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IMPROVED METRIC FOR IDENTIFYING FEMALE FACULTY REPRESENTATION IN ENGINEERING DEPARTMENTS

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Improved Metric for Identifying Female Faculty Representation in Engineering Departments

Abstract

Presence of female faculty members in colleges and universities is growing, but many programs continue to reduce the gender gap in an attempt to better balance gender representation in engineering faculty. While many programs report increasing percentages in female hires and retainment of women in faculty roles, reporting of gender as a percentage of the faculty body may not capture a full representation of interaction between students and female faculty. Faculty teaching assignments vary based on rank and professorship and the percent of the faculty body may not be the most insightful mechanism for capturing the true impact of a female hire on the students in a program. In order to better capture the female faculty impact, a study was conducted to map contact hours as a reporting mechanism that can be paired with percentage of faculty as a more robust representation of the gender distribution within a department. Course credit hours for undergraduate curriculum programs were mapped to faculty gender for multiple departments within a college of engineering. Credit hours as well as hours of in-class sessions were reported to capture the minimum contact between a student attending class and a faculty directing the class; results exclude office hours, email contact, and other out-of-class engagement, thereby representing a minimum contact hours number. The results from this exercise demonstrate that the faculty teaching assignment is not directly comparable to percent of body. Programs appearing to have less female faculty than national averages may not necessarily have less female faculty interactions. The compound metric capturing both credit hour and percent of body may be a preferred metric in understanding the exposure of students to female faculty role models.

Introduction

Strides in developing a gender-diverse faculty continue to enhance the experience for students in engineering programs across the country. Concerted efforts to hire female faculty have been made across all types of undergraduate programs, from those focused on education to research-intensive institutes, such that the population of faculty role models can best pair to the population of employed engineers in the workforce, found also in the students enrolled in such programs. While most institutes record and report the percentage of faculty members, there may be a missed opportunity in reporting the true experience encountered by students participating in the undergraduate curriculum. Simply reported as a fraction of the overall faculty count, institutes may be underreporting the true one-on-one engagement between student and female faculty. Often, institutes have a number of senior male faculty with limited teaching responsibilities, thereby not effectively influencing the undergraduate population as a junior female faculty with a more recurring undergraduate teaching assignment. The opportunity for a university to report a truer representation of the engagement with female faculty is valuable to recruitment of female students and may possibly be attractive to other minority factions. A series of 10 undergraduate engineering programs were reviewed at a single institute to compare the percentage of female faculty to an "engagement" percentage.

Literature Review

STEM Diversity initiatives and recruitment plans all over the world have increased the number of women choosing to pursue a career, and therefore education, in STEM topics. Universities are reporting increases in the number of female students entering into engineering programs, as well as female students obtaining doctorates, yet female faculty percentages remain low. Hiring diversity programs are increasing the number of female faculty in engineering departments, but a disproportionate number of female faculty fail to make tenure as compared to their male counterparts. One potential reason for female faculty failing to make tenure is the variability in what tasks they are required to do in comparison with their male counterparts. Men are traditionally asked to teach less and research more, while teaching becomes a larger requirement for tenure-track females [1].

As a whole, efforts are to increase the number of women in STEM careers, especially in higher education, are supported by major universities and funding agencies such as the National Science Foundation [2-4]. The NSF ADVANCE program is committed to increasing the participation and advancement of women in academic and non-academic STEM careers. A major factor in how well women perform in STEM careers is related to how many other women, especially women of color, are in leadership or decision-making positions [5]. An argument that many are making is that in order to increase the number of women in engineering courses at universities is to increase the number of women teaching engineering courses. Many universities are beginning to implement training programs for equal opportunity hiring, such as STRIDE (Strategies and Tactics for Recruiting to Improve Diversity and Excellence) training at The University of

Michigan and The University of Tennessee. STRIDE encourages hiring committees to attract and retain the best possible candidates [4], [6]. Specific efforts are applied to attract underrepresented minorities, and women in fields where women are underrepresented. Similar efforts have been noted at other universities across the United States such as Montana State [7], and MIT [8]. However, even with programs and university initiatives to increase female and minority presence in classrooms, many of the positions being filled by targeted employees are adjunct and non-tenure track roles; women and minorities who do secure tenure track positions are also less likely to make tenure as compared to male and non-minority counterparts [9]. Given the potential importance of increasing female faculty in engineering, female faculty need to be hired into both tenure track and non-tenure track roles to provide positive role models to female and minority students at all levels of academia.

Research on student performance suggests that female and under-represented minority students learn better from people who look the most like them, however research on the impact that female professors have on female students is variable. Some studies report that gender matching in first-year undergraduate STEM courses has either no impact or a slightly negative impact on female student retention [10-12]. Another study conducted by Carrell, Page, and West at the U.S. Air Force Academy removed selection bias, as students are randomly assigned to classes. The Air Force study uncovered substantial positive outcomes of female faculty on female students, specifically in STEM courses [13].

Even though diversity initiatives are trying to increase the number of female faculty in engineering programs, the overall percent of female faculty in an engineering school or department may not be the best way to represent female classroom contribution and interaction with students. While the number of female role models in a department is important, the amount of time that students actually spend interacting with these female role models may be a better indicator for female student success. Since female professors are generally required to teach more than their male counterparts [1], female professors may actually be interacting with students more frequently than the actual percent of female faculty members may insinuate.

Given that female faculty in engineering may improve the persistence of female students, and that female faculty tend to be required to teach more than their male peers, the percent of female faculty within a department may not equal the amount of time a female student will spend with a female professor. This study compares female faculty percentage and the time that a would spend with a female faculty member in classes based on course credit hours. For schools and departments looking to increase the enrollment of female students, the time a female student will spend with a female faculty member may become a beneficial recruitment tool.

Method

The data were collected from an R1 Land Grant university in the United States beginning with the Fall 2014 semester and concluding with the Spring 2020 semester. Initially focusing on students in the Civil and Environmental Engineering Department, the instructor of record for each undergraduate course offering was tabulated using archived course time tables. The faculty directory generated by the college of engineering was used to determine gender for each listed instructor and a credit hour multiplier value of one or zero was applied to each listing with one corresponding to a female faculty member and zero corresponding to a male faculty member. It should be noted the authors of this paper did not have access to any information that could identify a faculty member as non-binary. Possible course combinations for any given cohort of students were generated using the traditional four-year sequence listed in the student handbook along with pre-approved electives and concentrations. In the program examined, students are required to select two concentrations. These concentrations determine the course path for a given student. A total of nine concentration combinations (Table 1) met the requirements of the study. These combinations were used to generate course paths which were then cross-referenced with the table of instructors resulting in a maximum and minimum value for time spent with female faculty. This was completed using both the credit hours and the contact hours for each course.

Table 1 Civil & Environmental Engineering Concentration Combinations

Concentration 1	**Concentration 2**		**Concentration 1**	**Concentration 2**
Construction	Structures		Geotech	Water Resources
Construction	Transportation		Structures	Environmental
Construction	Water Resources		Transportation	Environmental
Geotech	Structures		Water Resources	Environmental
Geotech	Transportation			

In the second phase of data collection, a similar process was used to analyze nine additional degree programs in the college of engineering (Table 2). In the expanded analysis only the courses mandatory for each student were included.

Table 2 Engineering Degree Programs Addressed

Chemical and Biomolecular	Industrial and Systems	Aerospace
Civil and Environmental	Materials Science	Biomedical
Electrical	Mechanical	Nuclear
Biosystems and Soil Science		

Results

An initial analysis of the faculty directory for the college of engineering was used to generate a percentage of female faculty for each department (Table 3). The percentage for the individual departments ranges from five to 18 with Chemical and Biomolecular Engineering and Civil and Environmental Engineering as the lowest and highest respectively. The average for the college of engineering as a whole was calculated at 12 with a standard deviation of 3.76.

Table 3 Percent female faculty by department

Department	Total % Female Faculty
Chemical and Biomolecular Engineering	5%
Civil and Environmental Engineering	18%
Electrical Engineering and Computer Science	14%
Industrial and Systems Engineering	13%
Materials Science and Engineering	15%
Mechanical, Aerospace and Biomedical Engineering	9%
Nuclear Engineering	11%
Biosystems and Soil Science	10%
College of Engineering Average	**12%**

Ten degree programs were selected for analysis with a focus on determining the amount of time students could reasonably expect to spend with female faculty. A list of mandatory courses was generated for each degree using the student handbook. Electives were excluded from the calculations as they vary greatly from program to program and introduce an element of choice into the course path. Table 4 includes a summary of the percentage of female faculty teaching in each of the ten degree programs during the period applicable to the cohort of students graduating in Spring 2020. Also listed is the percentage of the mandatory credit hours taught by female faculty. The values range from 0 to 37% with the Biosystems and Soil Science degree program and the Civil and Environmental degree program having the lowest and highest percentages respectively. On average the percentage of credit hours spent with female faculty is 31% higher than the percentage of female faculty.

Table 4 Percentage of credit hours taught by female faculty per degree program

Spring 2020 Graduating Class		
Mandatory Courses	**% Female Faculty**	**% Female Credit Hours**
Chemical and Biomolecular	5%	9%
Civil and Environmental	18%	37%
Electrical	14%	8%
Industrial and Systems	13%	10%
Materials Science and Engineering	15%	13%
Mechanical	9%	14%
Aerospace	9%	20%
Biomedical	9%	24%
Nuclear	11%	7%
Biosystems and Soil Science	10%	0%

With the highest percentage of female faculty and the highest percentage of mandatory credit hours taught by female faculty, the Civil and Environmental Engineering department was selected for closer examination. A total of 18 course pathways were generated using the nine possible concentration combinations listed in Table 2 and the list of pre-approved technical electives provided in the student handbook. The mandatory courses for each student served as the baseline to which the concentration requirements and technical electives were added. If the concentration requirements listed more than one acceptable option, the course list generated for each possible option was analyzed. A maximum and minimum number of female taught technical elective credit hours was generated per semester. These numbers were incorporated into the final course tally as applicable. Each complete course list was examined for both credit hours and contact hours spent with female faculty. This process was completed for four cohorts of students and the results were broken into two categories, maximum possible time with female faculty (Table 5) and minimum possible time with female faculty (Table 6.)

Table 5 Maximum possible time with female faculty

Graduating Semester	Spring 2017		Spring 2018		Spring 2019		Spring 2020	
	% Female Faculty		% Female Faculty		% Female Faculty		% Female Faculty	
Concentrations	Credit Hours	Contact Hours	Credit Hours	Contact Hours	Credit Hours	Contact Hours	Credit Hours	Contact Hours
Const/Struct	29%	**37%**	18%	27%	27%	29%	33%	40%
Const/Trans	23%	28%	12%	18%	27%	29%	31%	35%
Const/Water	23%	28%	**23%**	29%	27%	29%	33%	40%
Geo/Struct	29%	**37%**	18%	27%	27%	29%	33%	40%
Geo/Trans	23%	28%	12%	18%	27%	29%	31%	35%
Geo/Water	23%	28%	12%	18%	27%	29%	33%	40%
Struct/Envir	**33%**	**37%**	**23%**	**32%**	**33%**	**37%**	**38%**	**44%**
Trans/ Envir	26%	28%	17%	23%	**33%**	**37%**	36%	40%
Water/Envir	26%	28%	17%	23%	**33%**	**37%**	**38%**	**44%**
Average	26%	31%	17%	24%	29%	32%	34%	40%

The maximum values for each data set in Table 5 are shown in bold. The combination of structural and environmental concentrations consistently has or shares the maximum percentage of female faculty credit hours and contact hours. The departmental average ranges from 17 to 40 percent with an increase in female faculty credit hours of 17 percent and female faculty contact hours of 16 percent between 2018 and 2020 after an initial drop-off from 2017 to 2018.

Table 6 Minimum possible time with female faculty

First Semester	Spring 2017		Spring 2018		Spring 2019		Spring 2020	
	% Female Faculty		% Female Faculty		% Female Faculty		% Female Faculty	
Concentrations	Credit Hours	Contact Hours	Credit Hours	Contact Hours	Credit Hours	Contact Hours	Credit Hours	Contac t Hours
Const/Struct	27%	35%	15%	24%	**27%**	**29%**	30%	37%
Const/Trans	**20%**	**26%**	**8%**	**16%**	**27%**	**29%**	**28%**	**33%**
Const/Water	**20%**	**26%**	20%	26%	**27%**	**29%**	30%	37%
Geo/Struct	27%	35%	15%	24%	**27%**	**29%**	30%	37%
Geo/Trans	**20%**	**26%**	**8%**	**16%**	**27%**	**29%**	**28%**	**33%**
Geo/Water	**20%**	**26%**	**8%**	**16%**	**27%**	**29%**	30%	37%
Struct/Envir	30%	35%	20%	29%	33%	37%	35%	42%
Trans/ Envir	23%	26%	13%	20%	33%	37%	33%	37%
Water/Envir	23%	26%	13%	20%	33%	37%	35%	42%
Average	**23%**	**29%**	**14%**	**21%**	**29%**	**32%**	**31%**	**37%**

The minimum values for each data set in Table 6 are shown in bold. The combination of geotechnical and transportation concentrations consistently has or shares the minimum percentage of female faculty credit hours and contact hours. The departmental average ranges from 14 to 37 percent with an increase in female faculty credit hours of 17 percent and female faculty contact hours of 16 percent between 2018 and 2020 after an initial drop-off from 2017 to 2018.

The course lists associated with Table 5 assume that, should a student have the option, they would choose the courses taught by female faculty. The percentage of female faculty employed by the department being examined will directly affect the number of courses offered and as such the possible course combinations available to a student. A student graduating in the Spring of 2020 will begin making these choices as early as their sophomore year. Figure 1 gives the average maximum percentages for credit hours and contact hours spent with female faculty along with the percentage of female faculty in the subject department beginning with the Fall 2014 semester. The percentage of female faculty was lowest between the Fall of 2015 and the Spring of 2017. This directly impacted the options available to the graduating class of 2018. Beginning with the Fall 2017 semester, the percentage of female faculty has incremental increased in proportion to the increase in maximum credit hours and contact hours a student can expect to spend with female faculty.

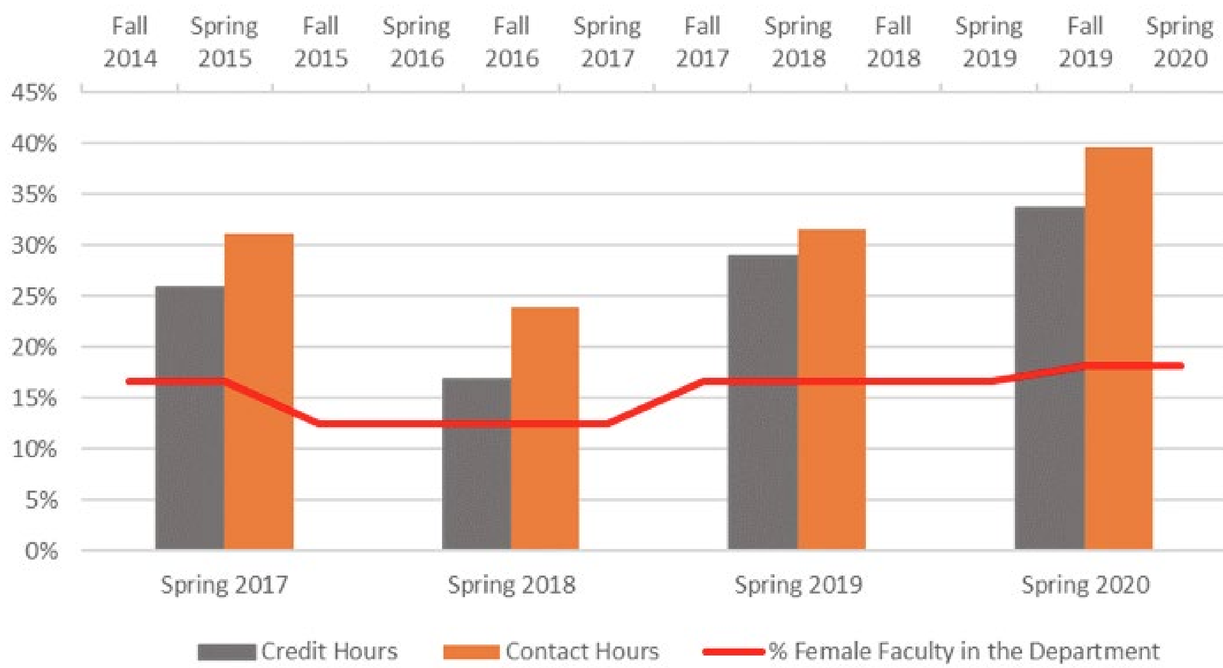

Figure 1 Departmental average maximum calculated percentage of female faculty credit hours and contact hours for students graduating between Spring 2017 and Spring 2020.

Discussion

As identified in this case study, the standard reporting metric of 18% female faculty in the civil engineering program significantly underrepresents the interaction occurring in the classrooms during the undergraduate courses. In most semesters, by credit hour, interaction with female faculty averages, at minimum, 10% greater than the standard metric; by contact hours in the course, interaction should be measured as nearly double the standard metric value. In both approaches, the standard reporting metric is not capturing the true classroom experiences and an opportunity to promote a more correct value is warranted at this time.

The imbalance could be attributed to a number of traits, some institution-specific, some potentially universal, and some representative of recent trends in employment. Of the institute studied, the current faculty profile has an uneven balance of female faculty across faculty positions. Many of the female faculty are in junior positions, both tenure-track and non-tenure, skewing the results as most undergraduate teaching assignments are not offered to full professors, which by population make up 51% of the civil engineering department. Nationally, across all engineering disciplines, approximately 67% full professors are male [14]. Given the pairing of lesser female faculty on the whole, of whom are primarily in junior engineering positions, the imbalance of credit hour mapping is not unexpected. Lastly, with recent efforts at this specific institute, and mirrored nationally, recent efforts have been more deliberate in hiring female faculty and the recent hires at this institute have been in early career positions, again assigned to many more undergraduate teaching responsibilities than more senior faculty members.

While the civil engineering program saw a significant imbalance, the trend is not consistent across all departments at the institute evaluated. Of the (10) engineering departments considered, variability existed such that the percent of female faculty could be nearly 15% less than the mandatory credit hours a student could experience with a female faculty or 10% more than the mandatory credit hours. Students seeking to understand the true experience within a department may be misled in knowing only the reporting faculty; as an example, a biosystems engineering student may expect nearly 10% of courses to engage female faculty, while that student may not actually engage with any female faculty within their mandatory core curriculum.

The use of the "credit hour" or "contact hour" reporting metric rather than the standard fraction of population is likely to closer align as the profession's positions find a gender balance. However, even in long term assessment of a program, review of all three metrics is recommended to better represent the diverse experiences in an undergraduate program even as the population of faculty finds equilibrium. Balancing the experience for students to have fair exposure to professionals of both genders not only allows for underrepresented genders to be better supported, but truly ensures that all students recognize both genders as equal contributors to the profession. As a tool for recruitment and retention of undergraduate students, a more comprehensive report of the experience should be available.

Conclusion

A more robust representation of opportunities to engage with faculty through course selection could be valuable as students explore the engineering profession and opportunities for depth of knowledge as they advance through an undergraduate curriculum. While research is divided on the need or value for students of certain demographics to experiences classes with professionals of the same demographics, the opportunity for a student to make a more informed decision on their curriculum path is expected improve individual success and retention. The release of a more detailed summary of the experience is recommended as a more valuable tool in recruiting a diverse population of students and engaging that population with a mirrored diverse course experience.

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