Students' Experiences of Unfairness in Graduate Engineering Education

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Abstract

A pilot inventory to develop measures of bias and discrimination experienced by engineering doctoral students asked if they have been treated unfairly by their primary advisor, secondary advisor, and other faculty. Analyses of pilot data (n = 250) revealed Women, Students of Color, and sexual minorities perceived experiences of unfair treatment in intricate patterns. Post hoc analyses show that Women experience more incidences of unfair treatment than men. Race/ethnicity identity groups report a different number of unfair treatment incidences, with Students of Color generally reporting more experiences than white students. Being a sexual minority contributed to reporting more incidences of unfair treatment. Unfair treatment from faculty significantly predicted students changing and considering changing research labs when controlling for gender, race/ethnicity, and sexuality. Unfair treatment from faculty significantly impacted engineering identity when controlling for gender, race/ethnicity, sexuality, lab changers, and change considerers. Analyses of pilot data demonstrated the negative impact of unfair treatment on students and their development as engineers.

Introduction

Limited data about STEM graduate student experiences and persistence exist [1]. However, the existing evidence demonstrates Women and Men of Color and white Women remain underrepresented in graduate STEM programs, particularly in engineering [1], [2]. Qualitative evidence shows that underrepresented groups face discrimination and bias in addition to the rigors and difficulties inherent in engineering graduate education [3 - 7]. Existing literature on the experiences of Men and Women of Color and white Women, discrimination, and bias in engineering primarily focus on undergraduate students and professionals while engaging qualitative methods. The existing literature would benefit from quantitative evidence of discrimination and bias experienced by graduate engineering students.

This paper presents a study's preliminary results to reveal the extent, scope, and content of discrimination and bias in engineering graduate education. The goal is to support changes in engineering education that reduce, eliminate, and remedy various forms of racism and sexism. Our inventory approaches discrimination and bias from two fronts: 1) students' perception of unfair treatment and 2) an inventory of discrimination experiences common to engineering graduate education. To develop the pilot inventory, we used previous research and semi-structured interviews to develop the survey inventory to investigate the unique environment, educational practices, and goals of engineering graduate study [8]. We analyzed students' perceptions of unfair treatment to capture the psychological, emotional, and social responses they report.

Background

Gender, racial and ethnic diversity in engineering, particularly in graduate education, does not reflect the general population diversity in the U.S. [1], [2], [9], [10]. In many ways, engineering represents a microcosm of the institutional and structural barriers to persistence traditionally underserved graduate students face in higher education across all majors, resulting in adverse educational outcomes [11]. Gender and race-based bias reduces STEM self-concepts and lowers persistence for Women, African American, and Hispanic/Latinx students [4], [12 – 16]. In addition, Lesbian, Gay, Bisexual, Transgender, Queer, Genderqueer, Asexual, Non-Binary Gender, as well as other traditionally oppressed gender and sexuality minority identities, face additional bias and discrimination in engineering spaces with complex intersections of gender and race/ethnicity mistreatment in both undergraduate and graduate education [17], [18].

STEM broadly, and engineering specifically, lacks quantitative discrimination and bias measures that capture the unique spaces (*e.g.*, labs, classes, offices) and experiences (*e.g.,* research, conferences, advisor, peer relationships) of graduate students. Qualitative research indicates that students experience discrimination and bias in their engineering education in various spaces and from multiple sources [3-7]. Based on this work, an inventory to measure discrimination and bias in engineering graduate education was developed by modifying existing items and developing new items based upon our qualitative research [8]. The inventory measures unfair treatment from advisors, faculty, and peers in multiple educational spaces (e.g. classroom, labs) to connect these experiences to leaving research labs or universities, and identity development as an engineer. The inventory can be used to explore the impact of discrimination and bias on engineering identity; investigate students' experiences; identify national trends; articulate differences between engineering disciplines and their success in supporting traditionally underserved students; and generating strategies to identify and remedy inequity in graduate engineering programs.

Graduate Experiences and Engineering Identity

Graduate engineering identity (GEI) provides a useful lens to investigate a wide variety of graduate student experiences and development. GEI represents graduate engineering students' identity as a member of the broader community of engineers and may be important in persistence to graduate degree and choice of engineering careers [cites]. Advisor and peer relationships, the number and type of lab members (*e.g.,* graduate student, undergrad, postdoc), and research experiences influence the domains and sub-constructs of GEI either supporting or hindering GEI development [19], [23, 24], [28 – 30]. Positive research group peer interactions in which students experience support in developing research, scholarly communication, and teaching skills support engineering identity development [29], [31 – 33]. Similarly, positive advisor and research peer relationships support strong engineer identity development [19], [34], [35]. Women of Color showed higher GEI scores than white Women when they experienced positive advisor relationships [23]. GEI varies based on the discipline of engineering study with the influence of gender and race/ethnicity such that Women and minoritized racial and ethnic groups express lower levels of GEI domains [19]. Engineering identity disparities indicate opportunities to investigate traditionally underserved students' experiences and how those experiences may limit their development as engineers perpetuating and contributing to continued lack of social justice demonstrated by issues of representation, discrimination, stereotypes, and bias [4], [7], [13 – 15]. Graduate engineering students' experiences supporting or hindering GEI development will help

identify experiences that disenfranchise, oppress, and lead already underserved student groups to leave engineering.

Positionality Statement

While positionality statements have become more prevalent in qualitative research, they are often absent from quantitative reports [36]. Due to our research topics' nature and sensitivity, we have chosen to break with that tradition to provide some context about us, our research, and our interest in equity in engineering. The authors of this work are all white and include three men and one woman. Two of the men are engineering educators, and the first and third authors are psychologists. Two men identify as gay cis-gendered men who have experienced our forms of oppression even while benefiting from unearned white male privilege. As a group, we have recognized our privileged positions and the disproportionate experience of unfair treatment experienced by Women and Men of Color at the hands of academics like ourselves. We recognize this as fact and wish to be part of the solution, providing empirical research to education institutions to combat and disrupt the continued mistreatment and lack of service to Women and Men of Color and white Women in engineering. Students report being treated differently or unfairly in the education system for many reasons, particularly due to different treatment based on or perceived to be based on social or personal identities (*e.g.*, race/ethnicity, gender). In this and other work on discrimination and bias, we view perception as reality - when people perceive experiences as race- or gender-based, people are impacted by the experience as racist or sexist, no matter the intentions or beliefs of others involved [3]. At the same time, we expect that all students entering graduate engineering programs possess the necessary skills for success, pointing instead to structures that do not serve students equitably, thereby hindering their ability to succeed [19].

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 prefer the term "traditionally underserved students" to indicate what many refer to as underrepresented minorities [37]. We make this choice to center the ways interpersonal relationships, instruction, and institutions systematically fail to satisfactorily support Women and Men of Color, white Women, sexual and gender identity minorities, disabled students, first-generation students, and other marginalized and oppressed groups [19], [37]. Second, we chose to capitalize Women and Men of Color and other socially constructed race and ethnicity groups to center the experiences of the *People* who live in these marginalized categories while not capitalizing white or man as a reminder to ourselves and our readers that white men should not be positioned as the norm or the comparison group for all others.

Finally, we would like to articulate our view of the distinction between discrimination and bias. *Discrimination* refers to the denial, withdrawal, or limitation of rights, expectations, privileges, and access for Women and Men of Color and white Women expected by and yielded to white men without merit as part of (unearned) privilege. A similar, but a distinct concept, *bias* then represents a preference or favoring, either unconsciously (implicit) or consciously (explicit) for one group over another [38]. The distinction is meaningful in why people behave in sexist and racist ways, while it may or may not be tied together in a cause and effect relationship. Discrimination and bias exist independently, influencing actions, stereotypes, and interactions.

We often chose to use both terms to indicate the possibility of either as the perceived source of negative experiences for students. However, we seek to demonstrate the negative effect on students, which occurs without delineating the source of the experience as discrimination or bias; instead, we tend to think both are likely influencing behavior that negatively impacts engineering graduate students. The student's perception of the experience remains at the center of our inquiry as it frames the impact of the experience on student outcomes.

Research Questions

Our research questions seek to explore the relationship between unfair treatment and traditionally underserved or minoritized groups and then link those findings to leaving research labs or universities and the overall impact on graduate engineering identity. Figure 1 illustrates the proposed relationships between these variables.

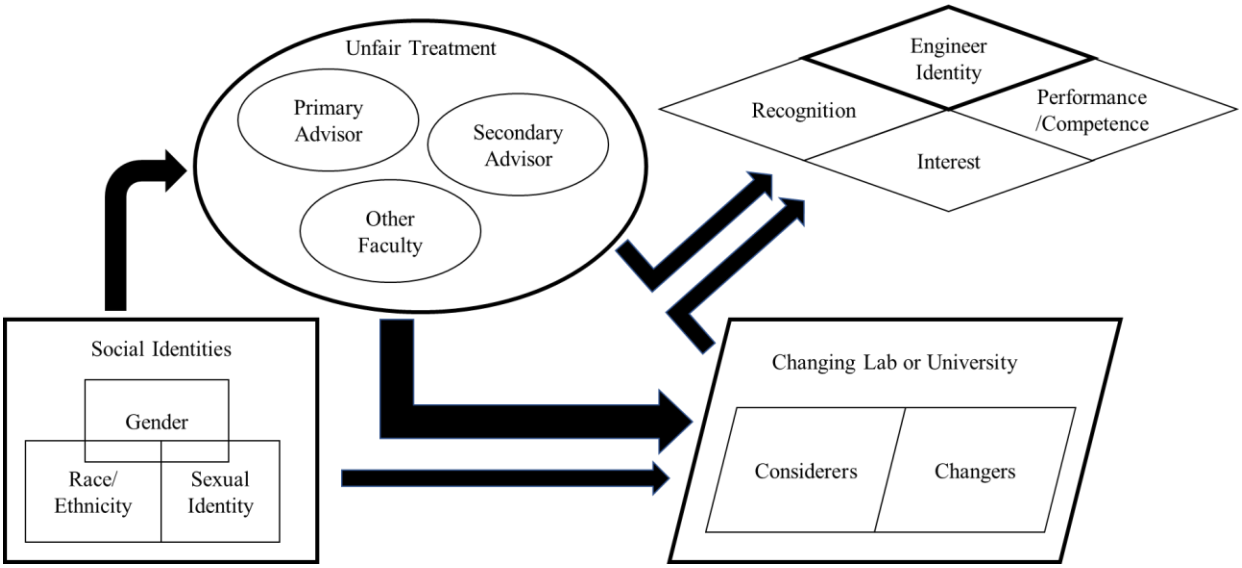

Figure 1. Proposed Variable Relationships

Research Question 1. (Demographics). Do gender, race/ethnicity, and sexual identity predict unfair treatment experiences from primary advisors, secondary advisors, or other faculty?
Research Question 2. (Considerers and Changers). Is unfair treatment from these groups associated with considering or leaving and changing research labs or universities?
Research Question 3. (Engineer Identity). Is unfair treatment from these groups associated with the engineer domain and its sub-constructs in graduate engineering identity?

Each research question is assessed by multivariate analysis of variance, as described below in methods. For ease of reference, we label these 1. Demographics, 2. Considerers and Changers, 3. Engineer Identity.

Methods

Recruitment

Participants in a previous national survey of engineering graduate students indicated an interest in additional research participation opportunities and provided an email address [26], [27]. All participants received an email invitation to participate in our survey's pilot test of a discrimination and bias experienced in graduate engineering education inventory. Volunteers participated in the survey through the Qualtrics online survey platform [39]. Participants could register for a $20 e-gift card drawing after they completed the survey. Of those who registered, 20 were randomly drawn and emailed a $20 e-gift card. The local institutional review board approved all materials and procedures used for this project.

Participants

Participants included 368 graduate engineering students. Of these, 61 participants were removed due to incomplete responses, with most answering less than 10% of the items. In addition, 57 participants with incomplete demographic information were eliminated, resulting in a total of 250 participants. All participants were enrolled in Ph.D. programs or recently (less than 1 year) completed a Ph.D. or left (less than 1 year) a doctoral program in engineering without a degree. Participants responded to additional demographic items to assist in contextualizing our sample, with 90% identified as heterosexual, 20% identified as having a disability, and 70% identified as being from the U.S.

Graduate engineering students from 104 universities participated. Participants represented the full range of engineering disciplines [2]. The demographic items used were previously validated and established as best practice for inclusivity [40]. Participants indicated their gender identity by selecting one or more of 5 options with a write-in option available. The gender minority categories were removed (n = 1) due to limited representation, resulting in two gender categories (male and female). Participants indicated their race/ethnicity by selecting one or more of 8 categories: American Indian or Alaska Native; Asian; Black or African American; Hispanic, Latino/Latina/Latinx, or Spanish origin; Middle Eastern or North African; Native Hawaiian or Other Pacific Islander; white; or other with a write-in option available. We had no American Indian, Alaska Native, Native Hawaiian, or Other Pacific Islander identified participants. Table 1 presents gender and race/ethnicity for the participants.

Table 1.
Gender Identity by Race/Ethnicity and Sexual Identity

	Heterosexual		Minority Sexual Identity		Total
Gender Identity	Female	Male	Female	Male	
Asian	23	19	3	1	46
Black/African American	1	2		1	4
Hispanic, Latino/Latina/Latinx, or Spanish origin	4	4			8
Middle Eastern or North African	4	5			9
White	62	84	7	11	164
Other Race or Ethnicity not Listed	6	12		1	19
Total	100	126	10	14	250

Instrument

The inventory piloted as part of this work was developed based on qualitative interviews and existing discrimination and bias inventory items [8]. In addition to demographic items, participants responded to questions asking about their experiences with advisors and other faculty members. We focused on a sub-set of questions for these analyses. For Research Question 1, participants answered the question, "Have you been treated unfairly by any of the following people within your engineering department?" by selecting yes or no for the primary advisor, secondary advisor, and other faculty (Yes = 1; No = 2). For Research Question 2, items asked if participants changed or considered changing labs or universities. Participants responded to two questions about staying in their current lab or leaving for another lab or university. Participants who answered yes to "Have you actively considered changing your research lab or university since beginning your Ph.D.?" are designated 'considerers' and those who answered yes to "Have you changed your research lab or changed universities since beginning your Ph.D.?" are 'changers'. If participants responded yes to both items they are 'changers. ' For Research Question 3, participants responded to graduate engineering identity items to assess three sub-constructs of the engineer domain of GEI: recognition (*e.g.,* "My department faculty see me as an ENGINEER); interest (*e.g.,* "I enjoy learning ENGINEERING"); and performance/competence (*e.g.,* "I understand concepts I have studied in ENGINEERING "; [25], [26], [27]. The sub-construct items' average provides three identity sub-construct scores within the engineer domain for recognition, interest, and performance/competence [27].

Analysis

SPSS was used for all analyses. Descriptive analyses were used to measure the mean, standard deviation, and range of the GEI engineer domain sub-constructs. A series of three analysis of variance analyses (ANOVAs) explored unfair treatment experiences of graduate students and their impact on graduate students. Each subsequent ANOVA included significant variables from the previous ANOVA to improve the model by controlling for the previous model's findings. The first ANOVA (demographics) analyzed the responses for the primary advisor, secondary advisor, and other faculty questions, controlling for sexual identity, to test if gender and race/ethnicity predicted unfair treatment. Post hoc pairwise comparisons explored significant differences for each type of faculty for gender and race/ethnicity groups. A second ANOVA (considerers and changers) measured the impact of unfair treatment from the same three faculty groups on the participants' consideration to leave their lab or university (considerers) and those that did change labs and universities (changers) while controlling for gender, race/ethnicity, and sexual identity. The post hoc pairwise comparisons measured differences between groups. A third ANOVA (Engineer Identity) measured the influence of unfair treatment from the faculty groups on the graduate engineering identity engineer domain sub-constructs of recognition, interest, and performance/competence while controlling for gender, race/ethnicity, sexual identity, and the considerer and changer variables. Post hoc pairwise comparisons measured the impact on each of the sub-constructs of graduate engineer identity.

Results

Descriptive statistics for each of the items used in these analyses are shown in Table 2. The GEI engineer sub-construct scores show that participants have generally high scores. The full range of possible averages is represented in the data. In our pilot research, 16% of participants reported unfair treatment from an advisor, 10% reported unfair treatment by a secondary advisor, and 12% for other faculty. Nineteen percent of participants had changed labs or universities, while 24% had seriously considered changing.

Table 2.
Incidence and Percentage for Unfair Treatment, Changers, and Considerers, and Mean, Standard Deviation (SD), and Range for GEI Items

	No (%)	Yes (%)	
Have you been treated unfairly by any of the following people within your engineering department?			
Primary Advisor	211 (84)	39 (16)	
Secondary Advisor	225 (90)	25 (10)	
Other Faculty	219 (88)	31 (12)	
Have you actively considered changing your research lab or university since beginning your Ph.D.	191 (76)	59 (24)	
Have you changed your research lab or changed universities since beginning your Ph.D.?	202 (81)	48 (19)	
Engineer Identity	Mean	SD	Range
Recognition	4.198	0.786	1, 5
Interest	4.502	0.694	1, 5
Performance/Competence	4.422	0.654	1, 5

Table 3 contains the results for all three ANOVAs. Using the test statistic Pillai's Trace, the first ANOVA (demographics) shows the model as a whole is significant and explains over 80% of the variance in unfair treatment from faculty ($F (4, 233) = 270.701$, $p < .001$, $\eta^2 = .823$). Analyses identified significant main effects for gender ($F (8, 468) = 1.748$, $p < .001$, $\eta^2 = .085$); and race/ethnicity ($F (20, 944) = 3.509$, $p < .001$, $\eta^2 = .069$) with an interaction of gender and race/ethnicity ($F (20, 944) = 1.608$, $p = .046$, $\eta^2 = .033$). Sexuality did not independently contribute to the model.

Gender

For the gender post hoc comparisons, significant results were found for primary advisor ($F (2, 236) = 3.186$, $p = .043$, $\eta^2 = .026$), with pairwise comparisons showing Women reporting significantly more instances of unfair treatment. The secondary advisor was not significantly different for Women and men. Gender was important for other faculty ($F (2, 236) = 4.104$, $p = .018$, $\eta^2 = .034$) such that Women were significantly more likely to report incidences of unfair treatment by other faculty than men ($p = .005$).

Race/Ethnicity

For Race/Ethnicity post hoc comparisons, significant difference was found for primary advisor ($F (5, 236) = 2.725$, $p = .020$, $\eta^2 = .055$) with Asian ($p = .016$) and Hispanic/Latinx ($p = .030$) reporting more instances of unfair treatment than Middle Eastern/North African participants. The secondary advisor was not significant in post hoc comparisons of Race/Ethnicity. For other faculty significant main effects were found ($F (5, 236) = 3.149$, $p = .009$, $\eta^2 = .063$) with Asian students reporting more instances of unfair treatment than Middle Eastern/North African students ($p = .002$); and Middle Eastern/North African students reporting fewer experiences of unfair treatment than white ($p = .006$) and other race/ethnicity ($p = .018$) students. The interaction of gender and race/ethnicity, while significant for the model as a whole was not significant in post hoc analysis of the individual items for the primary advisor, secondary advisor, or other faculty perhaps indicating a broader set of intersecting discriminatory experiences.

The second ANOVA (Changers & Considerers) significantly explained some of the variation in whether or not students changed or considered changing ($F (2, 238) = 9.877$, $p < .001$, $\eta^2 = .077$) with significant main effects for changers ($F (10, 239) = 2.085$, $p = .026$, $\eta^2 = .080$) and considerers ($F (2, 239) = 9.086$, $p < .001$, $\eta^2 = .275$). Gender, race, and sexuality while important for the model were not independently significant. Advisor unfair treatment was significant for considerers ($F (1, 236) = 24.212$, $p < .001$, $\eta^2 = .092$), but not changers likely due to participants' responses were for current advisors. The same pattern was true for secondary advisor unfair treatment ($F (1, 236) = 6.500$, $p = .011$, $\eta^2 = .026$). The interaction of secondary advisors and other faculty unfair treatment for considerers was significant ($F (1, 236) = 6.973$, $p = .009$, $\eta^2 = .028$) pointing to potential overlap in the two faculty categories. Other interactions were not significant.

The third ANOVA (Engineer Identity) was significant, explaining 65% of the variance in graduate engineering identity ($F (3, 220) = 136.774$, $p < .001$, $\eta^2 = .651$). The main effect for engineer:recognition was significant ($F (27, 222) = 2.558$, $p < .001$, $\eta^2 = .237$); engineer:interest was not significant ($F (27, 222) = 1.246$, $p = .195$, $\eta^2 = .132$); and engineer:performance/competence main effect was significant ($F (27, 222) = 1.733$, $p = .017$, $\eta^2 = .174$). Gender independently contributed to the model, however that contribution was not independently significant. Race/ethnicity contributed significantly only for engineer:performance/competence ($F (2, 222) = 5.044$, $p = .026$, $\eta^2 = .022$) . Sexuality significantly contributed to engineer:recognition ($F (1, 222) = 4.245$, $p = .041$, $\eta^2 = .019$); engineer:interest ($F (2, 222) = 5.166$, $p = .024$, $\eta^2 = .023$); and engineer:performance/competence ($F (1, 222) = 6.616$, $p = .011$, $\eta^2 = .029$). There was an interaction effect between advisor unfair treatment and those who changed labs or university for engineer:recognition ($F (1, 222) = 10.020$, $p = .002$, $\eta^2 = .043$) and other faculty unfair treatment and those who changed for engineer:performance/confidence ($F (1, 222) = 4.705$, $p = .031$, $\eta^2 = .021$). Three-way interactions could not be tested due to a lack of power.

Table 3.
ANOVA results with Pillai's Trace

	F	DF	*p*	η^2

Demographics ANOVA	Unfair Treatment	270.701	4, 233	<.001	0.823
Main Effects	Gender	1.748	8, 468	< .001	0.085
	Race/Ethnicity	3.509	20, 944	< .001	0.069
	Sexual Identity				
Interactions*	Gender*Race/Ethnicity	1.608	20, 944	1.608	0.033
Gender	Primary Advisor	3.186	2, 236	0.043	0.026
	Other Faculty	4.104	2, 236	0.018	0.034
Race/Ethnicity	Primary Advisor	2.725	5, 236	0.02	0.055
	Other Faculty	3.149	5, 236	0.009	0.063
Changers & Considerers ANOVA	Unfair Treatment	9.877	2, 238	< .001	0.077
Main Effects	Changers	2.085	10, 239	0.026	0.08
	Considerers	9.086	2, 239	< .001	0.275
Interactions* Considerers	Primary Advisor	24.212	1, 236	< .001	0.275
	Secondary Advisor	6.5	1, 236	0.011	0.026
	Secondary Advisor*Other Faculty	6.973	1, 236	0.009	0.028
Engineer Identity ANOVA	Engineer Identity Sub-Constructs	136.774	3, 220	< .001	0.651
Main Effects	Engineer:recognition	2.558	27, 222	< .001	0.237
	Engineer:interest	1.246	27, 222	0.195	0.132
	Engineer:perf/comp.	1.733	27, 222	0.017	0.174
Interactions* Race/ethnicity	Engineer:perf/comp.	5.044	2, 222	0.026	0.022
Sexual Identity	Engineer:recognition	4.245	1, 222	0.041	0.019
	Engineer:interest	5.166	2, 222	0.024	0.023
	Engineer:perf/comp.	6.616	1, 222	0.011	0.029
Primary Advisor*Changers	Engineer:recognition	10.02	1, 222	0.002	0.043

Other Faculty*Changer	Engineer:perf/comp.	4.705	1, 22	0.031	21

Notes: *Only significant interactions are reported with all other not significant at $p = .05$.

Discussion

The pilot data analyses provide answers to our research questions and additional information useful to engineering education. The substantial percentage of students who reported unfair treatment from advisors, the number who had changed labs or universities, and the number who have seriously considered changing labs or universities (Table 2) illustrates a significant and meaningful challenge for engineering graduate education. The analyses presented here begin exploring the implications of unfair treatment by faculty for engineering graduate students.

Research Question 1 asked if gender, race/ethnicity, and sexual identity predict unfair treatment from faculty. The results of the demographics ANOVA support previous research that Women and Men of Color and white Women experience unfair treatment from faculty in graduate engineering education [3], [4], [12 – 16]. The most unambiguous indication is that Women continue to be treated unfairly by their primary advisors despite the improved representation of Women in engineering and engineering faculty.

Post hoc comparisons following the demographics ANOVA for race/ethnicity suggest Students of Color do not experience or report instances of unfair treatment in the same ways across race/ethnicity identities. These indicate the experiences of being treated differently go beyond white students reporting fewer instances of unfair treatment than Students of Color, as exemplified by Middle Eastern students reporting fewer instances of unfair treatment from primary advisors than some other groups. Unfair treatment experienced by traditionally underserved race/ethnicity groups by other faculty similarly followed complex patterns that align with a more straightforward poor treatment of Students of Color. These results support existing evidence that Students of Color experience different types of unfair treatment that are not be consistent across racial and ethnic groups [11 - 13]. Further, our findings support the qualitative literature that describes a complex system of discrimination, bias, and intersections of racism and sexism that creates additional barriers for Students of Color in graduate engineering [3-7]. Further, the intersections of gender and race point to essential differences in the experiences of sexism and racism in engineering [23].

Research Question 2 asked if unfair treatment links to considering or changing lab or university. The Changers & Considerers ANOVA demonstrated unfair treatment from all three faculty categories strongly relate to students considering or changing their lab and university and is likely linked to experiences of unfair treatment based on gender, race/ethnicity, and sexual identity. Unfair treatment from primary advisor most significantly predicted considering or changing lab or university. Unfair treatment experiences from a primary advisor explained a robust 27% of the difference between those who considered or changed and those who did not consider or change. Experiences with advisors and faculty strongly impact graduate students' experiences [1], and the findings here support the qualitative demonstration of unfair treatment leading to considering or changing labs [20]. The non-significance for advisor unfair treatment

for changers may be due to a conflict in the questions' structure. Participants may have changed labs or universities previously while answering unfair treatment questions about their new and current advisor; this possibility should be clarified in future work.

In Research Question 3, we sought to explore the relationship between unfair treatment experiences, considering or changing lab or university, and demographic groups with engineer identity domain sub-constructs. The Engineer Identity ANOVA demonstrates the impact of unfair treatment from faculty on engineering identity sub-constructs of recognition and performance/competence when controlling for gender, race/ethnicity, sexuality, considerers, and changers. Experiences of unfair treatment specifically from primary advisors most significantly impacted the recognition sub-construct and explained 23% of the variation. Unfair treatment from the faculty groups did not significantly impact the interest sub-construct for gender or race/ethnicity identities. The importance of the recognition and performance/competence sub-constructs reinforces previous research connecting engineer identity to educational experiences and advisor relationships as influenced by gender and race/ethnicity [19], [34], [35]. While we did not measure change over time, the long-term implications of lower or suppressed graduate engineering identity may further erode the likelihood of persistence for traditionally underserved graduate engineering students.

As shown in this work, students experience unfair treatment from advisors and faculty impacting engineering identity development. Conflicts between roles (teacher, researcher, and student) may disrupt transitioning to a professional engineer identity [34]. As students experience role conflict, unfair treatment may further disrupt professional engineering identity. The disruption of changing labs may also increase role conflict as role expectations may change between labs and universities. Strong graduate student engineer identity is essential for persistence, career choice and may help students transition to professional identities [19], [21], [34].

Similarly, misalignment between current work and future goals may complicate professional engineering identity development [45], [46]. Unfair treatment from faculty, considering changing and changing labs, may contribute to the misalignment of current experiences and future goals, increasing the difficulty to connect tasks to future goals while also increasing the effort required to develop professional engineering identity. While not the focus of these analyses, identifying as a researcher may help students connect current tasks to their future careers as engineers [47]. While interest in and research on graduate students has expanded recently, engineering graduate experiences remain under-researched with engineering identity, providing a promising future research framework.

Finally, unfair treatment may vary between engineering disciplines contributing to discipline variations in engineer identity [44]. While emerging literature demonstrates the importance of engineer identity for graduate students, variation between disciplines provides essential insights into the differences in engineering students' development that may be influenced by differences in unfair treatment between disciplines [19].

The results presented here indicate practical solutions that may aid engineering in reducing unfair treatment at the graduate level. First, faculty training needs a wholistic response to address unfair treatment based upon gender, race, sexual identity, and their intersections. Further, training could engage faculty in self-examination to identify ways in which they may be behaving in ways students perceive as unfair and how to change their own behavior. Faculty may also benefit from training that assists them understanding that identity and perception of faculty behavior, no matter the intention, contributes to students leaving labs and universities.

Addressing unfair treatment requires a response more nuanced than one-time training intended to reduce implicit bias, gender discrimination, or racial discrimination. Institutions should move beyond implicit-bias training to engage faculty and graduate students in anti-sexist and anti-racist social justice perspectives. Institutional and faculty responses should go further to be anti-sexist and anti-racist, assisting faculty and students alike to resist the structural elements that perpetuate disparities in engineering with a social justice focus [41], [42]. The results of such training may improve not only individual student experiences but also assist faculty in becoming advocates for students in overcoming and dismantling structural elements of graduate education that perpetuate disparities in engineering [41], [42]. The integration of social justice viewpoints may have the additional benefit of engaging engineers in problem-solving for problems faced by traditionally oppressed and marginalized communities. Similarly, engineering education can actively stand for a broader set of social justice issues to assist in positioning engineering to answer problems for all people, such as in the recent editorial by Justin Major reflecting on worker's rights and conferences [43].

Engineering institutions could also track problematic faculty and departments based on the number of students who leave an individual lab or department and transfer to another lab, department, or university. Institutional responses may then address specific needs for additional training while also providing the opportunity to engage with students before they reach a point where changing labs or universities is the only solution. Further, when change is necessary, institutional support through specific and well-known mechanisms that facilitate changing labs may benefit institutions and students by retaining qualified and partially trained students. When the process for changing labs is established, students may benefit from a clear understanding of the process and experience less stigma, effort, and emotional turmoil in their attempts to establish an alternative advisor [22].

Limitations and Future Work

The primary limitation of the work presented here is the pilot data itself. The sample size is smaller and less representative than optimal, reducing our ability to perform analyses and draw firm conclusions from the analyses. Similarly, future work should focus on separating items to identify if students changed labs within the same university or changed labs and universities in the same change. Selection bias in participant recruitment may have disproportionately increased the number of considerers and changers in this pilot sample.

The lack of significant results for the secondary advisor may be due to fewer participants having a second advisor. Analyses including only those with a secondary advisor may uncover significant findings but were not possible with the small number of students with a secondary

advisor in the pilot data. Similarly, the non-significant interaction of gender and race/ethnicity for individual items may be due to the decreasingly small cell size when interaction effects are tested. Future research with a national sample may have the power necessary to test this interaction more accurately.

Conclusions

Our analyses explored unfair treatment from advisors and faculty to answer our research questions. We first explored connections between unfair treatment and the demographic groups of gender, race/ethnicity, and sexual identity. Next, we explored the impact of unfair treatment on graduate students considering or changing their lab or university. Our last research question connected the previous two questions to the expression of engineering identity. Broadly, we found meaningful connections between variables in answer to all three research questions. The connections provide important implications for graduate engineering education, future research on discrimination in academia, and potential research implications in other STEM fields.

Women and Men of Color and white Women experience unfair treatment in engineering graduate education. The experiences need to be addressed to improve persistence to degree and equity in engineering as a field. Across analyses, the impact of unfair treatment from primary advisors explained a more substantial percentage of the variance than secondary advisors and other faculty unfair treatment supporting the importance of advisor relationships, as found in other studies [1], [3]. Primary advisors contact students more frequently and hold a stronger impact on degree completion and future careers, increasing the meaningful impact of unfair treatment on students [1]. However, the importance of unfair treatment from other faculty should not be discounted. Non-advisor faculty unfair treatment can jeopardize student performance in classwork and on comprehensive exams, meaningfully impacting a students' ability to complete the graduate program successfully [3].

Equity for Women and Students of Color cannot be reached while unfair treatment remains in graduate engineering education [37]. Differences in unfair treatment experiences between groups show that inequity and perceptions of unfair treatment are complex and impacted by the relationship (primary advisor, secondary advisor, other faculty) of the unfair actor to the perceiving student. Unfair treatment increases the students' considerations for leaving their lab or university, a costly consequence for individuals and programs. In addition, graduate engineering identity reflects unfair treatment, illustrating the psychological cost incurred as students seek in-group identification as advanced engineers.

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