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WIP: Exploring the relationship between female engineering faculty and degree attainment of women in engineering

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Introduction

A diverse workforce in science, technology, engineering, and mathematics (STEM) fields is necessary to address global problems, create new knowledge, and produce innovative technologies benefiting our society. Unfortunately, a gender gap persists in most STEM disciplines even though men and women comprise a similar proportion of the total U.S. workforce[1]. In engineering, while there has been an increase in degrees awarded to women, they continue to earn fewer undergraduate and graduate degrees than their male counterparts [1] and comprise approximately 16.1% of the U.S. engineering workforce in 2022 [2].

To address the problem of female underrepresentation in STEM fields, researchers have been interested in learning how faculty can serve as potential role models or mentors to students interested in obtaining degrees in STEM [3]–[5] . The research proposes that a higher representation of female faculty can positively influence female students in these fields. However, the literature on this topic provides mixed results. For instance, some studies indicate no effect between female role models and success in STEM for women [6], [7] other studies point out the benefits female STEM students experience when taking courses from female faculty [4], [5], [8]–[12].

To further understand this phenomenon, this study aims to examine if the representation of women engineering faculty can predict the number of degrees awarded to women. We aim to analyze U.S. research-focused universities classified as very-high (R1) or high (R2) research doctoral institutions by the Carnegie Classification [13]. Specifically, our main research question is: Can the percentage of female faculty at a university predict the percentage of women graduating with engineering degrees at such an institution?

This paper begins by sharing information from previous studies on the topic of faculty representation on student outcomes, then moves to describe representative bureaucracy as a theoretical framework that can provide explanations of why representation can have a positive impact. Next, we present a summary of our results and conclude this paper with a brief discussion and future recommendations.

Literature review

Various studies have investigated the relationship between female faculty representation in higher education and the influence on student outcomes. These studies have focused on understanding if female faculty members can positively influence factors such as academic success [9], [11], [12] increase the likelihood of students taking additional courses within the same discipline taught by the female faculty [12], major selection [8], [12], persistence [6], [14]–[16], or graduation rate of students from the same demographic group as them [17], [18]. Overall, the results of these studies show mixed results. For example, Bettinger and Long [12] investigated whether introductory courses taught by female instructors influenced the number of future courses taken in the subject, the total number of credit hours taken, and major choice by female students. Their results show female instructors can increase students' interest in course selection and major choice in some disciplines, mainly mathematics, geology, sociology, and journalism. However, they have no statistically significant effect in physics, engineering, and computer science fields. Other studies indicate that STEM female faculty have little to no effect on the number of female or minority students persisting in STEM fields [6] [15] [14].

On the other hand, a larger body of literature points to the benefits of having female professors. Research conducted by Hale and Regev [10] analyzing the gender composition of faculty and graduate students in economics, another field where women are underrepresented, found a positive correlation between the proportion of female faculty and doctoral graduation rates of women. A study by Bowman et al. [11] showed how women taking STEM courses benefited academically from having female instructors in those courses. Also, female and male students who took courses with female instructors reported an increase in self-efficacy and confidence measures[9]. Additionally, Carrell et al. [8] 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, a longitudinal study from Sonnert, et. al [18] 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 [19]

Theoretical framework

For this study, we are interested in determining if the representation of female engineering faculty impacts the number of degrees awarded to women in this field. We use the theory of Representative Bureaucracy as a framework to interpret our results. According to this theory, passive representation of underserved groups in a bureaucracy can lead to improvements for the underserved groups [20]–[23]. A representative can act for the benefit of the represented by "making decisions consistent with the policy of the represented" [23, p. 156].

While researchers have primarily used Representative Bureaucracy as a framework in public policy, Grissom et al. [22] argue that public schools can act as bureaucracies and teachers are *street-level bureaucrats* directly serving in favor of their students by implementing policy. Educational studies at the K-12 level, applying this theoretical lens, have found that greater ethnic representation of school teachers leads to gains in the population served [21], [24]. Looking at gender and education, Keiser et al. [20] report that passive bureaucratic representation based on female teachers translates to active representation for girls. However, they also stress the importance of the organization's structure and the number of female administrators in their results. In higher education, Lee and Won [25]use the theory of representative bureaucracy to examine the role of women administrators and faculty positions in compliance with Title IX gender equity outcomes in intercollegiate athletics.

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 [13], and the Integrated Postsecondary Education Data System (IPEDS) [26]. The ASEE Profiles Survey annually collects information from higher education institutions that provide at least one engineering or engineering technology program [27]. We used data from this survey to compile our dependent and independent variables. To predict female faculty's effect on women obtaining engineering degrees, we established our dependent variable as the percentage of degrees awarded to women at an institution. Our dependent variable, *Percent Female Graduates*, consists of the percentage of bachelor's, master's, and doctoral degrees awarded to women in 2017 and 2019. Our independent variable, *Percent Female Faculty*, was calculated from the total number of full-time engineering faculty at the Assistant, Associate, or Full Professor level. We collected the data for our independent variable two years before the year's value of the dependent variable to account for the contact between female engineering faculty and students. Four institutional factors served as statistical controls due to their potential to act as confounding variables. The factors include fall student enrollment, institutional type, research classification, and Minority Serving Institution type. The fall student enrollment information was collected from IPEDS. Additionally, the Carnegie Classification database provided information about the institutional type (private or public institution), research classification (R1-very high research, R2-high research), and Minority Serving Institution (MSI).

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. Institutions classified as R1 and R2 award at least 20 doctoral degrees annually and receive at least $5 million in research expenditures. 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 only selected institutions reporting faculty and degree awarded information by gender. 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.

Table 1. Demographic characteristics of the sample universities.

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

Statistical analysis

This study uses hierarchical regression analysis to determine if the *Percent of Female Faculty* impacts the *Percent of Female Graduates* when controlling for confounding variables. Hierarchical regression is a multiple regression method that involves adding predictor or control variables in stages, to determine if the model improves the prediction of the dependent variable at each stage. The larger the R^2 value the better the fit [28], [29]. As mentioned, we controlled four variables: Institution Type, Research Classification, MSI, and Enrollment. We ran two models to analyze the 2017 and 2019 *Percent Female Graduates* variable. The Restricted Model only includes the control variables, while the Full Model also includes the independent variable and the control variables. We also conducted descriptive statistics on both the dependent and independent variables.

Results

The results from a hierarchical regression analysis indicated that both the Restricted and Full Models significantly predicted the percentage of engineering degrees awarded to women in 2017 and 2019. The Restricted Model, which only included the four control variables, accounted for 42% of the variance of the *Percent Female Graduates* in 2017 ($F_{Restricted} = 26.58$, $p < .01$). The Full Model that included both *Percent Female Faculty* and the four control variables, accounted for 48.7% of the variance in the dependent variable ($F_{FullModel} = 27.76$, $p < .01$). The change in R^2 between the Restricted and Full model is significant and indicates that *Percent Female Faculty* accounts for an additional 6.8% of the variance in *Percent Female Graduates* ($\Delta R^2 = .068$, $p < .01$). The analysis of the unstandardized coefficient indicates that when controlling for institutional factors, a one percent increase in the *Percent of Female Faculty* at a university can be associated with a .43% increase in the *Percent of Female Graduate* at the university.

Similarly, the Restricted and Full models using the 2019 *Percent Female Graduates* data also significantly predict the dependent variable. The Restricted Model accounted for 51.6% of the variance in the dependent variable ($F_{Restricted} = 43.65$, $p < .01$). In comparison, the Full Model accounted for 55.8 % of the variance in the dependent variable ($F_{FullModel} = 41.23$, $p < .01$). The change in R^2 between both models is also statistically significant ($\Delta R2 = .043$, $p < .01$) and shows that *Percent Female Faculty* explains an additional 4.3% of the variance in *Percent Female Graduates*. Table 2 displays the full results of the hierarchical regression analysis.

Discussion and future recommendations

Advances in science and engineering are dependent upon a diverse range of talented people working in STEM careers. However, women who decide to major in these fields experience a variety of factors that can influence them from obtaining a college degree such as prior educational experience and institutional factors [6]. In engineering fields, approximately 24% of the degrees awarded in 2020 were earned by women [1]. While there are many reasons that can positively influence the persistence and graduation of women in engineering [6], [12], [19] more research needs to be conducted to understand the best strategies to support women interested in obtaining engineering degrees.

Table 2. Hierarchical regression analysis results

Variables	% Female Graduates 2017 Restricted	% Female Graduates 2017 Full Model	% Female Graduates 2019 Restricted	% Female Graduates 2019 Full Model
Institutional Factors				
Research Classification	-.06**	-.05**	-.06**	-.06**
	(.01)	(.01)	(.01)	(.01)
Institution Type	.07**	.06**	.07**	.07**
	(.01)	(.01)	(.01)	(.01)
MSI	.01	.003	.01	.01
	(.01)	(.01)	(.01)	(.01)
Enrollment (per 1,000)	-.001*	-.001*	.000	-.001
	(.00)	(.00)	(.00)	(.00)
Representation				
% Female Faculty	-	.43**	-	.27**
		(.10)		(.07)
Constant	1.13**	.91**	1.09**	1.03**
	(.18)	(.17)	(.14)	(.14)
R^2	.420	.487	.516	.558
ΔR^2	-	.068	-	.043
F-stat	26.58**	27.76**	43.65**	41.23**
Δ F-stat	-	19.26**	-	15.80**
N	151	151	168	168

Cells present unstandardized coefficient with standard errors in parentheses. Change in F (Δ F-stat) indicates the likelihood of whether the additional factor (% Female Faculty) is significantly improving prediction of the model.
*p < .05; **p < .01

This study aimed at understanding if the representation of female engineering faculty could predict the percentage of degrees awarded to women. Our analysis indicates that when we consider institutional factors such as institution type, research classification, and enrollment numbers, an increase in female faculty percentage can positively impact female engineering graduates. While most of the studies presented in the literature look at the educational outcomes of students who have taken classes with female faculty, the theory of Representative Bureaucracy indicates that just having a higher number of female engineering faculty (passive representation) can positively impact women pursuing engineering degrees. Female faculty may play a role in supporting departmental policies that assist female students, such as making changes in the curriculum, providing funding resources, or improving the department's climate. However, future research should focus on understanding how female faculty working in engineering departments are supporting women students or influencing the policies and practices of their department that lead to positive outcomes for their female students.

The underrepresentation of women in engineering continues to be a problem society needs to address. Our results reveal the importance of employing women faculty to increase the number of degrees awarded to women in engineering fields. Engineering Deans and Department Chairs need to make a conscious effort to determine if and how their recruitment and hiring policies might negatively impact women. Additionally, administrators must ensure that engineering departments provide a positive work environment to retain female faculty, as our study indicates that more female engineering faculty will positively impact the number of women earning engineering degrees.

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