Predicting Degree Attainment of Underrepresented Students in Engineering: The Impact of Faculty Representation

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Abstract

The underrepresentation of women and people of Color in STEM remains a societal challenge. This study investigates the potential link between faculty gender and racial representation in engineering departments and the number of degrees awarded to underrepresented students in engineering. Employing the theoretical framework of Representative Bureaucracy, we use multiple linear regression to analyze this relationship. Our findings indicate a positive predictive association between faculty gender and racial representation and the percentage of degrees awarded to students with congruent identities when controlling for four institutional factors. Our study highlights the importance of promoting diversity among faculty members as they may support departmental policies aiding underrepresented students and fostering a more inclusive climate in their departments.

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Women and people of Color continue to be underrepresented in science, technology, engineering, and mathematics (STEM) professions. To address this problem, researchers have been interested in understanding how faculty can serve as potential role models to students pursuing STEM degrees (Herrmann et al., 2016; Johnson et al., 2019; Shapiro & Sax, 2011). The research proposes that a higher representation of faculty with a similar demographic makeup to their students can lead to positive outcomes for them. However, the literature on this topic provides mixed results. For instance, some studies indicate no effect between the gender of role models and success for women in STEM (Cheryan et al., 2011; Griffith, 2010). While other studies point out the benefits that females and students of Color experience when taking courses from women faculty (Bettinger & Long, 2005; Bowman et al., 2022; Carrell et al., 2010; Hale & Regev, 2014; Herrmann et al., 2016; Johnson, 2017; Johnson et al., 2019) and faculty of Color (Llamas et al., 2019; Price, 2010).

This study aims to examine if the gender or racial representation of faculty in engineering can predict the number of degrees awarded to engineering students with congruent demographic identities. For this research, we analyzed U.S. doctoral-granting universities classified as very-high (R1) or high (R2) research institutions by the Carnegie Classification. This paper addresses two research questions: 1) Can the percentage of female faculty at a university predict the percentage of women graduating with engineering degrees? 2) Can the percentage of faculty of Color[1] at a university predict the percentage of students of Color graduating with engineering degrees?

[1] In this study, the term people of Color comprise those who identify as Asian, Black/African American, Hispanic, Native American, Pacific Islander, or Multiracial

This paper begins by sharing information from previous studies on faculty representation on student outcomes, then describes representative bureaucracy as a theoretical framework used to analyze this study. Finally, we summarize our results and conclude this paper with a brief discussion and recommendations.

Literature Review

Various studies have investigated the relationship between the demographic characteristics of faculty and the influence it has on outcomes for underrepresented students. These studies have focused on understanding if the gender or race of faculty members can positively influence factors such as academic success (Bettinger & Long, 2005; Bowman et al., 2022; Johnson, 2017; Price, 2010), major selection (Bettinger & Long, 2005; Carrell et al., 2010), persistence (Griffith, 2010; Griffith & Main, 2019; Price, 2010; Robst et al., 1996), or the graduation rate of students with congruent demographic backgrounds (Perry et al., 2022; Rothstein et al., 1995). The studies display mixed results. For example, Bettinger and Long's 2005 research on the influence of courses taught by female instructors on female students' academic choices found female instructors can increase students' interests in course selection and major choice in mathematics, geology, sociology, and journalism but had no significant effect in physics, engineering, and computer science disciplines. A study by Koch & Zahedi (2019) observed an association only between Black faculty and graduation rates of Black students but no other student groups.

In contrast, other studies point to the benefits of faculty diversity. For instance, (Sonnert et al., 2007) found a positive association between the percentage of women faculty in science and engineering and the percentage of women majoring and receiving bachelor's degrees in these fields (Sonnert et al., 2007). Carrell and associates (2010) suggest that having a female instructor in math and science classes seems more beneficial for high-performing female students as they are more likely to take future math and science courses and graduate from STEM undergraduate programs. Similarly, students taught by faculty of their own race are more likely to persist in STEM (Price, 2010) and improve grades and retention (Llamas et al., 2019).

Theoretical Framework

In this research, we focus on investigating whether the gender or race of engineering faculty influences the number of degrees awarded to students who share similar backgrounds. To analyze our findings, we adopt Representative Bureaucracy as our theoretical framework. Representative Bureaucracy is a concept in public administration suggesting that having bureaucrats who mirror the demographic characteristics of a clientele group can lead to advancements for those individuals within the group (Grissom et al., 2015; Hawes, 2022; Keiser et al., 2002; Meier & Stewart, 1992). A representative who aligns with the background of a marginalized group can actively work towards their benefit by "making decisions consistent with the policy of the represented" (Meier & Stewart, 1992, p. 156).

We draw a connection between Representative Bureaucracy and higher education by considering the similarities between universities and public bureaucracies. Both have hierarchical structures with divisions of labor and specialization. They operate within a framework of rules and regulations, following formalized decision-making processes (Bidwell & Stroup, 1967). Specifically, Grissom et al. (Grissom et al., 2015) argue that public schools function as bureaucracies, where teachers act as *street-level bureaucrats* for their students by implementing policy. Applying this lens in K-12 education shows that more racially diverse teachers lead to positive outcomes for the served population (Hawes, 2022; Pitts, 2007). Keiser et al. (Keiser et al., 2002) found that passive bureaucratic representation through female teachers translates to active representation for girls while also highlighting the importance of organizational structure and female administrators in their results.

Methodology

For this study, we collected data from the ASEE Profiles of Engineering and Engineering Technology Survey, the Carnegie Classification of Institutions of Higher Education (Carnegie Classification of Institutions of Higher Education, n.d.), and the Integrated Postsecondary Education Data System (IPEDS) (National Center for Education Statistics, n.d.). The ASEE Profiles Survey annually collects information from higher education institutions that provide at least one engineering or engineering technology program (American Society for Engineering Education, n.d.). We used data from this survey to compile our outcome and predictor variables.

Variables

We use two outcome variables in our analysis. The first outcome variable, *Percent Female Graduates*, is the percentage of engineering degrees (bachelor's, master's, and doctoral level) awarded to women at an institution in 2017 and 2019. The second outcome variable (*Percentage Graduates of Color*) is the percentage of engineering degrees awarded to students of Color in those same two years.

Our research includes two predictor variables. Predictor variable one (*Percent Female Faculty*) is the percent of full-time female engineering faculty employed at the Assistant, Associate, or Full Professor level. Predictor variable two (*Percent Faculty of Color*) consists of the percentage of engineering faculty of Color employed at the same three levels. We collected the data for both predictor variables two years before the year of the outcome variables to account for the contact between engineering faculty and students.

Additionally, four institutional factors served as statistical controls due to their potential to act as confounding variables. The factors include research classification (R1-very high research, R2-high research), institutional type (private or public institution), Minority Serving Institution (MSI), and average fall student enrollment. We collected the fall student enrollment information from IPEDS and information on the universities' research classification, institution type, and MSI from the Carnegie Classification database.

Sample Selection

For this research study, we focused on investigating doctoral universities in the U.S. We sampled institutions classified as very-high research (R1) and high-research (R2) universities by the Carnegie Classification. These two research categories accounted for 97% of the institutions that completed the ASEE Profiles survey. Second, when reviewing the ASEE faculty and degrees awarded data, we selected institutions reporting faculty and degree awarded information by gender or race. The final sample included 154 institutions for the 2017 sample and 176 for the 2019 sample. Table 1 shows the institutional characteristics of the universities selected for this study.

Statistical Analysis

This study uses multiple linear regression analyses to evaluate both research questions. Researchers use multiple linear regression to predict the relationship between one dependent variable and two or more independent variables. Using two or more independent variables provides a more comprehensive explanation (Dimitrov, 2013; Field, 2017).

Model 1 and Model 3 are used to answer the first research question and analyze the first outcome variable, *Percent Female Graduates*. Model 1 includes the four control variables and predictor variable one, *Percentage Female Faculty*. Model 3 incorporates the four control variables and both predictor variables, *Percentage Female Faculty and Percentage Faculty of Color*. Model 2 and Model 4 focus on the second research question and use *Percent Graduates of Color* as the outcome variable. Model 2 includes the four control variables and *Percentage Faculty of Color*. In comparison, Model 4 comprises the four control variables and the two predictor variables. We ran the four models with the 2017 and 2019 data. We were not able to run regression models on the intersection of race and gender due to the small sample size.

Results

The multiple regression analysis for Models 1-4 yielded statistically significant results for both 2017 and 2019 data. Model 1 (F_{Model1}= 27.76, $p < .01$) accounted for 49% of the *Percent Female Graduates* variance in 2017. Model 3 (F_{Model3}= 23.05, $p < .01$) accounted for 50% of the variance. *Percent Female Faculty* significantly contribute to Models 1 and 3 when controlling for the four institutional factors; however, *Percent Faculty of Color* did not help predict *Percent Female Graduates* for Model 3. Model 2 (F_{Model2}= 21.30, $p < .01$) accounted for 43% of the variance of the *Percent Graduates of Color* in 2017, while Model 4 (F_{Model4}= 17.65, < .01) accounted for 43% of the variance. In Models 2 and 4, when we account for the four institutional factors, *Percent Faculty of Color* was the only predictor variable to significantly contribute to these models. In Model 4, *Percent Female Faculty* does not significantly predict the *Percent Graduates of Color.* We found similar results for the 2019 data. Refer to Table 2 for the complete results for Models 1-4.

Discussion and Future Recommendations

This study aimed at understanding if the gender or race of engineering faculty could predict the percentage of degrees awarded to engineering students with congruent social identities. Our analysis indicates that when we consider institutional factors such as institution type, research classification, and enrollment numbers, the percentage of female faculty present at a university can positively predict the percentage of degrees awarded to women, and the percentage of faculty of Color can positively predict the percentage of degrees awarded to students of Color. However, the percentage of faculty of Color does not predict the percentages of degrees awarded to women and vice versa, supporting the idea that faculty who share congruent demographic characteristics with their students can impact their degree attainment.

The theory of Representative Bureaucracy indicates that having a higher number of engineering faculty (passive representation) that mirrors the student population can positively impact the represented group. Faculty from underrepresented backgrounds may support departmental policies that assist underrepresented students, such as changing the curriculum, providing funding resources, or improving the department's climate. Future research should focus on understanding how underrepresented faculty working in engineering departments support students or influence their department's policies and practices that can lead to positive outcomes for them. Additionally, authors might want to collect individual data rather than aggregate data, as in the case of this study, to interact with the terms of gender and race and apply Intersectional theory in addition to Representative Bureaucracy.

The underrepresentation of women and people of Color in engineering continues to be a problem society needs to address. Our results reveal the importance of employing faculty with congruent gender and racial characteristics of students in engineering fields. Engineering Deans and Department Chairs need to determine if and how their recruitment and hiring policies might negatively impact underrepresented faculty. Additionally, administrators must ensure that engineering departments provide a positive work environment to retain women and faculty of

Color, as our study indicates that engineering faculty diversity can play a significant role in the number of degrees awarded to underrepresented students.

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Table 1

Demographic characteristics of the sample universities.

Variable	2017	2019
Research Classification		
Doctoral Very-High Research (R1)	86	99
Doctoral High Research (R2)	68	77
Institution Type		
Public	108	124
Private Non-profit	46	52
Minority Serving Institution		
MSI	23	26
Non-MSI	131	150
Average Fall Student Enrollment (per 1,000)	23.86	22.89

Table 2

Multiple regression analysis results.

Variables	2017 Model 1	2017 Model 2	2017 Model 3	2017 Model 4	2019 Model 1	2019 Model 2	2019 Model 3	2019 Model 4
Institutional Factors								
Research Classification	-.05**	-.13**	-.05**	-.13**	-.06**	-.10**	-.06**	-.10**
	(-.01)	(.03)	(.01)	(.03)	(.01)	(.03)	(.01)	(.03)
Institution Type	.06**	.09**	.06**	.09**	.07**	.12**	.07**	.12**
	(-.01)	(.03)	(.01)	(.03)	(.01)	(.03)	(.01)	(.03)
MSI	.00	.28**	.01	.28**	.01	.35**	.02	.35**
	(-.01)	(.03)	(.01)	(.04)	(.01)	(.03)	(.01)	(.03)
Enrollment (per 1,000)	-.001*	.001	-.001	.00	-.001	.002	-.001	.002
	(.00)	(.001)	(.00)	(.00)	(.00)	(.00)	(.00)	(.001)
Representation								
% Female Faculty	.43**	-	.42**	.10	.27**	-	.25**	.04
	(.10)	-	(.10)	(.30)	.07	-	(.07)	(.23)
% Faculty of Color	-	.33**	-.07	.34**	-	.38**	-.05	.38**
	-	(.11)	(.04)	(.11)	-	(.09)	(.03)	(.09)
Constant	.90	2.04	0.92	2.00	1.03	1.57	1.01	1.53
	(.17)	(.50)	(.18)	(.53)	(.14)	(.44)	(.14)	(.45)
R^2	0.49	0.43	0.50	0.43	0.56	0.55	0.56	0.55
F-stat	27.76**	21.30**	23.05**	17.65**	41.23**	38.29**	32.84**	31.72**
N	151	146	147	146	168	161	163	161

Note. Cells present unstandardized coefficient with standard errors in parentheses. Models 1 and 3 use *Percent Female Graduates* as the outcome variable. Models 2 and 4 use *Percent Student of Color* as the outcome variable.
*p < .05; **p < .01