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A MEASURE OF INTRA-UNIVERSITY COLLABORATION: FACULTY GENDER IMBALANCE ON DOCTORAL DISSERTATION COMMITTEES IN ENGINEERING DISCIPLINES

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ABSTRACT

Aim/Purpose	This article presents an analysis of female faculty representation on dissertation committees in comparison to the percentage of women faculty in departments of engineering in 2013 and 2014.
Background	Collaboration is an indication of a robust research program, and the consequences of collaboration may benefit one's academic career in numerous ways. Gender bias, however, may impede the development of intra-university collaborations, thereby inhibiting professional success.
Methodology	Nine universities were examined (Carnegie Mellon University, Case Western Reserve University, Cornell University, Duke University, Massachusetts Institute of Technology, Northwestern University, Rice University, University of Pittsburgh, and Vanderbilt University) across six different engineering departments (civil, chemical, mechanical, materials, biomedical, and electrical).
Contribution	This paper reveals how an analysis of gender balance of faculty representation on doctoral committees can help advance an institution's understanding of the level to which collaboration with female colleagues may be occurring, thereby providing insight to the climate for women.
Findings	A potential gender imbalance does exist in select cases. In aggregate, the percentage of female engineering faculty on dissertation committees compared to within each university revealed a disparity of less than 6% points.

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Recommendations for Practitioners	Examining how well represented female engineering faculty are on dissertation committees can be an important measure of levels of collaboration within an institution and of how well women are being integrated into the existing culture.
Impact on Society	The results of this study may increase awareness of gender bias and encourage faculty to be more inclusive and collaborative, particularly with their female colleagues, and as a result may help improve the climate for women faculty in engineering.
Future Research	This study opens a discussion about the potential for gender imbalance and bias within an institution, particularly with respect to collaboration and inclusion. Future work may explore other indicators beyond doctoral committee representation.

Keywords gender bias, gender imbalance, doctoral committee, collaboration

INTRODUCTION

The representation of women as professors of engineering has increased over the past several decades, but various issues are impeding further attraction and retention. Lack of mentoring, life-work balance, and general work climate have been cited as specific challenges for women faculty in STEM fields (Aiston & Jung, 2015; Fox, 2010; Hill, Corbett, & St. Rose, 2010; Mason & Goulden, 2004; Monroe, Ozyurt, Wrigley, & Alexander 2008; Sax, Hagedorn, Arredondo, & Dicrisi 2002; Ward & Wolf-Wendel, 2004). Women who experience a negative work climate point to instances of discrimination, sexual harassment and/or off-putting interpersonal interactions (Settles, Cortina, Malley, & Stewart 2006). Moreover, Bilimoria, Joy, and Liang (2008) cite that an oftentimes non-inclusive workplace is the main contributor to the "leaky pipeline" (Mason, Stacy, Goudlen, Hoffman, & Frasch 2005) of women who choose to leave or not to pursue an academic career in STEM. More recently, Hart (2016) studied 25 mid-career faculty at one research university and found that, compared to men, women were not as well integrated into external networks, sometimes carried a larger burden of service work, and reported an unsupportive climate when facing the potential for promotion or leadership opportunities. Given these extensive studies, there has been limited investigation into how collaboration (or lack thereof) might influence a female engineering faculty member's success or job satisfaction at a research-intensive university. Here, we recognize that collaboration might involve sporadic interaction or a deeper day-to-day interfacing. Bozeman and Gaughan (2011) showed that women faculty oftentimes vary in their approach to research collaboration compared to men, which can impact professional success. In science and engineering fields specifically, collaboration is often a requirement for success since leading multi-investigator research projects is now an expected component of tenure and promotion packages (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2005). Having collaborators can increase one's chances of attracting more funding since multiple proposals can be written when multiple researchers are engaged. Bozeman and Corley (2004) showed that faculty who have larger grants have more collaborators, and interestingly, female researchers collaborate with females at a higher rate than their male colleagues (24%). Working with collaborators also can increase one's ability to be listed as a co-author on multiple journal papers and increase one's number of citations, metrics by which tenure and promotion are evaluated (Ghiasi, Lariviere, & Sugimoto, 2015). Zeng et al. (2016) reported that female faculty have fewer distinct co-authors and a lower probability of repeat co-authors on publications than their male counterparts. The latter is particularly important because research has shown that collaborative teams tackling newer research questions produce higher impact work (Guimera & Amaral, 2005). Having collaborators as colleagues at one's own institution can also be an important source of mentorship and contribute to job satisfaction (Belle, Smith-Doerr, & O'Brien, 2014; Jung, Bozeman, & Gaughan, 2017). Even more, Jha and Welch (2010) showed a correlation between the existence of close relationships and the execution of research collaborations. Therefore, understanding the level to which collaboration with female colleagues may be occurring within a department or engineering school can provide insight to the climate for women and the potential for their own professional success.

One mechanism that may be used to measure collaboration at one's own institution is the level at which female faculty participate on doctoral dissertation committees. At research-intensive universities, the graduation of Ph.D. students is a measure of success for the faculty advisor. If the graduating student has been working on a collaborative project, it is very common for the collaborating faculty member to be a member of the dissertation committee. Even more, serving on a dissertation committee can be an opportunity to more closely engage with a colleague, thereby attracting a new potential collaborator. However, different from being a co-author on a journal publication or a co-PI on grant proposal, being asked to serve on a dissertation committee may not require such close collaboration to have occurred. The invitation to a female colleague (particularly a newly hired colleague) to serve on a student's doctoral dissertation committee may be influenced by one's existing relationships in the department or a perception of the female colleague's abilities, intelligence, collegiality, and other less tangible traits. Consequently, examining how well represented female engineering faculty are on dissertation committees can be an important measure of levels of collaboration within an institution and how well women are being integrated into the existing culture. To explore this further, this project investigated the representation of female engineering faculty serving on dissertation committees in comparison to their representation within specific engineering disciplines at select universities. Note that we surveyed the nine universities studied herein and found that all expect that the student and his/her advisor together identify and request the participation of select members. The findings indicate that a potential gender bias may exist.

METHODS

To investigate the potential gender imbalance on dissertation committees, a quantitative, historical research design method was employed. Data was collected and analyzed from 2013 and 2014 doctoral dissertations in engineering departments of nine U.S. Research I universities. The universities selected for analysis satisfied the following criteria: 1) the universities fall within the top forty research universities in the United States as identified from the 2016 U.S News and World Report list of Best Engineering Schools (U.S. News & World Report, 2015); 2) from 2013 to 2015, the universities granted Ph.Ds. in at least four of the six following areas: mechanical engineering, electrical engineering, materials science/engineering, civil engineering, biomedical engineering and chemical engineering (or their equivalents); and 3) the 2013 and 2014 doctoral dissertations and associated committee member participation information were available by online public access to databases. In addition, since this research was conducted at Case Western Reserve University (CWRU), we were interested in comparing the results at CWRU to other universities with similarly sized graduate student populations in engineering (in 2015) (Yoder, 2015). As a result, four universities were chosen of similar size to CWRU (635 engineering graduate students in 2015): Vanderbilt University (466 engineering graduate students), the University of Pittsburgh (Pitt) (796 engineering graduate students), Rice University (868 engineering graduate students), and Duke University (1041 engineering students). Note that Duke does not have a chemical engineering department, and Vanderbilt and Duke do not offer a specific degree in materials science and engineering. Four other universities were chosen for notability (i.e., rankings in the 2016 U.S. News and World Report, 2015): Northwestern University (1857 engineering graduate students), Cornell University (1966 engineering graduate students), Massachusetts Institute of Technology (MIT) (3143 engineering graduate students), and Carnegie Mellon University (CMU) (3400 engineering graduate students).

All of the 2013 and 2014 dissertations were collected from the universities' corresponding online thesis and dissertation databases. The databases were filtered by year of thesis defense (2013-2014), department, and by PhD candidate (to remove any Masters Degree theses) to produce all relevant data that could be found for each department and university. For each dissertation, the graduate student's name (i.e., the author), student's degree granting department, year of thesis defense, and associated committee members names, primary departments, and genders were recorded. University and other websites were accessed (in 2015 and 2016), and photos of faculty members were used to determine gender. Primary department designation was determined as described below. Committee members from outside the university and outside engineering departments were excluded from the analysis although the names, organizations, and genders were recorded. For example, a dissertation committee of four members, including one from a non-engineering department, was treated as though it was a committee of three members.

To identify potential gender imbalance on committees, the gender ratios across faculty within the corresponding individual engineering departments of each school were compared to those of the committees. The total faculty and gender composition within each department was determined using the American Society for Engineering Education (ASEE) College Profile faculty count (Ghiasi et al., 2015). While the ASEE data was used as the primary source of faculty count information, a survey distributed to departments was used to verify counts using the criteria described below and to identify unusual circumstances. Tenured and tenure-track faculty and/or any other faculty (e.g., Research Professors) eligible to serve on dissertation committees were included in the analysis (faculty not eligible, such as those on leave or emeritus and not active, were not included), and only primary faculty appointments were counted; secondary or courtesy appointments in other departments were ignored. True dual appointments in two engineering departments were counted as 0.5 in each, and dual appointments in an engineering department and outside of engineering were counted as 0.5 for the associated engineering department unless through direct communication, the department representative noted a different fractional representation should be used. Any faculty that were present for only part of the year were counted as a fraction (i.e., 0.5 for a July through December appointment). In some instances, female engineering faculty had primary appointments in engineering departments different from the student's designated department (e.g., a mechanical engineering faculty member might serve on a dissertation committee for a student earning a degree in electrical engineering). These cases were still counted accordingly and included in the comparison since one of the main goals of this work is to elucidate if male faculty may be biased toward not including female faculty on dissertation committees no matter in what engineering department the women reside.

Fifty-one departments were responsive to our survey, but only forty-four departments voluntarily confirmed or corrected their faculty counts accordingly. For these departments, the ASEE data agrees with the department reported data with less than a 20% margin of error. Since the fractional system applied above differs from the ASEE method of collection, this margin of error was deemed within acceptable limits. For data analysis, the faculty count given by the forty-four departments which voluntarily responded was used while the ASEE data was used for the ten departments that did not report their faculty counts. Note that data collection for the years of 2013 and 2014 could not be completed until late 2016 given the delay at some institutions for theses to be uploaded to their respective databases and because receiving confirmation from departments of faculty gender at the different institutions was a lengthy process.

Additionally, comparisons among like departments required certain generalizations be made since some of the universities use different names or groupings for similar fields. These regroupings into generalized department names included:

- Civil engineering: civil engineering; and civil and environmental engineering
- Chemical engineering: chemical engineering; chemical and petroleum engineering; and chemical and biomolecular engineering
- Materials science and engineering: materials science and engineering; materials science; and materials science and nano-engineering
- Mechanical engineering: mechanical engineering; mechanical and aerospace engineering; and mechanical engineering and materials science;

- Biomedical engineering: biomedical engineering, biological engineering, and bioengineering
- Electrical engineering: electrical engineering, electrical engineering and computer science, and electrical and computer engineering.

From the data collected, a large variation in the number of data points associated with each department was observed. In other words, smaller departments or departments with fewer Ph.D. candidates had significantly fewer dissertations published than more prolific departments at larger universities. To ensure statistical significance, the dataset was required to demonstrate a minimum confidence interval of 98% and a z-score of 2.33. Due to the potential for missing data, the margin of error (MOE) for sampling was set to 20%. Then, to determine the minimum acceptable sample size, the standard deviation, σ, for the dataset as a whole was calculated, and the following formula used:

$$minimum\ sample\ size = (z\text{-}score * \sigma / MOE)^2$$

Given these parameters, only two departments did not meet the requirement for statistical significance: CWRU's Department of Civil Engineering and CMU's Department of Materials Science and Engineering. These two departments' datasets therefore were omitted from the analysis.

The percentage of female engineering faculty on each committee was determined and the percent average for the department was found from averaging these percentages. The percent average was compared to the percentage of female faculty corresponding to the student's degree granting department. The percent averages for each department and the faculty percentages were used to generate the bar graphs shown in Figures 1, 2, 3, 4, 5, 6, 7, and 8. The programming language, R Studio, was used to generate a box and whisker chart from the percentages to illustrate variance between different fields of engineering as seen in Figure 2.

RESULTS AND DISCUSSION

Figure 1 is a bar chart comparison of the percentage of female engineering faculty across disciplines on dissertation committees (blue) and within each university (green), accounting only for those engineering departments included in the study for the years 2013 and 2014. The percentage of female faculty across the nine universities' aggregate engineering departments interquartile ranges from approximately 12% to 18%. Rice, Pitt, Cornell, and Northwestern all have female engineering faculty who are represented in committees at percentages equal to (i.e., within +/- 1 percentage point) or greater than the total percentage. The other universities, including Vanderbilt, Duke, CWRU, MIT and CMU have lower (i.e., greater than 1 percentage point below) representations of their female faculty on committees as compared to their respective total percentages.

These discrepancies may be attributed to a variety of factors. While not explored quantitatively, here we offer some anecdotal reasons why the percentage of female faculty on committees might be lower than the corresponding representation within a university's engineering departments. Dissertation committees are typically comprised of three to four faculty selected by the student's primary advisor in consultation with the student. The primary advisor may have a bias toward selecting faculty colleagues with which he or she has worked in the past (Bozeman & Corley, 2004), and since the rise in hiring of female faculty in engineering departments may be a relatively recent occurrence (National Research Council, 2010; Williams & Ceci, 2015; Yoder, 2015), he or she may not choose to include newer (and therefore newer female) faculty. For similar reasons, there may just be a time lag between when a female faculty member joins and when she might lead her own student's dissertation committee or be invited to participate on a faculty colleague student's committee. Certainly, a new Assistant Professor will likely take at least four years before graduating his or her first Ph.D. student. Moreover, sometimes committees are active for years before the student finally graduates (i.e., committees sometimes meet to review a dissertation proposal presentation 1-3 years prior to graduation), leading to a time lag experienced by all new faculty members before a dissertation is finally published. Of course, there may also be a conscious or unconscious bias against collaborating with or including female faculty colleagues on dissertation committees.

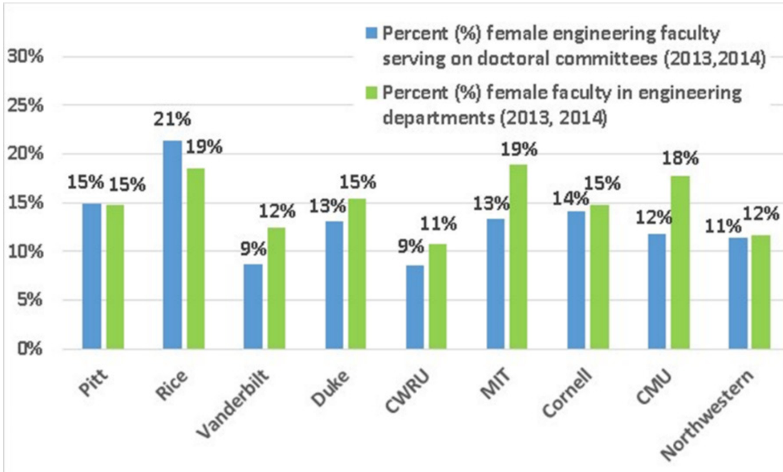

Figure 1. Percentage of female engineering faculty serving on engineering dissertation committees in 2013 and 2014 compared to the total percentage of female engineering faculty at each institution

The variation of female representation on dissertation committees within each discipline aggregated across the nine universities was were examined as shown in Figure 2. Only departments with statistically significant data were included. The percentage of female faculty serving on dissertation committees within the respective departments exhibit interquartile ranges from approximately 6% to 15% with electrical, mechanical and materials science engineering departments exhibiting a median that is more than 2 percentage points lower than the medians of the other disciplines. Additionally at about 6%, the electrical and mechanical engineering departments have statistically significant lower interquartile ranges then the other disciplines. Departments of biomedical, civil and materials science demonstrate relatively high levels of inconsistency (i.e., large boxes), indicating strong variation from one university to the next. Civil, materials science, and mechanical all have instances of female faculty experiencing 0% representation on committees in 2013 and 2014 at certain institutions even though dissertation student committees occurred at statistically significant levels (albeit with all male committees). The following analysis further examines these discipline-specific disparities in comparison with variations of female representation in the respective departments.

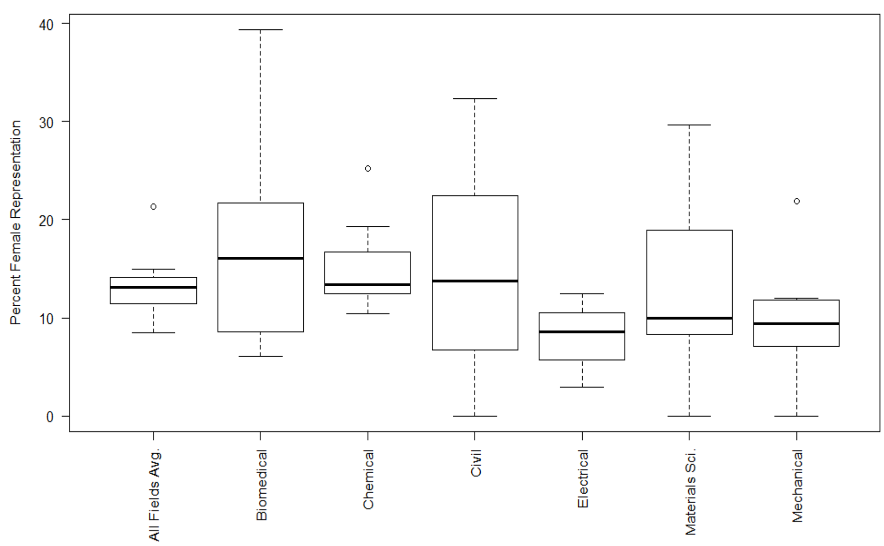

Figure 2. Box-and-whisker plot of the distribution of female representation on committees at the department level. Dark lines within each box indicate the median across the nine universities.

Figure 3 provides a breakdown of the results for the generalized discipline of biomedical engineering for each university with a comparison at the committee level (blue) to the department level (green). Looking more closely at Figure 2, the interquartile range in biomedical engineering is large (approximately 14%) with Rice exhibiting the largest positive discrepancy: 39% female faculty representation on dissertation committees even though the department comprises only 28% women faculty. In fact, equal or high representation (greater than -2% point difference) of women on committees is present for five of the nine universities: Rice, Pitt, Vanderbilt, Cornell, and CMU. Biomedical engineering has historically comprised a higher percentage of women overall (West, Jacquet, King, Correll, & Bergstrom, 2013), which could contribute to the discipline exhibiting a relatively high median percentage of female participation. Figure 4 shows the results for the generalized departments of chemical engineering for which there was statistically significant data (note that Duke does not have a Chemical Engineering department so was not included here). In contrast to biomedical engineering, the interquartile range spans only 5% (Figure 2) with Rice, CWRU, MIT, Cornell, and Northwestern exhibiting an equal or positive (greater than -2% points) discrepancy, also indicating generally good female representation on dissertation committees in this discipline at these institutions.

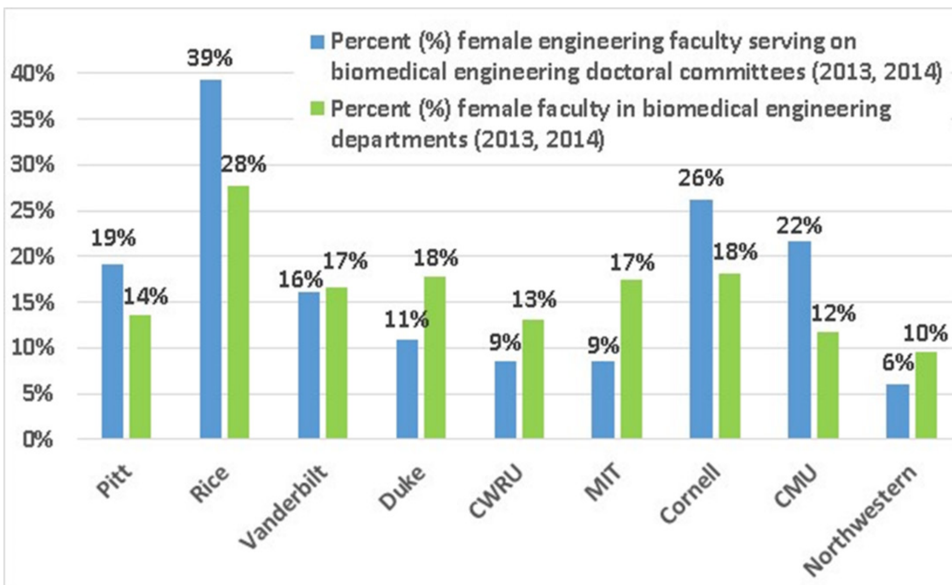

Figure 3. Biomedical engineering departments: percent female engineering faculty serving on dissertation committees (blue) compared to percent composition in the department (green)

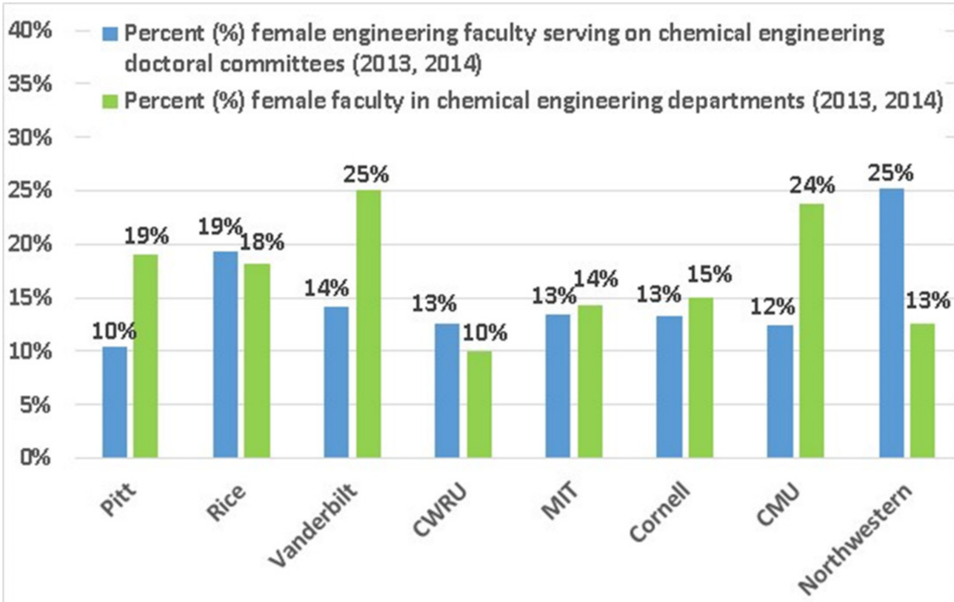

Figure 4. Chemical engineering departments: percent female engineering faculty serving on dissertation committees (blue) compared to percent composition in the department (green)

Figure 5 illustrates the results for the generalized civil engineering departments for each university for which there were statistically significant dissertation committee data. CWRU was omitted from the analysis due to insufficient data as described above. Again from Figure 2, the interquartile range of committee participation across institutions for civil engineering is high at approximately 17%, indicating large variation across universities, which may point to the impact of embedded culture differences from department to department rather than a systemic problem inherent to the discipline. Equal to high representation (greater than a 2% point difference) of female engineering faculty on committees was exhibited by Pitt, Rice and Duke. Interestingly, even though 8% of the faculty at Vanderbilt was female in 2013 and 2014, 0% of the female faculty participated on dissertation committees during that time frame.

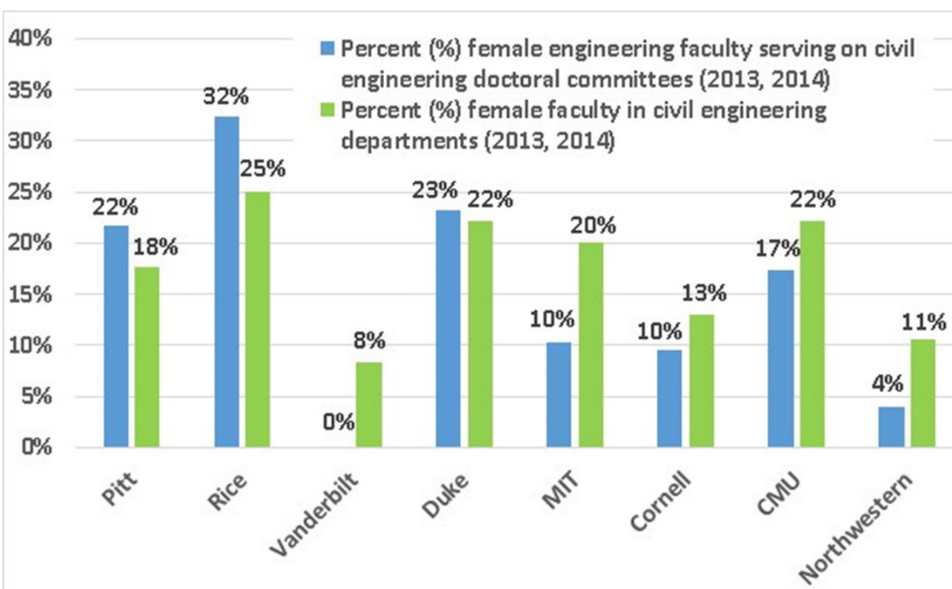

Figure 5. Civil engineering departments: percent female engineering faculty serving on dissertation committees (blue) compared to percent composition in the department (green)

Figure 6 depicts the results for the generalized department of materials science and engineering, which according to Figure 2 exhibits an interquartile range across women faculty on committees at the universities of approximately 12%. CMU was omitted from this analysis since its Department of Mechanical Engineering and Materials Science was considered only under the category of Mechanical Engineering. Vanderbilt, and Duke does not offer a specific degree in materials science and engineering. The universities that exhibit an equal or high percentage (greater than 2% point difference) of female participation on dissertation committees include Pitt, Duke, Cornell and Northwestern. For the case of CWRU's materials science and engineering department, their one female tenure-track faculty member began at the Assistant Professor level in 2012. The time lag explanation discussed above may be responsible for the discrepancy, but even so, no women from other engineering departments at the institution were invited to participate on dissertation committees during the two-year time frame.

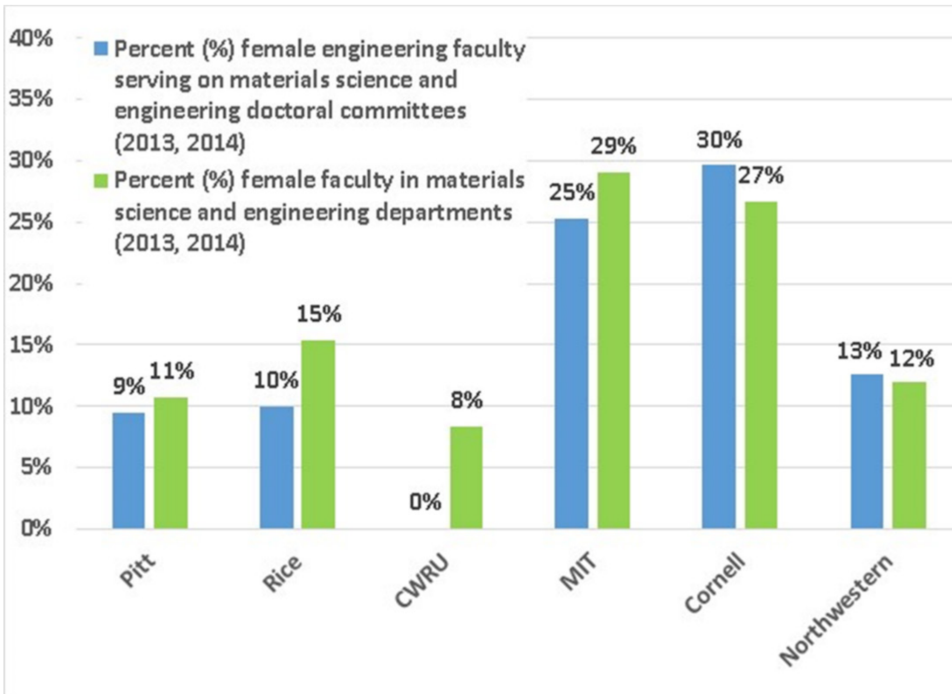

Figure 6. Materials science and engineering departments: percent female engineering faculty serving on dissertation committees (blue) compared to percent composition in the department (green)

Figure 7 shows the results for the generalized electrical engineering departments for the nine universities, with an interquartile range of approximately 6% according to Figure 2. Electrical engineering exhibits the lowest median for female faculty participation on committees across the nine universities studied. Nonetheless, Pitt, Rice, Cornell, CMU, and Northwestern demonstrate an approximate parity between the percentage of female faculty serving on dissertation committees and the percentage within the department (greater than 2% point difference). Figure 8 depicts the results for the generalized mechanical engineering departments, which also exhibits an interquartile range of approximately 6% according to Figure 2. The percentage female faculty participation on dissertation committees is similar to or higher than (greater than 2% point difference) the percentage in the department at Pitt, Vanderbilt, Duke, MIT, and Northwestern. Note that Vanderbilt University reported 0% female faculty in 2013 and 2014 in the mechanical engineering department, but female engineering faculty from other departments still served on these students' dissertation committees. Interestingly, CWRU has a relatively high percentage of female faculty in their mechanical engineering department (21%), but a very low percentage of female engineering faculty (8%) appear to serve on dissertation committees.

Only 1 of the 4 female faculty began in this department within two years of the beginning of data collection, so time lag could not be the only explanation behind the discrepancy.

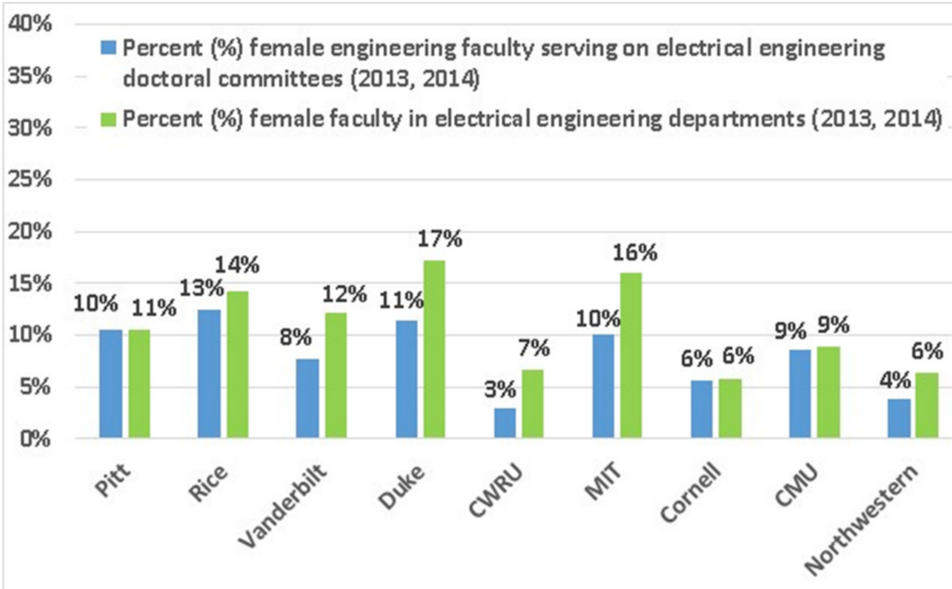

Figure 7. Electrical engineering departments: percent female engineering faculty serving on dissertation committees (blue) compared to percent composition in the department (green).

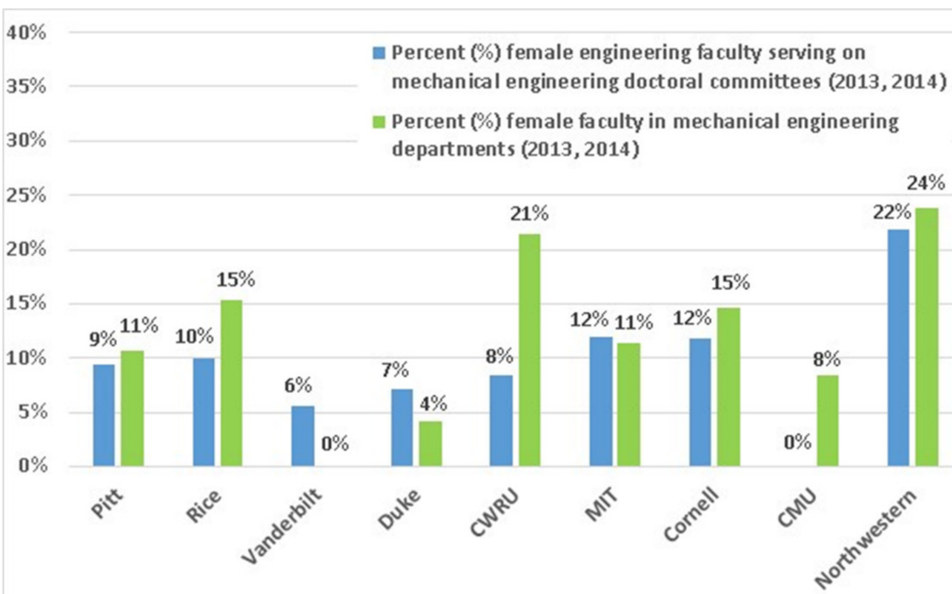

Figure 8. Mechanical engineering departments: percent female engineering faculty serving on dissertation committees (blue) compared to percent composition in the department (green).

Examining these results together, Pitt's departments achieves parity or greater of female faculty participation on committees in comparison to percentage women in the department in five out of six departments, with Rice, Northwestern, and Cornell demonstrating the same in four out of six departments, and Duke reaching similar results for three out of four departments. Vanderbilt, CWRU, MIT, and CMU only demonstrate parity or greater in comparison for one or two of the departments studied. When examined as engineering as a whole (Figure 1), the differences between participation on committees and the percentage of women faculty in departments are not extreme (i.e., < a 6% point difference), but cases of greater disparities occur in several departments at select institutions as discussed above.

CONCLUSION

A comparison of female faculty representation on dissertation committees to department composition indicates a potential bias may exist. However, a relatively high variation among data across departments and institutions was observed. More specifically, Rice, Pitt, Cornell, and Northwestern all have female engineering faculty who are represented in committees at percentages equal to (i.e., within +/- 1 percentage point) or greater than the total percentage. The other universities, including Vanderbilt, Duke, CWRU, MIT, and CMU have lower (i.e., greater than 1 percentage point below) representations of their female faculty on committees as compared to their respective total percentages. The respective departments in aggregated, electrical, mechanical and materials science engineering departments exhibit a median that is more than 2 percentage points lower than the medians of the other disciplines. Additionally at about 6%, the electrical and mechanical engineering departments have statistically significant lower interquartile ranges then the other disciplines. Civil, materials science, and mechanical all have instances of female faculty experiencing 0% representation on committees in 2013 and 2014 at certain institutions even though dissertation student committees occurred at statistically significant levels.

This lack of inclusion of women in this type of collaboration activity exists in certain cases even though strong evidence shows that women are generally more collaborative in both professional and non-professional situations (Abramo, D'Angelo, & Murgia, 2013; Berdahl & Anderson, 2005; Bozeman & Gaughan, 2011). Understanding the root cause of the disparities was not the basis for this work, but anecdotally various issues have been cited by colleagues. These include: an embedded culture of certain faculty historically working only with each other (i.e., the "old boys' network"); a time lag between when a female faculty member joins a department and when she might lead her own student's dissertation committee or be invited to participate on a faculty colleague's student's committee; or a conscious or unconscious bias against collaborating with or including female faculty colleagues on dissertation committees.

There have been other studies that have examined women's representation on journal publications (Ghiasi et al, 2015; West et al, 2013; Zeng et al, 2016), grant proposals (Shen, 2013), and in research collaboration (Bozeman & Corley, 2004). In contrast, the work presented here reveals a metric that might be used to help uncover potential gender bias being experienced by faculty within a department and at an institution. Like the landmark study by senior faculty at MIT in 1999 (Massachusetts Institute of Technology, 1999), making the university community aware of potential collaboration bias may encourage action. The results of this study hopefully will encourage faculty to be more inclusive and collaborative, particularly with their female colleagues, and as a result may help improve the climate for women faculty in engineering. Even more, various institutional and public policies such as those implemented by government agencies, may include incentives for gender balance on collaborative teams. This may indirectly and positively influence gender diversity on dissertation committees.

This historical research design study was the first to investigate the potential for gender imbalance and potential bias in dissertation committees, which may be an indicator of the appetite for collaboration at a particular institution or department. This study opens a discussion about the potential for gender bias within an institution, particularly with respect to collaboration and inclusion. Future work may explore other indicators beyond doctoral committee representation.

REFERENCES

Abramo, G., D'Angelo, C. A., & Murgia, G. (2013). Gender differences in research collaboration. *Journal of Infometrics, 7*(4), 811-822. https://doi.org/10.1016/j.joi.2013.07.002

Aiston, S. J., & Jung, J. S. (2015). Women academics and research productivity: An international comparison. *Gender and Education, 27*(3), 205-220. https://doi.org/10.1080/09540253.2015.1024617

Belle, D., Smith-Doerr, L., & O'Brien, M. L. (2014). Gendered networks: Professional connections of science and engineering faculty. In V. Demos, C. W. Berheide, & M. T. Segal (Eds.), *Gender transformation in the academy, Vol. 19* (pp. 153-175). England: Emerald Group Publishing. https://doi.org/10.1108/S1529-212620140000019007

Berdahl, J. L. & Anderson, C. (2005). Men, women, and leadership centralization in groups over time. *Group Dynamics: Theory, Research, and Practice, 9*(1), 45-57. https://doi.org/10.1037/1089-2699.9.1.45

Bilimoria, D., Joy, S., & Liang, X. (2008). Breaking barriers and creating inclusiveness: Lessons of organizational transformation to advance women faculty in academic science and engineering. *Human Resources Management, 47*(3), 423–441. https://doi.org/10.1002/hrm.20225

Bozeman, B., & Corley, E. (2004). Scientists' collaboration strategies: Implications for scientific and technical human capital. *Research Policy, 33*(4), 599-616. https://doi.org/10.1016/j.respol.2004.01.008

Bozeman, B., & Gaughan, M. (2011). How do men and women differ in research collaborations? An analysis of collaborative motives and strategies of academic researchers. *Research Policy, 40*(10), 1393-1402. https://doi.org/10.1016/j.respol.2011.07.002

Fox, M. F. (2010). Women and men faculty in academic science and engineering: social-organizational indicators and implications. *American Behavior Scientist, 53*(7), 997-1012. https://doi.org/10.1177/0002764209356234

Ghiasi, G., Lariviere, V., & Sugimoto, C. R. (2015). On the compliance of women engineers with a gendered scientific system. *PLoS One*, *10*(12), e0145931. https://doi.org/10.1371/journal.pone.0145931

Guimera, R., & Amaral, L. A. N. (2005). Functional cartography of complex metabolic networks. *Nature, 433*(7028), 895-900. https://doi.org/10.1038/nature03288

Hart, J. (2016). Dissecting a gendered organization: Implications for career trajectories for mid-career faculty women in STEM. *The Journal of Higher Education,* 87(5), 605-634. https://doi.org/10.1353/jhe.2016.0024

Hill, C., Corbett, C., & St. Rose, A. (2010). *Why so few? Women in science, technology, engineering and math*. Washington D.C.: American Association of University Women.

Jha, Y., & Welch, E. M. (2010). Relational mechanisms governing multifaceted collaborative behavior of academic scientists in six fields of engineering. *Research Policy, 39*(9), 1174-1184. https://doi.org/10.1016/j.respol.2010.06.003

Jung, J. W., Bozeman, B., & Gaughan, M. (2017). Impact of research collaboration cosmopolitanism on job satisfaction. *Research Policy, 46*(10), 1863-1872. https://doi.org/10.1016/j.respol.2017.09.003

Mason, M. A., & Goulden, M. (2004). Marriage and baby blues: Redefining gender equity in the academy. *Annals of the American Academy of Political and Social Science, 596,* 86-103.

Mason, M. A., Stacy, A., Goudlen, M., Hoffman, C., & Frasch, K. (2005). *Faculty family-friendly edge*. Berkeley, CA: University of California Press. https://doi.org/10.1177/0002716204268744

Massachusetts Institute of Technology. (1999). *A study on the status of women faculty in science at MIT*. Cambridge, MA: Massachusetts Institute of Technology.

Monroe, K., Ozyurt, S., Wrigley, T., & Alexander, A. (2008). Gender equity in academia: Bad news from the trenches, and some possible solutions. *Perspectives on Politics, 6*(2), 215-233. https://doi.org/10.1017/S1537592708080572

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. (2005). *Facilitating interdisciplinary research*. Washington, D.C.: The National Academies Press. https://doi.org/10.17226/11153

National Research Council. (2010). *Gender differences at critical transitions in the careers of science, engineering, and mathematics faculty*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12062

Sax, L. J., Hagedorn, L. S., Arredondo, M., & Dicrisi, F. A. (2002). Faculty research productivity: Exploring the role of gender and family-related factors. *Research in Higher Education, 43*(4), 423-446. https://doi.org/10.1023/A:1015575616285

Settles, I. H., Cortina, L. M., Malley, J., & Stewart, A. J. (2006). The climate for women in academic science: The good, the bad, and the changeable. *Psychology of Women Quarterly,* 30, 47-58. https://doi.org/10.1111/j.1471-6402.2006.00261.x

Shen, H. (2013). Inequality quantified: Mind the gender gap. *Nature, 495*(7439), 22-24. https://doi.org/10.1038/495022a

U.S. News and World Report. (2015) *Find the best colleges for you.* Washington, DC: U.S. News and World Report.

Ward, K., & Wolf-Wendel, L. (2004) Academic motherhood: Managing complex roles in research universities. *Review of Higher Education, 27*(2), 233-257. https://doi.org/10.1353/rhe.2003.0079

West, J. D., Jacquet, J., King, M. M., Correll, S. J., & Bergstrom, C. T. (2013). The role of gender in scholarly authorship. *PLoS One, 8*(7), e66212. https://doi.org/10.1371/journal.pone.0066212

Williams, W. M., & Ceci, S. J. (2015). National hiring experiments reveal 2:1 faculty preference for women on STEM tenure track. *Proceedings of the National Academy of Sciences, 112*(17), 5360-5365. https://doi.org/10.1073/pnas.1418878112

Yoder B. L. (2015). *ASEE college profiles*. Washington, D.C.: American Society of Engineering Education.

Zeng. X. H. T., Duch, J., Sales-Pardo, M., Moreira, J. A. G., Radicchi, F., Ribeiro, H. V., Woodruff, T. K., & Amaral, L. A. N. (2016). Differences in collaboration patterns across discipline, career stage, and gender. *PLOS Biology, 14*(11). https://doi.org/10.1371/journal.pbio.1002573

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