering identity developed within specific institutional contexts (Choe & Borrego, 2019, 2020).

Previous works utilizing measures of advisor and peer interactions show that lab composition bolsters GEI (Crede & Borrego, 2012; Perkins et al., 2018b); advisor and peer relationships influence researcher and scientist recognition (Bahnson et al., 2018); and research experiences positively contribute to GEI (Bahnson et al., 2019). While this body of work explores the different structures that influence GEI, it has not examined the ways opportunity structures foster or hinder GEI development. Utilizing opportunity structure concepts and GEI constructs together, we examine how structural and individual factors concurrently contribute to stronger GEI development.

Our approach to discipline differences research utilizes individual identity as a reflection of the cultures, institutions, norms, and practices of the individual's discipline. These aspects of each discipline work together as active agents in the socially constructed professional identity of GEI. We did not measure the discipline-as-institution in this work; rather, we focus on the individual experience of the environment the discipline fosters. Student-level identity provides a window to quantify the impact of the discipline environment on the development of students. Here we use these ideas to explore differences in GEI among disciplines and the influence of graduate education experiences on GEI (advisor relationship, gender, race/ethnicity, and years in a program).

2.2 | Influences on graduate education experiences

The literature supports many variables as contributors to graduate engineering student success (NASEM, 2018). Conceptually, successful GEI development relates to the opportunity structures that support and hinder GEI development such that successful engagement with opportunity structures leads to stronger GEI development that then leads to increased persistence or reduced attrition. We focus on three independent variables due to their demonstrated impact on students, particularly traditionally underserved students' development and differential experience of opportunity structures: gender, race/ethnicity, and advisor relationship. First, including gender allows for measurement of meaningful variation around the experiences of Women (Pawley et al., 2016). For instance, Women experience gender bias in STEM and engineering spaces that negatively affect STEM self-concepts (Erickson, 2012; Robnett, 2016; Wang & Degol, 2017). Further, Women benefit from strong female advisor relationships leading to increased degree completion (Main, 2018).

Second, race/ethnicity requires similar attention due to established differences in the experience of the educational environment for Students of Color. For example, African American and Latino/a students experience barriers, bias, and racism in STEM environments, lowering their STEM self-concept and persistence in college education (Burt et al., 2018; Byars-Winston et al., 2010; McGee, 2016). Gender and race/ethnicity are important factors in discipline differences in representation, participation, stereotypes, motivation, and choice of engineering field (Brawner et al., 2012; Hartman & Hartman, 2009; Kirn & Benson, 2013; Lattuca et al., 2010; Shivy & Sullivan, 2005; Trytten et al., 2005; Verdín et al., 2018). Traditionally underserved gender and racial/ethnic identities lack access to traditional opportunity structures in engineering (Bancroft, 2018), leading to lower engineer identity and increased risk of attrition.

Third, advisor (and mentor) relationships significantly impact the experience and persistence of doctoral students based on their level of access and working relationship (NASEM, 2018) and represent a significant opportunity structure for students as these relationships are tied to persistence and attrition in graduate education. Students' relationship to their dissertation chair, often the primary advisor, exerts significant influence on completion of the doctoral degree (Bégin & Gérard, 2013; Gittings et al., 2018). Traditionally underserved students often do not have access to advisors or mentors who share their identities and experiences (NASEM, 2018; Sowell et al., 2015). In examining intersecting gender and race/ethnicity identities, differences in experience emerge (Ro & Loya, 2015; Verdín et al., 2015). For instance, when Women of Color reported positive advisor relationships, they benefited more than white Women (Perkins et al., 2020).

Also, we include a fourth independent variable (year started program) in recognition that GEI evolves throughout the doctoral degree and involves identity trajectory changes in the experiences, relationships, and intentions for the degree (McAlpine & Lucas, 2011). As students advance through doctoral training, their performance abilities and feelings of competence should increase. Students demonstrate their abilities to perform the tasks of a professional engineer, scientist, and researcher by completing doctoral milestones such as comprehensive exams, the dissertation proposal, and dissertation defense. Including the year a participant started their doctoral program compensates for the expected changes students experience as they progress to degree.

3 | RESEARCH QUESTIONS AND HYPOTHESES

Our research questions (RQs) sought to identify if and where variation occurs in GEI based on engineering discipline. To do so, we explored if and how disciplinary differences, advisor relationship, gender, minority status, and years in a program relate to GEI, providing insight into necessary changes in opportunity structures. The answers to these questions provide an exploratory basis to understand the current landscape of differences in GEI between discipline and institutional, programmatic, and disciplinary action to develop opportunity structures that support traditionally underserved students. Specifically, our research questions were as follows:

RQ1a. Are there disciplinary differences in GEI domains (engineer, researcher, scientist)?
RQ1b. For GEI domains with significant differences by discipline, are there disciplinary differences in GEI identity domain sub-constructs (recognition, performance/competence, interest)?
RQ1c. For GEI domains and sub-constructs with significant differences by discipline, how are disciplines different from other disciplines in GEI sub-construct expression?
RQ2. What are the within-discipline differences (main effects) for advisor relationship, gender, race/ethnicity minority status, or years in a program among GEI domains or sub-constructs?
RQ3. Do the main effect relationships of gender and race/ethnicity vary among engineering disciplines?
RQ4. How much within-discipline and between-discipline variability in GEI is explained by advisor relationship, gender, race/ethnicity minority status, and years in a program?

To explore these questions, we used multilevel modeling as it allows for exploration of the variation among individuals within a discipline and variation among disciplines to be addressed in one model (Raudenbush & Bryk, 2002). Using multilevel modeling, we investigated the differences due to individual factors compared with membership in a group (here, an engineering discipline).

4 | METHODS

This analysis is part of a larger research project investigating engineering graduate students' social identities, role identities, future time perspectives, identity-based motivations, and graduate school experiences (Cass et al., 2017; Perkins et al., 2018a). Here participant selection, analytic methods, and variables considered for the research questions are described. The variables considered are highlighted in detail to demonstrate the connections between the conceptual and theoretical frameworks and previous graduate education research.

4.1 | Positionality

The sensitivity of our research topic requires careful consideration of our place as researchers in posing and attempting to answer questions that investigate experiences and social identities we do not share with our participants. We have chosen to present a positional statement to assist in framing our approach to this project and data analysis. The authors of this work are predominantly white, with both the first author and primary investigator identifying as cisgender white gay men. Two authors, including the first author, are psychologists and all other authors are engineers. As a group, we have experienced various forms of oppression even while benefiting from opportunity structures not equally available to our participants. In recognition of this, we approach this research as an attempt to contribute to equity in engineering while providing empirical research to educational institutions to combat and disrupt the inequitable availability of opportunity structures.

Two notes on our nomenclature and how our nomenclature represents how we think about diversity, equity, and inclusion and our position as advocates for social justice: First, we choose to include Asian-identified participants in our concept of People of Color. Asian people experience microaggressions and discrimination in US culture, despite being well-represented in engineering and not included in underrepresented minorities as defined by NSF. Second, we chose to capitalize Women, Women of Color, and Men of Color and other socially constructed gender, race and ethnicity groups to center the experiences of the *People* who live in these marginalized categories while not capitalizing white or man to de-emphasize these privileged identities.

4.2 | Recruitment

Utilizing the American Society for Engineering Education's (ASEE's) list of doctorate-granting engineering programs, we generated a nationally representative sample of doctoral-granting engineering programs based on geography, discipline, and program size. Geography referred to the state in which the program resides, discipline came from the list of engineering graduate programs (ASEE, 2015), and the number of doctoral degrees granted by each program in 2014 represented program size (Yoder, 2015). Probability proportional to size sampling, a sampling technique where the probability of being included is proportional to the frequency similar codes appear in the population, was used to select programs. For instance, large construction engineering programs in California and Texas comprise approximately 2% (n = 27) of the national population of 1382 programs and 2% (n = 5) of the final list of 263 programs invited to participate. Programs were randomly selected from the population list to maintain proportionality. A replacement program was randomly selected if a previously chosen program declined participation.

Selected programs received an email request to participate in the survey. Programs that participated submitted a list of graduate engineering student emails or forwarded an invitation email with participation requirements, confidentiality information, and an embedded survey link to their engineering graduate students. Participants completed the survey online through the Qualtrics platform. The primary investigators' Institutional Review Board approved this research (NCSU 6053; UNR 770030-21).

4.3 | Participants

Of the 263 programs invited to participate, 98 Ph.D.-granting engineering departments in the United States participated (n = 2348). Individual participants were eliminated if they did not complete at least 50% of the survey, resulting in 1754 engineering graduate students for analysis. A large portion of the eliminated participants stopped participating when asked to identify their university. We have interpreted this as a fear of reidentification and retribution for involvement in the survey. This trend presents an opportunity for future research to explain this pattern better. We cannot definitively account for the drop-out at the university question nor for how these participants may differ from those analyzed here. For this analysis, only engineering Ph.D.-seeking students were used, eliminating "other field Ph.D." and all Master's degree-seeking participants. We removed participants from the analysis with missing responses to one or more variables of interest (described below), resulting in a final sample of 944 participants. We chose not to impute data due to the nature of the variables as identities. While imputation would provide a reasonable statistical approximation for the numerical values, the process cannot truly reproduce individual identity variables.

Participant demographics (Table 1) show that most participants identified as white (55.9%) or Asian (32%), male (63.3%), originated from the United States (62%), and heterosexual (92%). Participants indicated gender by selecting one or more of seven options (n = 1092; 97 missing). Participants indicated their race/ethnicity by selecting one or more of eight categories (n = 1046; 143 missing). Of participants who provided complete demographic responses, more than half of the US participants represent the traditionally underserved student groups of white Women (n = 193) or Students of Color (n = 109) and most non-US participants represent traditionally underserved students: white Women (n = 16) or Students of Color (n = 327). Year started Ph.D. ranged from 1999 (n = 1) to 2017 (n = 292), with 89.3% starting since 2012. As expected, most participants were within 5 years of starting the Ph.D. program (see Figure S1). We used the Statistical Package for the Social Sciences for descriptive statistics (IBM, 2017). To examine the representativeness of our study sample in terms of race/ethnicity and gender, we used chi-square tests to compare our sample to the NSF's reports of recent engineering Ph.D. recipients (Cornell Statistical Consulting Unit [CSCU], 2018; NSF, 2013; Pawley, 2017). This NSF report on doctoral engineering student demographics provides the best available population estimates for comparison to measure the representativeness of our sample. Given the limited availability of national data sets (NASEM, 2018), this comparison was limited as we were comparing two different experiences: earned doctoral degrees and enrollment in doctoral programs. As chi-square tests are sensitive to sample size (Tabachnick & Fidell, 2013), we evaluated the standardized residuals (SR) instead of p values when detecting significant differences. Previous work recommends that residuals greater than three are meaningful (e.g., residuals between j3j and j5j are small, j5j and j7j are moderate, etc.; CSCU, 2018). The results of this analysis indicated the overrepresentation of multiracial students (SR = 11.46) and white students in our sample (SR = 3.22). Asian and Latinx students were moderately underrepresented (SRs = −5.71 and −3.96, respectively). The percentages of men and Women did not differ

TABLE 1 Student-reported gender identity and race/ethnicity

	Domestic students				International students				
	Gender				Gender				
Race/ ethnicity, *n* (%)	Women *n* (%)	Men *n* (%)	Another identity *n* (%)	Total *n* (%)	Women *n* (%)	Men *n* (%)	Another identity *n* (%)	Total *n* (%)	Total
American Indian or Alaska Native	0	0	0	0	0	0	0	0	0
Asian	31 (12.8)	29 (8)	0	60 (9.8)	74 (64.9)	182 (69.2)	0	256 (67.7)	316 (31.9)
Black or African American	7 (2.9)	8 (2.2)	0	15 (2.5)	0	5 (1.9)	0	5 (1.3)	20 (2.0)
Middle Eastern or Native African	2 (0.8)	3 (0.8)	0	5 (0.8)	16 (14)	25 (9.5)	0	41 (10.8)	46 (4.6)
Native Hawaiian or other Pacific islander	0	1 (0.3)	0	1 (0.2)	0	0	0	0	1 (0.1)
White	193 (79.8)	306 (84.3)	3 (0.5)	502 (82.2)	16 (14)	34 (12.9)	1 (2.0)	51 (13.5)	553 (55.9)
Hispanic, Latino, or Spanish origin	7 (2.9)	14 (3.9)	0	21 (3.4)	0	0	0	0	21 (2.1)
Another race/ ethnicity not listed	2 (0.8)	2 (0.6)	3 (0.5)	7 (1.1)	3 (2.6)	7 (2.7)	0	10 (2.6)	17 (1.7)
Total	242 (39.6)	363 (59.4)	6 (1.0)	611[a]	114 (30.2)	263 (69.6)	1 (0.3)	378[a]	989

Note: Participants could select multiple races or ethnicities.
[a]Two hundred participants did not provide race/ethnicity and/or gender.

significantly (p = .151). These results suggest that, with few exceptions, our sample displays similar demographic trends as the national population of doctoral degree earners.

4.4 | Instrument

The GEI survey was developed based on the mixed-methods process described previously. This process indicated that GEI focuses on areas beyond engineering and should include research and science. Viewing oneself as belonging or not belonging in graduate school was particularly important in the qualitative interviews. We added the item “I see myself as a/n … Scientist/Engineer/Researcher” to assess self-beliefs about belonging in each domain directly. This item reflects a similar item used by Godwin et al. (2016) to measure overall identity self-concept: “I see myself as a [math or physics] person” (p. 318).

Exploratory factor analysis on pilot survey responses indicated the three domains consistently loaded with the sub-constructs of recognition, performance/competence, and interest with sufficiently high Cronbach's alpha to merit inclusion (Perkins et al., 2018a). Scientist domain items included some low scores with the Cronbach's α ranging from .354 to .883 (Perkins et al., 2018a). Engineer domain items ranged from .410 to .904, and researcher domain items from .469 to .958 (Perkins et al., 2018a). Retaining items with low but acceptable Cronbach's alphas allowed for consistency of questions across domains (Perkins et al., 2018a). Items that did not load in the exploratory factor analysis were eliminated to maintain consistency of questions across domains (Perkins et al., 2018a). The pilot survey included a wide range of students, like the sample analyzed here. However, the instrument would benefit from additional validation with traditionally underserved students to ensure the items and constructs function similarly across demographic groups.

The survey asked participants about the identity domains of researcher, scientist, and engineer on Likert-type scales (1, *strongly disagree* to 5, *strongly agree*; Table 2). Within each identity domain (engineer, scientist, researcher), items for each sub-construct (recognition, performance/competence, interest) were included, resulting in 45 total GEI items (Appendix A). All identity domain and sub-construct scales had high internal reliability in confirmatory factor analysis as measured by Cronbach's alpha with consistent factor loadings to the pilot study (Table 2). Cronbach's alpha calculated for all participants, white Women, and People of Color indicates the strong function of the scales across groups, including traditionally underserved groups (Table 2). Each identity domain was measured by averaging all domain-specific items and by averaging domain: sub-construct items. For example, the engineering domain had one overall score and three sub-construct scores for engineer: recognition, engineer: performance/competence, and engineer: interest. The resulting identity scores allowed for independent exploration of the GEI domains and sub-constructs.

4.4.1 | Variables

Dependent variables

Graduate engineering identity: The GEI scale resulted in nine sub-construct scores, one for each domain: sub-construct from the mean of domain: sub-construct items (Perkins et al., 2020). Cronbach's alpha for each sub-construct was consistent with norms (α between .88 and .96).

Level variables

We used two levels of variables as follows: (1) engineering disciplines and (2) individual student variables. Participants entered text responses to indicate their major field of study. Text responses were grouped into 24 disciplines to reduce the total number of entries and correct spelling, typos, and abbreviations (see Appendix B). "Acoustic Engineering" and "Engineering Education" were added to the "Engineering, Other" group due to low participant numbers in those groups, resulting in 22 disciplines used in the analyses. The resulting discipline groups represented broad disciplines of study within engineering (e.g., industrial, nuclear, mechanical).

TABLE 2 Number of items, Cronbach's alpha, and examples for each domain and sub-component scale

Identity domain		Cronbach's alpha			
Identity sub-component	Number of items	All	White Women	People of Color	Example items
Engineer	14	.94	.94	.93	I see myself as an ENGINEER
Recognition	5	.91	.92	.89	My advisor(s) sees me as an ENGINEER
Performance-competence	6	.92	.92	.90	I am confident I can understand ENGINEERING outside of class
Interest	3	.88	.91	.90	I enjoy learning ENGINEERING
Scientist	15	.92	.92	.88	I see myself as a SCIENTIST
Recognition	7	.92	.92	.88	My department faculty see me as a SCIENTIST
Performance-competence	5	.88	.87	.86	I can overcome setbacks when learning SCIENCE
Interest	3	.95	.96	.96	I find satisfaction when learning SCIENCE concepts
Researcher	16	.96	.93	.93	I see myself as a RESEARCHER
Recognition	7	.95	.90	.90	I want to be recognized for my contributions to RESEARCH
Performance-competence	5	.89	.85	.84	I am confident that I can design a RESEARCH study
Interest	4	.94	.89	.90	I find satisfaction when doing RESEARCH

Individual independent variables

1. Gender: Participants selected one or more of seven options with a write-in option to indicate their gender identities. Nearly all the discipline categories had zero or one self-identified nonbinary gender participants ($n = 7$), creating a large number of zero cells. Multilevel modeling handles small cell sizes well, and some zero cells (Raudenbush & Bryk, 2002). However, the inclusion of nonbinary gender participants violated the minimum cell sizes needed for multilevel modeling assumptions. As such, binary categories of men and Women were used for the gender variable. Gender of participants was dummy coded (men = 0 and Women = 1). Dummy coding allows for a reference group when variables are not continuous (Raudenbush & Bryk, 2002). Here, we compared Women's experience to men's experience.
2. Advisor relationship score: Participants rated the quality of their primary research advisor relationship from 1 (*strongly disagree*) to 5 (*strongly agree*) on eight Likert-type items (Appendix A; e.g., My Advisor … is knowledgeable about my research). The scale has a strong Cronbach's reliability ($\alpha = .92$). The average of these items provided an advisor relationship score.
3. Race/Ethnicity: Participants self-identified their race/ethnicity by selecting one or more of eight options, including a write-in option. Race/ethnicity variables were included in two ways, first with six categories (white, Asian, African American/Black, Hispanic/Latinx, Middle Eastern, and all other self-identified race or ethnicity [American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander, or more than one race or ethnicity identity]). Second, exploratory analyses measured if minoritized status would influence the model with the race/ethnicity items dichotomized to white (white = 0) and Students of Color (all others = 1). The categories of Asian, American Indian or Alaska Native; Black or African American; Hispanic; Latino/Latina/Latinx or Spanish origin; Middle Eastern or North African; Native Hawaiian or Other Pacific Islander were small when engineering discipline was included, and thus the models could not converge on a solution.

However, these students' experiences must be better understood for engineering to be successful in supporting a more racially and ethnically diverse population. In our analysis, we chose to include race/ethnicity as a binary to illustrate that minoritized racial/ethnic groups experience engineering identity development and graduate engineering education differently from their overrepresented peers. Further, we chose not to capitalize "white" to reflect the difference in minoritized experiences for People of Color and the lack of a coherent "white" identity. Minoritized race/ethnicity and some engineering disciplines had significantly smaller representation in our data but were handled well by multilevel modeling (Raudenbush & Bryk, 2002). The possibility remains that extreme inequity in some discipline cell sizes has some undue influence on the model fit.

The inherent weakness and limitations of the dichotomization of gender and race/ethnicity are discussed below. Asian student experiences of underrepresentation are not the same as other Students of Color. However, the sample size remained too small to include Asian students as a third group within the multilevel model. We have reported on the differences in Asian students' GEI, advisor, and peer relationships elsewhere (Perkins et al., 2020).

4. Year started: Participants provided the year they started their Ph.D. program in an open-ended text box.

Independent continuous variables were centered, ensuring that the lack of true-zero referents did not influence model interpretations (Raudenbush & Bryk, 2002). Centering is a standard procedure and facilitates comparisons among variables of different scales (Raudenbush & Bryk, 2002). For example, using the year a participant started in school does not have a meaningful zero, which makes the intercept uninterpretable. The advisor relationship score and year started in a program were group-mean centered by discipline type. Group-mean centering created a variable representing each person's deviation from the average of the group. Finally, previous analyses indicated data were missing at random for the variables used here, and thus it is safe to proceed with analyses (Perkins et al., 2019).

5 | ANALYSIS

5.1 | Multilevel modeling

Multilevel modeling allowed us to measure differences among individual engineering students and the differences caused by grouping variables (tau; τ, in these analyses, engineering discipline) (see Figure S1; Raudenbush &

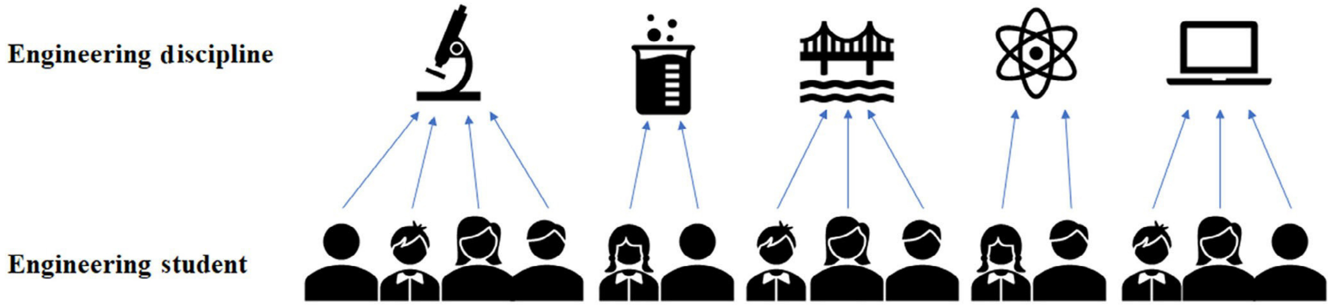

FIGURE 2 Representation of multilevel modeling measures variance of nested variables

Bryk, 2002). Concurrently, multilevel modeling measures the levels or intercepts of the dependent variable represented by beta (β). Multilevel modeling measures variation shared by disciplines to account for variation in the effect of independent variables on the dependent variable (such as individual student experiences; Figure 2).

Group membership can cause members to have similarities beyond random chance, causing nonindependence of observations (Field, 2019). Nonindependence of observations violates assumptions of more common analyses such as analysis of variance (ANOVA) and linear regression (Raudenbush & Bryk, 2002). Multilevel modeling analyses measure nonindependence to detect the influence of group membership on the dependent variable. Raudenbush and Bryk's (2002) modeling steps and notation served to guide these analyses.

5.2 | Data analysis

For multilevel modeling, we use the MIXED Procedure (ProcMixed) in SAS/STAT 9.2 (SAS, 2008). The first step of multilevel modeling is to measure differences at both levels (discipline and individual) in GEI (the dependent variable). The difference at each level was measured for the GEI domains of engineer, researcher, and scientist. Next, differences in the sub-constructs of recognition, performance/competence, interest were measured within each domain that displayed significant differences. Lastly, independent variables at the individual level were added to measure the main effects of gender and race/ethnicity status while controlling for advisor relationship and years in a program. Gender and race/ethnicity main effects are the focus of this analysis. Advisor relationship and years in a program significantly impact identity development for doctoral students and were controlled for in the analysis (McAlpine & Lucas, 2011).

To answer RQ 1c, ANOVAs provided the opportunity to explore how domain sub-constructs differed among disciplines with pairwise post hoc comparisons. ANOVAs were conducted for sub-constructs with significant variation by discipline in the multilevel modeling analyses. ANOVAs included covariates of gender, race/ethnicity, advisor relationship score, and year started in a program.

6 | RESULTS

For RQ1a and RQ1b, the model identified limited variations at each level of GEI. The engineer identity domain showed significant differences among disciplines (τ_{00} = .06, Table 3). Scientist and researcher identity sub-construct analyses are not reported due to nonsignificant variation among disciplines at the domain level (Domain (τ_{00}); Table 3). Without significant variation among disciplines, additional multilevel modeling analyses were not warranted. Within the engineer domain, only the engineer: recognition sub-construct differed significantly among engineering disciplines (τ_{00} = 0.09, Table 4). With race/ethnicity in six categories, race/ethnicity was not significant for any sub-construct (Table 5). Male participants scored higher on engineer: recognition (β_1 = −0.21, Model 3a) and engineer: performance/competence (β_1 = −0.19, Model 3b, Table 5). Stronger advisor relationships related to stronger scores for all three sub-constructs (β_2 = 0.23; 0.12; 0.11, Table 5). It was surprising to see no significant results for race/ethnicity in the context of past research (e.g., Burt et al., 2018; Perkins et al., 2020) that has shown race/ethnicity does influence the experience and engineering identity of students.

TABLE 3 Unstandardized coefficients (and standard errors) of null multilevel models of engineer identity and graduate engineering identity domains

	Model 1a (Engineer)	Model 1b (Scientist)	Model 1c (Researcher)
Fixed effects			
Model, β_0			
Intercept, γ_{00}	4.16*** (0.06)	4.06*** (0.04)	4.27*** (0.02)
Random effects			
Discipline (τ_{00})	0.06* (0.03)	0.02 (0.01)	0.00 (0.00)
Individual (σ^2)	0.49*** (0.02)	0.37*** (0.02)	0.39*** (0.02)
ICC[a] Level 2	11%	4%	<1%

[a]Interclass correlation coefficient.
*$p < .05$; **$p < .01$; ***$p \leq .001$.

TABLE 4 Unstandardized coefficients (and standard errors) of null multilevel models of engineer identity sub-constructs

	Model 2a (Engineer: Recognition)	Model 2b (Engineer: Performance-competence)	Model 2c (Engineer: Interest)
Fixed effects			
Eng: Identity, β_0			
Intercept, γ_{00}	3.95*** (0.08)	4.33*** (0.05)	4.21*** (0.07)
Random effects			
Identity			
Discipline (τ_{00})	0.09* (0.04)	0.02 (0.02)	0.07 (0.04)
Individual (σ^2)	0.76*** (0.03)	0.53*** (0.02)	0.7*** (0.03)
ICC[a] discipline	10%	4%	9%
Individual	90%	96%	91%

[a]Interclass correlation coefficient.
*$p < .05$; **$p < .01$; ***$p \leq .001$.

When dichotomized, race/ethnicity was significant in the engineering domain. The model identified significant unique effects of gender, race/ethnicity, and advisor relationships, addressing RQ2. Participants who were men (β_1 = −0.20) or white (β_3 = −0.16) scored higher on engineer: recognition (Table 6, Model 3a). Higher advisor relationship scores (β_2 = 0.23) positively related to higher engineer: recognition sub-construct scores (Table 6, Model 3a). Time spent in the program (Year Started, β_4) was not significantly related to engineer: recognition scores. The results partially addressed RQ4 and explained 30% of the difference in engineer: recognition sub-component scores among engineering disciplines (see Table 6, Model 3a). This model explained 6.6% of individual differences.

Engineer: performance-competence results supported significant main effects but did not support discipline variance, nor did they explain significant amounts of variance in the model. The main effects were similar to engineer: recognition main effects in that engineer: performance-competence scores were higher for men (β_1 = −0.19) and white participants (β_3 = −0.11; Table 6, Model 3b). Advisor relationship scores (β_2 = 0.13) positively related to engineer: performance-competence (Table 6, Model 3b). Year started in a program was significantly related to engineer: performance-competence scores such that the more time someone was enrolled, the higher they scored (β_4 = −0.03; Table 6, Model 3b). However, engineer: performance-competence scores did not differ among disciplines, and the model did not explain a significant portion of the individual or discipline-level differences.

Engineer: interest sub-construct scores did not significantly vary among discipline types and did not have significant relationships for gender, race/ethnicity minority status, or year started in a program. However, advisor relationship

TABLE 5 Unstandardized coefficients (and standard errors) of multilevel models of influences on engineer identity sub-constructs

	Model 3a (Engineer: Recognition)	Model 3b (Engineer: Performance-competence)	Model 3c (Engineer: Interest)
Fixed effects			
Eng: Identity, β_0			
Intercept, γ_{00}	3.96*** (0.19)	4.21*** (0.15)	4.23*** (0.18)
Gender, β_1			
Intercept	−0.21*** (0.06)	−0.19*** (0.05)	−0.08 (0.06)
Advisor relationship, β_2			
Intercept	0.23*** (0.03)	0.12*** (0.03)	0.11*** (0.03)
Ethnicity, β_3			
Black/African American intercept	0.06 (0.27)	0.07 (0.22)	−0.03 (0.26)
Hispanic/Latinx intercept	0.03 (0.18)	0.26 (0.18)	0.26 (0.21
Middle East intercept	0.09 (0.21)	0.31 (0.17	0.05 (0.20)
Asian intercept	−0.01 (0.18)	0.08 (0.15)	−0.16 (0.17)
White intercept	0.14 (0.18)	0.24 (0.15)	0.08 (0.17)
Other intercept	0.21 (0.23)	0.35 (0.2)	0.24 (0.23)
Year Started, β_4			
Intercept	−0.01 (0.01)	−0.03* (0.01)	−0.00 (0.01)
Random effects			
Identity			
(τ_{00})	0.08* (0.05)	0.02 (0.02)	0.08 (0.06)
(τ_{11})	0 (−)	0.00 (0.01)	0.01 (0.02)
Gender			
(τ_{10})	0.00 (0.02)	0.01 (0.01)	−0.01 (0.03)
Within-program variation (σ^2)	0.71*** (0.03)	0.50*** (0.02)	0.67*** (0.03)

*$p < .05$; **$p < .01$; ***$p \leq .001$.

(β_2 = 0.11) related to engineer: interest (RQ2; Table 6, Model 3c). The model explained a large portion (33% Table 6, Model 3c) of the discipline-level variance, although variance among disciplines on engineer: interest was not significant (τ_{00} = 0.14 Table 6, Model 3c). The model did not explain a significant portion of the variance within disciplines.

The relationship between gender and identity sub-constructs was allowed to vary among engineering disciplines to enable exploration of the ways the relationship between gender and identity sub-constructs may be different among engineering disciplines. Similarly, the relationship between race/ethnicity minority status and identity sub-constructs also varied among disciplines. Gender and race/ethnicity minority status were not different in their relationship to any identity sub-construct in any analysis, indicating the relationships for gender and race/ethnicity minority status to GEI sub-constructs were stable across disciplines, addressing RQ3.

Engineer: recognition was the only sub-construct with significant variation based on discipline in multilevel modeling analyses. Table 7 contains the results for the engineer: recognition sub-construct ANOVA. Using the test statistic Pillai's trace, engineer: recognition significantly varied with this set of variables. Table 8 presents post hoc pairwise comparisons of engineer: recognition. The upper diagonal presents the mean difference (MD) for the pairwise disciplines. The lower diagonal shows significant differences among disciplines with indications for $p \leq .05$, $p \leq .01$, and $p \leq .001$. Pairwise comparison of disciplines for engineer: recognition indicates 78 significant differences (Table 8).

TABLE 6 Unstandardized coefficients (and standard errors) of multilevel models of influences on engineer identity recognition

	Model 3a (Engineer: Recognition)	Model 3b (Engineer: Performance-competence)	Model 3c (Engineer: Interest)
Fixed effects			
Eng: Identity, β_0			
Intercept, γ_{00}	4.11*** (0.10)	4.45*** (0.06)	4.30*** (0.1)
Gender, β_1			
Intercept	−0.20*** (0.06)	−0.19*** (0.05)	−0.07 (0.07)
Advisor relationship, β_2			
Intercept	0.23*** (0.03)	0.13*** (0.03)	0.11*** (0.03)
Minoritized ethnicity, β_3			
Intercept	−0.16* (0.06)	−0.11* (0.04)	−0.07 (0.09)
Year Started Program, β_4			
Intercept	−0.01 (0.01)	−0.03* (0.01)	−0.00 (0.01)
Random effects			
Eng: Identity			
(τ_{00})	0.15* (0.09)	0.03 (0.03)	0.14 (0.08)
(τ_{11})	0 (−)	0.002 (0.01)	0.02 (0.03)
(τ_{22})	0.03 (0.03)	0 (−)	0.09 (0.049)
Gender			
(τ_{10})	0.04 (0.03)	1.01 (0.01)	0.01 (0.03)
Minoritized ethnicity			
(τ_{20})	−0.07 (0.05)	−0.01 (0.01)	−0.09 (0.07)
(τ_{21})	0.005 (0.03)	−0.01 (0.01)	−0.03 (0.04)
Within-discipline variation (σ^2)	0.71*** (0.04)	0.50*** (0.02)	0.71*** (0.04)
R^2_{between}	30%	7.8%	33%
R^2_{within}	6.6%	5.7%	4%

*$p < .05$; **$p < .01$; ***$p \leq .001$.

TABLE 7 Engineer recognition ANOVA with Pillai's trace

	F	DF	*p*	η²	AR²
Engineer recognition	6.676	27, 1038	<.001	0.148	0.126
Discipline					
Main effects					
Gender	6.757	1, 1038	.009	0.006	
Race/ethnicity	0.011	1, 1038	.917	0.000	
Advisor	57.289	1, 1038	<.001	0.052	
Year started	1.379	1, 1038	.241	0.001	
Discipline	4.647	23, 1038	<.001	0.093	

Abbreviations: ANOVA, analysis of variance; AR^2, adjusted R squared; DF, degrees of freedom; F, F-statistic; p, p value; η^2, eta squared, effect size.

6.1 | Results summary

A summary of our results aids the discussion of the results in relation to our research questions (Table 9). Our first research question asked if there are disciplinary differences in GEI domains and domain sub-constructs. The mixed

TABLE 8 Engineer recognition discipline pairwise comparison

	Engineer recognition		1	2	3	4	5	6	7	8	9	10	11	12
	Engineering discipline	Mean	4.143	4.324	4.236	3.827	3.786	3.997	4.076	4.334	3.745	4.094	3.981	4.085
1	Acoustic	4.143		0.181	0.093	−0.316	−0.358	−0.146	−0.067	0.191	−0.398	−0.049	−0.162	−0.058
2	Aerospace	4.324	0.778		−0.088	−0.496	−0.538	−0.327	−0.248	0.010	−0.579	−0.230	−0.343	−0.239
3	Ag. and Biolog.	4.236	0.884	0.694		−0.409	−0.451	−0.239	−0.160	0.098	−0.491	−0.142	−0.255	−0.151
4	Biomedical	3.827	0.614	0.010	*0.018*		−0.042	0.170	0.249	0.506	−0.083	0.267	0.154	0.258
5	Chem./Biomol.	3.786	0.586	0.052	0.088	0.861		0.211	0.291	0.548	−0.041	0.309	0.196	0.300
6	Chemical	3.997	0.815	0.079	0.150	0.164	0.365		0.079	0.337	−0.252	0.097	−0.016	0.088
7	Civil and Env.	4.076	0.915	0.193	0.348	0.052	0.218	0.501		0.257	−0.332	0.018	−0.095	0.009
8	Comp. Eng.	4.334	0.770	0.970	0.700	0.026	0.068	0.128	0.251		−0.589	−0.239	−0.352	−0.249
9	Comp. Science	3.745	0.528	0.005	0.010	0.588	0.870	0.081	*0.026*	*0.014*		0.350	0.237	0.340
10	Comp. Sci. and Eng.	4.094	0.940	0.381	0.570	0.231	0.299	0.653	0.935	0.405	0.137		−0.113	−0.009
11	Elec. and Comp.	3.981	0.800	0.130	0.225	0.385	0.461	0.927	0.585	0.168	0.218	0.653		0.104
12	Electrical	4.085	0.926	0.203	0.370	*0.040*	0.200	0.440	0.942	0.262	*0.020*	0.966	0.544	
13	General	3.727	0.699	0.505	0.568	0.910	0.949	0.760	0.693	0.502	0.984	0.684	0.776	0.685
14	Eng. Education	4.507	0.734	0.837	0.760	0.440	0.424	0.562	0.624	0.847	0.388	0.646	0.554	0.631
15	Physics	3.313	0.258	*0.019*	*0.029*	0.207	0.296	0.091	0.060	*0.022*	0.295	0.079	0.114	0.056
16	Environmental	3.705	0.495	0.009	*0.016*	0.518	0.770	0.112	*0.048*	*0.018*	0.847	0.137	0.217	*0.041*
17	Geological	2.591	*0.035*	<0.001	<0.001	0.002	0.008	<0.001	<0.001	<0.001	0.005	0.001	0.001	<0.001
18	Industrial	4.023	0.851	0.204	0.338	0.307	0.386	0.887	0.777	0.240	0.175	0.784	0.852	0.737
19	Materials Sci.	3.541	0.334	<0.001	<0.001	*0.014*	0.288	<0.001	<0.001	<0.001	0.146	0.010	0.008	<0.001
20	Mechanical	4.174	0.960	0.411	0.703	0.003	0.091	0.095	0.384	0.463	0.002	0.707	0.247	0.408
21	Nuclear	3.479	0.295	<0.001	<0.001	*0.040*	0.238	0.001	<0.001	0.001	0.152	*0.012*	*0.015*	<0.001
22	Ocean	4.775	0.405	0.336	0.243	*0.034*	*0.044*	0.080	0.118	0.362	*0.024*	0.158	0.087	0.122
23	Petroleum	4.391	0.714	0.836	0.621	0.054	0.086	0.171	0.278	0.868	*0.032*	0.385	0.193	0.289
24	Systems	4.333	0.791	0.982	0.803	0.173	0.192	0.360	0.487	0.998	0.120	0.561	0.365	0.500

			13	14	15	16	17	18	19	20	21	22	23	24
	Engineering discipline	Mean	3.727	4.507	3.313	3.705	2.591	4.023	3.541	4.174	3.479	4.775	4.391	4.333
1	Acoustic	4.143	−0.416	0.364	−0.830	−0.438	−1.552	−0.120	−0.602	0.031	−0.664	0.632	0.248	0.190
2	Aerospace	4.324	−0.597	0.183	−1.011	−0.619	−1.733	−0.301	−0.783	−0.150	−0.845	0.451	0.067	0.009
3	Ag. and Biolog.	4.236	−0.509	0.271	−0.923	−0.531	−1.645	−0.213	−0.695	−0.062	−0.757	0.539	0.155	0.097
4	Biomedical	3.827	−0.100	0.680	−0.514	−0.122	−1.236	0.196	−0.287	0.347	−0.348	0.947	0.564	0.505
5	Chem./Biomol.	3.786	−0.058	0.722	−0.472	−0.080	−1.194	0.238	−0.245	0.389	−0.307	0.989	0.605	0.547

(Continues)

TABLE 8 (Continued)

	Engineering discipline	Mean	13 3.727	14 4.507	15 3.313	16 3.705	17 2.591	18 4.023	19 3.541	20 4.174	21 3.479	22 4.775	23 4.391	24 4.333
6	Chemical	3.997	−0.270	0.510	−0.684	−0.292	−1.406	0.026	−0.456	0.177	−0.518	0.778	0.394	0.336
7	Civil and Env.	4.076	−0.349	0.431	−0.763	−0.371	−1.485	−0.053	−0.536	0.098	−0.597	0.698	0.315	0.256
8	Comp. Eng.	4.334	−0.606	0.173	−1.021	−0.629	−1.743	−0.311	−0.793	−0.160	−0.855	0.441	0.057	−0.001
9	Comp. Science	3.745	−0.017	0.763	−0.432	−0.040	−1.153	0.278	−0.204	0.429	−0.266	1.030	0.646	0.588
10	Comp. Sci.and Eng.	4.094	−0.367	0.413	−0.781	−0.389	−1.503	−0.071	−0.554	0.080	−0.615	0.681	0.297	0.238
11	Elec. and Comp.	3.981	−0.254	0.526	−0.668	−0.276	−1.390	0.042	−0.441	0.193	−0.502	0.793	0.410	0.351
12	Electrical	4.085	−0.358	0.422	−0.772	−0.380	−1.494	−0.062	−0.544	0.089	−0.606	0.690	0.306	0.247
13	General	3.727		0.780	−0.414	−0.022	−1.136	0.296	−0.187	0.447	−0.248	1.047	0.664	0.605
14	Eng. Education	4.507	0.530		−1.194	−0.802	−1.916	−0.484	−0.967	−0.333	−1.028	0.268	−0.116	−0.175
15	Physics	3.313	0.666	0.215		0.392	−0.722	0.710	0.228	0.861	0.166	1.462	1.078	1.019
16	Environmental	3.705	0.980	0.368	0.361		−1.114	0.318	−0.164	0.469	−0.226	1.070	0.686	0.627
17	Geological	2.591	0.238	*0.046*	0.195	0.009		1.432	0.949	1.583	0.888	2.184	1.800	1.741
18	Industrial	4.023	0.741	0.587	0.098	0.177	0.001		−0.482	0.151	−0.544	0.752	0.368	0.309
19	Materials Sci.	3.541	0.832	0.271	0.572	0.361	*0.017*	0.008		0.633	−0.062	1.234	0.850	0.792
20	Mechanical	4.174	0.612	0.705	*0.033*	0.009	<0.001	0.401	<0.001		−0.695	0.601	0.217	0.159
21	Nuclear	3.479	0.780	0.247	0.693	0.299	*0.034*	*0.012*	0.696	<0.001		1.296	0.912	0.854
22	Ocean	4.775	0.287	0.784	*0.014*	*0.022*	<0.001	0.109	0.005	0.176	0.005		−0.384	−0.442
23	Petroleum	4.391	0.471	0.899	*0.026*	*0.034*	<0.001	0.254	0.003	0.447	0.003	0.459		−0.058
24	Systems	4.333	0.523	0.854	0.056	0.112	0.001	0.432	*0.030*	0.664	*0.026*	0.434	0.897	

Note: Means and pairwise comparison significant difference based on ANOVA. $p \le .05$ Italics; $p \le .01$ Underlined; $p \le .001$ Bold.

Abbreviations: Ag. and Biolog., Agricultural and Biological; Chem./Biomol., Chemical and Biomolecular; Civil and Env., Civil and Environmental; Comp. Eng., Computer Engineering; Comp. Science, Computer Science; Comp. Sci. and Eng., Computer Science and Engineering; Elec. and Comp., Electrical and Computer; Materials Sci., Materials Science.

TABLE 9 Results summary

Research question	Sub-construct	Domain: Engineer	Researcher	Scientist
RQ1a. Are there disciplinary differences in GEI domains?		Yes	No	No
RQ1b. For GEI domains with significant differences by discipline, are there disciplinary differences in GEI identity domain sub-constructs?	Recognition	Yes	–	–
	Interest	No	–	–
	Perfor/Comp	No	–	–

	Engineer sub-construct	Advisor relationship	Gender	Race/ethnicity	Years in a program
RQ2. What are the within-discipline differences (main effects) for additional variables on GEI domains or sub-constructs?	Recognition	Positive relationship	Males Higher	White Higher	None
	Interest	Positive relationship	None	None	None
	Perfor/Comp	Positive relationship	Males Higher	White Higher	Positive relationship
RQ3. Do the main effect relationships of gender and race/ethnicity vary among engineering disciplines?	No—Main effects are stable across disciplines				

	Engineer sub-construct	Between	Within
RQ4. How much within-discipline and between-discipline variability in GEI is explained by advisor relationship, gender, race/ethnicity, and years in a program?	Recognition	30%	6.60%
	Interest	7.8%[a]	5.7%[a]
	Perfor/Comp	33%[a]	4%[a]

Note: Basic findings of the research for each research question.

Abbreviations: GEI, graduate engineering identity; Perfor/Comp, performance/competence.

[a]Nonsignificant result.

result showed a significant difference in the engineer domain and the engineer: recognition sub-construct. Each of the additional variables of interest in RQ2 demonstrated significant main effects: higher advisor relationship scores had a positive relationship with higher GEI engineer domain sub-construct scores; males reported higher recognition and performance/competence scores than their female peers; similarly, white participants reported higher recognition and performance/competence scores than Students of Color; and more years in a program positively related to higher performance/competence scores. The lack of variation among disciplines in the main effects found in RQ2 showed that the main effects were stable across disciplines and answered RQ3. The answer to RQ4 focused on the recognition sub-construct of the engineer domain such that the model explained a large and significant portion of the between-discipline variation. The post hoc comparison of disciplines for engineering: recognition identified 78 significant pairwise differences (Table 8).

7 | DISCUSSION

RQ1 has a relatively uncomplicated answer: the engineer domain of GEI varies among engineering disciplines. Primarily, the result indicates the need for additional research and exploration to ascertain how and then why identity varies among disciplines, as reflected in our additional research questions. Additional analyses and research are required to identify the meaning behind these variations. For instance, biomedical engineers reporting different engineering identity than that reported by nuclear engineers does not indicate the value of the difference—a difference may be appropriate given the difference in goals, approaches, and problems each discipline seeks to solve.

However, when male students and white students report higher recognition and performance/competence (RQ2) and that relationship is stable across engineering disciplines (RQ3), the difference implies that minoritized gender and race/ethnicity-based experiences negatively impact engineering identity recognition and performance/competence.

These results indicate a systemic problem impacting most engineering disciplines: Women and People of Color (and likely other traditionally underserved student groups) lack the support and opportunities provided to the men and white students in their disciplines. Finally, the large and significant amount of between-discipline variance explained by the model indicates that the combination of all measured variables does point to meaningful differences among disciplines. This may be that individual variables do not explain variation (no main effect variation in RQ2), but in combination do explain variation among disciplines. Additional research is needed to explore and explain the relationships between these variables and discipline differences (see future work below).

The significant variation for engineer: recognition in the multilevel modeling results is supported by the significance of the ANOVA and a large number of significant pairwise differences in engineer: recognition. With 78 significant differences, meaningful interpretation of these pairwise differences requires more detailed analysis than is possible here. Generally, significance is clustered around geological engineering, materials science and engineering, and nuclear engineering. The significance of these clusters may indicate that recognition of another professional identity outweighs engineer identity—for instance, geologist for geological or physicist for nuclear.

As an example, the largest doctorate-granting discipline of mechanical engineering (Yoder, 2018) demonstrates some interesting examples of pairwise differences in engineering: recognition (Table 8). Mechanical engineering engineering: recognition is significantly different from several other disciplines: biomedical (MD 0.347, $p = .003$), computer science (MD 0.429, $p = .002$), physics (MD 0.861, $p = .033$), environmental (MD 0.469, $p = .009$), geological (MD 1.583, $p < .001$), materials science (MD 0.633, $p < .001$), and nuclear (MD 0.695, $p < .001$; Table 8). The differences may reflect the interdisciplinary nature of these disciplines with strong nonengineering influences on the discipline's historical development. For instance, computer science has generally lower engineer identity, reflecting a discipline that developed from and continues to incorporate aspects of information systems/business, mathematics, and technology as well as electrical engineering (Bailey et al., 2006).

Opportunity structures often mirror established cultural norms and represent ways in which the education system enables or disables students to participate and succeed. Disparate opportunity structures may influence and support students' GEI development in unique ways. In turn, these cultural and structural influences may contribute to inequality and inequity in GEI reported by Women and minoritized racial/ethnic groups. Significant differences and a large amount of explained disciplinary variance (30%) in the engineering domain of GEI support the idea that engineering graduate students experience opportunity structures in graduate education differently depending upon their engineering discipline.

Mirroring western cultures, traditional opportunity structures in engineering tend to favor white men from higher socioeconomic and well-educated backgrounds (Bancroft, 2018). The differences in engineering sub-constructs of recognition and performance/competence highlight that traditional opportunity structures do not serve female and racial/ethnic minority students in the same ways as their male or white peers. The structures that exist may perpetuate norms of recognizing and measuring performance/competence, which values male and white standards of academic performance (Pawley, 2019). Structural change is necessary to engage traditionally underserved students fully.

Strong advisor and peer relationships positively influence recognition and performance/competence sub-constructs in engineering identity (Perkins et al., 2020). Significant variation among disciplines may indicate how advisor and peer influence is applied unevenly and inequitably among disciplines, with some disciplines more successful in promoting supportive relationships than others (Artiles & Matusovich, 2020). Differences exist between Women and men and white students and Students of Color in feeling recognized and performance/competence, but not in their engineering interest. This finding indicates the need to abandon cultural anecdotes that Women or Students of Color leave due to a lack of interest (e.g., McArdle, 2008). Lower recognition and performance/competence scores for Women and Students of Color did not significantly vary among disciplines, indicating the differences for these groups were consistent across disciplines. Engineering has room to improve equity in recognizing traditionally underserved graduate students and supporting their performance/competence. While significant difference occurs at the disciplinary level in the engineering domain, the consistent pattern of lower GEI for traditionally underserved students at the sub-component level points to inequity that exists across disciplines.

While the significant results for Women and Students of Color are similar, the issues faced are distinct and multifaceted. For example, Hispanic/Latinx students complete STEM degrees at higher rates than their Black or African American peers (Sowell et al., 2015). In this analysis, the aggregation of the minority racial/ethnic groups complicates the finding that minoritized students express different levels of GEI sub-constructs. When analyzed separately, Asian students' GEI sub-constructs were lower, but not significantly so, than other People of Color (Table 5). However, Asian student GEI scores were closer to Peers of Color than to their white peers.

Asian students are often not considered a minoritized group in STEM due to the National Science Foundation designations of racial/ethnic minority student groups (NSF, 2017). However, the Asian demographic marker is problematic, given the number of cultures, ethnicities, countries, and geographic areas the term is intended to cover. Further, Asian Women continue to be underrepresented, while Asian men are well-represented in engineering (NSB, 2018). When students enter spaces in which Asians are not a minority group, the salient distinctions of nationality and culture may result in feelings of isolation, minority status, and compound stereotypes of Asian Women (Sambamurthy et al., 2016). While well-represented, Asian students still bring cultural and social experiences of racism with them into graduate engineering education spaces. Asians experience discrimination in the general public and high levels of microaggressions in academia (Berk, 2017; Ong et al., 2013).

As an interpersonal opportunity structure, the advisor–advisee relationship plays a distinct role in graduate student development and success. Therefore, the significant positive correlation between advisor relationships and all three engineer sub-constructs should not be surprising. Good advisor relationships are a vital support to engineering graduate students as they navigate the transition into and through doctoral studies (NASEM, 2018). These relationships reflect the socialization of students into graduate and professional roles (Golde, 1998). Indeed, the socialization process for graduate students is both gendered and raced, marginalizing students who do not fit the mold (Baird, 1990; Turner & Thompson, 2017).

Further, these relationships are a primary source of recognition and performance/competence evaluations for graduate students. The level of access to an advisor, the close working relationship with that advisor, and the advisor's constructive engagement with students' research experiences strongly influence doctoral persistence (Blume-Kohout, 2017; NASEM, 2018). The best advisors allow for student independence while providing consistent and constructive advice (Zhao et al., 2007). However, the advisor role may be filled by multiple mentors who together contribute to the success of the student (Higgins, 2000). A doctoral student's relationship to their dissertation chair, often the primary advisor, exerts significant influence on the completion of their doctoral degree (Bégin & Gérard, 2013; Gittings et al., 2018). Unfortunately, traditionally underserved students often do not have access to advisors or mentors who share their experiences (Sowell et al., 2015), creating a knowledge and experience gap advisors need to overcome to facilitate interpersonal opportunity structures. Addressing faculty members' limited knowledge and experiences of traditionally underserved students is a mechanism for institutions to alter existing opportunity structures to ensure equity for all students.

The expected significant relationship between year started in a program and the engineering domain sub-construct of performance/competence matches findings that indicate the positive development of doctoral student identities through advanced experiences, relationships, and clearly defined intentions for the degree (McAlpine & Lucas, 2011). Broadly, existing opportunity structures reward the performance/competence of students by socializing doctoral students into the inequitable defaults of academic engineering culture. However, we must also consider that higher performance/competence scores may represent those who survived their program longer and may represent the attrition of students with lower performance/competence or identifications (Berdanier et al., 2020).

Differences in GEI by discipline, gender, and race/ethnicity highlight how opportunity structures are inconsistently applied across students, particularly traditionally underserved students. We propose that institutions of higher education engage across institutional boundaries to create, implement, and evaluate opportunity structures that can better serve traditionally underserved students. Through opportunity structures, institutions of higher education can engage with traditionally underserved students to facilitate their participation and persistence in engineering graduate education. Intervention across all three interactive levels of opportunity structures (individual, instructional, and institutional) is necessary to effect lasting change (Gray et al., 2018).

8 | IMPLICATIONS: ADDRESSING DISPARITIES WITH OPPORTUNITY STRUCTURES

Individual opportunity structures are those that enable students to engage successfully with faculty, staff, and peers. Discipline-based individual opportunity structures may include the norm for social or extracurricular interaction between advisors and graduate students. Similarly, they may promote or discourage student interaction with faculty at discipline conferences. The results suggest that educators should work to ensure that when they facilitate social ties, it is done with intention and care to engage all students involved in social interaction. Further, students who may not be familiar with or comfortable in the traditional academic structure could be actively engaged and supported when developing individual opportunity structures. The advisor relationship, gender, and race/ethnicity results suggest that fostering social ties can be accomplished through the establishment of mentorship roles that extend beyond those traditionally filled by one's advisor. Having a dedicated mentor early in one's doctoral program may help students express and explore their GEI beyond their primary advisor's influence (Artiles & Matusovich, 2020; NASEM, 2018). Intentional development and explanation of the purpose and goals of these mentorship relationships may ensure the active engagement of both faculty and students.

Instructional opportunity structures can encourage students to engage their cultural and personal backgrounds in their engineering work if engineering shifts to instructional defaults that embrace students' personal and cultural backgrounds (e.g., service-learning and community research). By creating these shifts, a broader set of students can receive support (Bosman et al., 2017; Ricks et al., 2014). Some disciplines may find engaging cultural and personal backgrounds more "natural" or that doing so fits more easily within the broader discipline culture. For instance, civil or environmental engineering may find incorporating student-identified problems easier while covering course material or developing dissertation research topics. In comparison, some disciplines may require more effort to incorporate students' cultural or personal backgrounds, such as physics or nuclear engineering. The promotion of other opportunities, such as industry engagement, may support competence and interest in engineering (NASEM, 2018).

Additionally, instructional practices could intentionally engage students in ways that allow them to incorporate their cultural meaning into academic activities. Intentionally engaging a diverse curriculum represents an instructional opportunity structure that could support interest and performance/competence (Du & Kolmos, 2009; Mejia & Wilson-Lopez, 2015; Wilson-Lopez et al., 2016). Experiments that intentionally consider gender in diversifying representations in the engineering curriculum in project-based learning environments show positive impacts on the learning process for both men and Women and aid in the persistence of Women in engineering classrooms (Du & Kolmos, 2009). Culturally engaging instructional opportunity structures could support GEI sub-constructs of recognition and competence as engineers by valuing personal and social identities such as gender and race/ethnicity.

Societies, conferences, and professional affiliation groups may be in prime positions to influence their disciplines as institutions—for example, investigating discipline culture and practices to evaluate how practices, assumptions, or norms support men and white people more readily than other groups. Similarly, disciplines may perpetuate culture into academic departments: engineers within a specific discipline expect their academic department to function in specific ways with norms for student–faculty interaction and engagement with students' personal and cultural backgrounds—or rather, the norm to ignore them.

Traditionally defined institutions (colleges, departments) can also engage in improving institutional opportunity structures. Institutional opportunity structures could be changed to allow faculty the time required to fulfill their obligations to doctoral students. As demonstrated in this research, the advisor relationship is meaningful across GEI domains and sub-constructs as such institutions need to provide systematic training and support to allow advisors to be better mentors (NASEM, 2018). Mentoring training provided by an institution could allow for engagement in the development of models that can better support traditionally underserved students and address gaps in the skills of doctoral advisors (NASEM, 2018). Mentoring workshops for advisors could develop new avenues for advisor–doctoral student engagement.

Other institutional opportunity structures could address the experiences of traditionally underserved students within the institution (Kumashiro, 2000). Minority or diversity offices are not enough. While they can provide essential and necessary services to the institution, engineering departments must not deflect the responsibility for traditionally underserved students solely onto these offices. The entirety of the institution needs to engage in efforts to increase the success of traditionally underserved students (Jones, 2016; Newman, 2016).

Institutional opportunity structures exist in ways that are hard to see for those accustomed to the academic system and can become embedded in academic cultures and discipline-specific practices. Disciplinary differences in GEI indicate some disciplines may be better at addressing these inequities than others. Highlighting the exemplary practices of disciplines that have shown high levels of success in supporting traditionally underserved students such as industrial or biomedical engineering serves to model potential change efforts for a broad range of programs, professional societies, and national institutions (e.g., Brawner et al., 2012). All institutional levels need to support institutional opportunity structures through policy and action to engage a more comprehensive group of students to participate and persist in engineering graduate education.

9 | LIMITATIONS AND FUTURE WORK

A few limitations to this project should be mentioned. First, the sample population, like engineering, is mostly white and male. The GEI construct and conclusions made based on this research may not fit well with People of Color, Women, or other traditionally underserved students, and especially for intersectional identities such as Women of Color. Similarly, our data do not represent nonbinary gender identifying individuals who may experience engineering identity development and expression in unique ways. Further research is needed to investigate the impact of existing as a traditionally underserved student in engineering on GEI expression and development. A focused intersectional analysis would provide the opportunity to more deeply explore the intersection of gender, race/ethnicity, and GEI.

Further, these intersections create an increased burden from inequitable social structures. International students face multiple layers of burden, particularly for international students who are also Women of Color (Dutta, 2015). Our sample did not allow for including a comparison between international and domestic students in our analysis. The intersection among gender, race, international, and domestic identifiers reduced the cell sizes for many disciplines to zero, resulting in an inability to make any comparisons. Future work would benefit from attention to the ways international students experience engineering disciplines differently.

While opportunity structures are used as a conceptual framework to understand how engineering contributes to identity development, we did not directly measure opportunity structures or any proxy variable specific to the opportunity structure constructs. Future research would benefit from including direct measures of opportunity structures to determine their impact on graduate students and GEI development specifically. Direct measures of opportunity structures could then guide improvements in engineering educational structures to better support students and the development of GEI.

Master's degree-seeking students were not included in this model. The high number of engineering Master's degree-seeking students and degree holders points to the importance of investigating this group as an independent set of engineers. The intentions of doctoral work are different from Master's work (Council of Graduate Schools [CGS], 2013; NASEM, 2018), which may lead to a differential meaning of GEI domains and sub-constructs. Future work should explore how these students are similar to or different from doctoral students in their expression and development of GEI.

Additional research is needed to measure the impact of other factors on graduate student identity development. For instance, the importance of lab group composition (Crede & Borrego, 2013; Perkins et al., 2018b), research experience (Bahnson et al., 2019), and the impact of other faculty mentors other than academic advisors could guide future analyses. For instance, does a strong relationship with a non-advisor mentor serve a similar function in supporting GEI development? Research to explore the different impacts of relationships and the quality of those relationships will help support our understanding of how faculty can support GEI development.

Work on engineering identity and GEI proposes that high engineering identity benefits students, increases the likelihood of degree completion, and should be supported by educators (Berdanier et al., 2020; Choe & Borrego, 2020; Crede & Borrego, 2013; Godwin, 2016; Godwin et al., 2016; Godwin & Kirn, 2020). The work reported here investigates the disciplinary differences in GEI with the proposal that disciplinary differences point to opportunity structures that may harm traditionally underserved students. We note that variation in GEI may be related to differences in disciplinary emphasis. For instance, multidisciplinary fields such as biomedical engineering may draw students with a science focus rather than an engineering focus. This type of variation may be inherent to the undergraduate identity work of the students and the priorities of the discipline. Future work should investigate disciplinary differences in GEI expression while controlling for students' prior experiences (e.g., undergraduate degree, prior research experience). Finally, comparisons among all disciplines used in this analysis lack meaning without explicit consideration of disciplinary context and priorities. The high number of significant differences limits the amount of meaning-making possible in one discussion. Future work can compare smaller groups of disciplines while considering their contexts and priorities to investigate specific differences among disciplines in GEI. One option would be to explore differences in disciplines that already share overlap in many engineering departments, such as computer and electrical or civil and environmental. Another option would be to explore differences among disciplines with large differences identified in this work—that is, to explore what makes geology, materials, and nuclear different from other disciplines. In addition, future work could more directly investigate connections between disparities in engineer: recognition and traditionally underserved student participation and degree completion rates by discipline. These approaches would also allow for more nuanced and thorough comparisons of where differences exist among disciplines, including additional individual-level variables. Future work should look at smaller groups of disciplines.

10 | CONCLUSIONS

GEI varies among engineering disciplines, reflecting differences in opportunity structures for Women and race/ethnicity minority students. ANOVA results confirm the significance of differences in engineer recognition identity measures, thereby supporting the concept that graduate engineering students develop engineer identity differently based on their discipline. Differences in identity development in recognition may reflect the disparity in support systems for students equitably engaging in all disciplines. However, the ANOVA results do not provide the level of support multilevel modeling does for the indication that traditionally underserved students do not receive equitable recognition across disciplines. The engineer: recognition sub-construct shows significant variation among disciplines and is significantly influenced by gender, advisor relationship, and racial/ethnic status, explaining 30% of the variation among engineering disciplines. The variation indicates that engineering graduate students may experience sexism and racism within their engineering education. Institutions can use this information to better support the development of strong GEI with interventions targeted to their discipline and the needs of their specific subfield. Intentionally developed opportunity structures to support traditionally underserved students in their fields would improve their experiences and potentially persistence to a degree. The importance of advisor relationships indicates the need to develop individual opportunity structures to support the advisor–advisee relationship. Doctoral engineering students represent the leaders in their fields and fill leadership roles within and beyond academia. Increasing equity at the engineering graduate student level will help increase equity in the field at large through improved representation of traditionally underserved students. Special attention to improving equity in recognition and performance/competence for traditionally underserved students should be a priority in response to long-standing calls for increased participation of traditionally underserved students in engineering.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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APPENDIX A

Complete list of graduate engineering identity and advisor relationship items; Responses 1—Disagree Strongly to 5–Agree Strongly; See Table 2 for Cronbach's alpha for each domain and sub-construct.

Scientist items

Q: To what extent do you disagree or agree with the following statements:

(Recognition Items)

1. I see myself as a SCIENTIST.
2. My department faculty see me as a SCIENTIST.
3. My peers see me as a SCIENTIST.
4. I have had experiences in which I was recognized as a SCIENTIST.
5. I want to be recognized for my contributions to SCIENCE.
6. My advisor(s) see me as a SCIENTIST.
7. Other scientists see me as a SCIENTIST.

(Interest Items)

8. I find satisfaction when learning SCIENCE concepts.
9. I am interested in learning SCIENCE concepts.
10. I enjoy learning SCIENCE.

(Performance/Competence Items)

11. I can overcome setbacks when learning SCIENCE.
12. I am confident that I can understand SCIENCE in class.

13. I am confident that I can understand SCIENCE outside of class.
14. I can perform well when my SCIENCE knowledge is tested (for instance, in exams or defenses).
15. I understand concepts I have studied in SCIENCE.

Engineer items

Q: To what extent do you disagree or agree with the following statements:

(Recognition Items)

1. I see myself as an ENGINEER.
2. My department faculty see me as an ENGINEER.
3. I have had experiences in which I was recognized as an ENGINEER.
4. Others ask me for help with ENGINEERING.
5. I want to be recognized for my contributions to ENGINEERING.
6. My advisor(s) sees me as an ENGINEER.
7. Other engineers see me as an ENGINEER.

(Interest Items)

8. I find satisfaction when doing ENGINEERING.
9. I enjoy learning ENGINEERING.

(Performance/Competence Items)

10. I am confident I can understand ENGINEERING in class.
11. I am confident I can understand ENGINEERING outside of class.
12. I can perform well when my ENGINEERING knowledge is tested (for instance, in exams or defenses).
13. I understand concepts I have studied in ENGINEERING.
14. I am confident I can apply ENGINEERING to solve problems.

Researcher items

Q: To what extent do you disagree or agree to the following statements:

(Recognition Items)

1. I see myself as a RESEARCHER.
2. My department faculty see me as a RESEARCHER.
3. My peers see me as a RESEARCHER.
4. I have had experiences in which I was recognized as a RESEARCHER.
5. I want to be recognized for my contributions to RESEARCH.
6. My advisor(s) see me as a RESEARCHER.
7. Other researchers see me as RESEARCHER.

(Interest Items)

8. I find satisfaction when learning about my RESEARCH topic.
9. I am interested in learning more about how to do RESEARCH.
10. I enjoy conducting RESEARCH.

(Performance/Competence Items)

11. I find satisfaction when doing RESEARCH.
12. I can publish RESEARCH results in my field.
13. I can present RESEARCH related topics to relevant audiences.
14. I am confident that I can network with other RESEARCHERS.
15. I understand the concepts needed to analyze and interpret data.
16. I am confident that I can design a RESEARCH study.

Advisor relationship items

Q: To what extent do you disagree or agree with the following statements:

My advisor …

1. … has clearly stated his or her expectations for satisfactory participation in my program.
2. … is easy to approach.

3. … is knowledgeable about my research.
4. … encourages and supports my research.
5. … values my work.
6. … provides advice in a timely manner.
7. … is also my mentor.
8. … and I have a positive relationship.

APPENDIX B

Engineering disciplines

1. Acoustic Engineering (included in Engineering, Other)
2. Aerospace Engineering
3. Agricultural and Biological Engineering
4. Biomedical Engineering
5. Chemical and Biomolecular Engineering
6. Chemical Engineering
7. Civil and Environmental Engineering
8. Computer Engineering
9. Computer Science
10. Computer Science and Engineering
11. Electrical and Computer Engineering
12. Electrical Engineering
13. Engineering, Other
14. Engineering Education (included in Engineering, Other)
15. Engineering Physics
16. Environmental Engineering
17. Geo Engineering
18. Industrial Engineering
19. Material Science and Engineering
20. Mechanical Engineering
21. Nuclear Engineering
22. Ocean Engineering
23. Petroleum Engineering
24. Systems Engineering