Faculty Composition and Doctorates Awarded: An Analysis and Comparison of the Colleges of Engineering at ADVANCE Institutions and their Non-ADVANCE Peers (2001 - 2009)

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Abstract

In 2001, an inaugural group of nine universities received the NSF ADVANCE Institutional Transformation (IT) awards. The NSF ADVANCE program seeks to increase the representation of women in science and engineering with the understanding that systematic transformation of the U.S. institutions of higher education is essential to this effort. Using the American Society of Engineering Education (ASEE) data, we examine faculty composition and Ph.D.s awarded as indicators in these transformational initiatives. We find that, with regard to faculty composition and engineering doctorates awarded to women, ADVANCE institutions have made significant gains and generally exceed national average rates, but do not uniformly outperform their non-ADVANCE peers. We are further unable to distinguish a clear relationship between the presence of women faculty and the changes in the percentage of women graduating with engineering Ph.D.s across all institutions studied. We discuss these findings in light of extant literature on the ADVANCE IT program and increasing women's representation in STEM fields. We conclude by suggesting that while there are some immediate results apparent from the NSF ADVANCE program, institutional transformation is a long-term process that requires on-going multidimensional monitoring and assessment.

Introduction

U.S. competitiveness in the global economy depends on training a diverse and highly technically proficient science and engineering workforce. Critical to these efforts is the growth of the number of women obtaining STEM doctoral degrees and entering the academic workplace as faculty members. Although many STEM disciplines show progress, change in engineering, especially with regard to granting Ph.D. degrees to women, has not kept pace with other fields. For example, during the time period, 2001 and 2009, the share of engineering Ph.D.s earned by women increased from 16.9% to 21.3%. In comparison, in natural sciences, between 2001 and 2007, the percentage of women earning Ph.D.s increased from 39.2% to 50%. Further, the gap in the representation of women among Ph.D. recipients in engineering and the natural sciences has grown in recent years.[1-2] With regard to faculty, a 2007 study of 100 top academic departments in the U.S. revealed that women accounted for 15% of faculty in natural science departments and 10.9% of faculty in chemical, civil, electrical, and mechanical engineering departments.[3] With regard to the overall numbers of women faculty in engineering[4,5], between 2001 and 2009, their share grew from 8.9% to 12.7%.

In 2001, the NSF inaugurated an institutional transformation program with the goal of increasing the representation of women entering STEM fields. One primary way of achieving this goal was

to address the problem of the "leaky pipeline," or the attrition rates of women students and faculty in science and engineering fields. Reasoning that women faculty members "serve as intellectual, professional, personal and organizational role models that shape the expectations of many prospective scientists and engineers," the NSF connected the underrepresentation of women faculty to "women students' critical relationships with mentors, full participation as members of research and education teams, and self-identification as potential researchers".[6] To increase the recruitment, participation, and advancement of women faculty members in science and engineering, the NSF ADVANCE IT program provides support to academic institutions "to create positive, sustainable, and permanent change in academic climates."[6]

To increase the percentage of women on the faculty of engineering colleges, therefore, qualified women must also be well represented in the academic pipeline. Increasing the percentage of doctorates awarded to women is a logical first step in this process. However, there is no clearly established relationship between having women on the engineering faculty and women receiving Ph.D.s in engineering. Indeed, Chesler et al.[7] note that in biomedical engineering, in which the percentage of women obtaining Ph.D. degrees is higher than other fields, the higher participation rates have not led to significant increases in the percentage of women faculty in this subfield.

The purpose of this study, therefore, is to consider the degree to which having female role models on the faculty affects the percentage of women obtaining engineering Ph.D.s. More specifically, we examine the relationship between women on the engineering faculty at ADVANCE institutions and the rates of awarding doctorates to women at those schools. To gain insight into this issue, for the period 2001-2009, we track the share of full-time tenure-track women engineering faculty and women earning engineering Ph.D.s at universities that received ADVANCE IT funding. We then compare percentages of women faculty and students across ADVANCE institutions and with the same measures at the engineering colleges of each university's peer institutions.[i] Through our analysis, we hope to understand the longer term impact of the ADVANCE IT program in increasing women on the faculty and women obtaining doctorates at engineering colleges. We begin from the premise that understanding the academic pipeline is essential to achieving greater representation of women in academia and achieving diversity in the workforce. Indeed, the ADVANCE goal of diversifying the engineering workforce implicates the rigorous training of female graduate students and, in turn, encouraging women to pursue academic research careers.

Prior research assessing the relationship between faculty composition and undergraduate majors indicates that there is some positive correlation between the number of female students and the number of women faculty in any given department. For example, Canes and Rosen[8] compare enrollment and employment data from 1973-1989 at Princeton, the University of Michigan, and Whittier College. Although unable to show a causal relationship between the gender composition of the faculty and undergraduate science and engineering majors, they stress the importance of having women on the faculty to increase diversity in science and engineering disciplines since the "role-model concept" will "encourage female students to pursue careers in science and engineering by providing greater visibility for women scientists and engineers in industry, government, and academic institutions".[8]

Another study by Sonnert et al.[9] on outcomes of undergraduate female students in STEM focused on four basic factors: "(1) the percentage of faculty who are women in the students' major science/engineering area; (2) the students' disciplines (biology, physical sciences, and engineering); (3) the type of institution in which students are enrolled (''Research I'' vs. others); and (4) a time trend (1984–2000)". The authors found that the percentage of women receiving bachelor's degrees from science and engineering departments are associated with the percentage of women among the faculty in these fields, albeit a small effect. They conclude, "[T]hese results provide at least mild encouragement to both those who believe that female "role models" (and other supporters) are beneficial for female students, and those who think that the mere presence of women in an occupation signals to young women that the occupation might be an appropriate choice for them".[9]

However, Bettinger and Long[10] find no significant relationship between female undergraduates having a female professor in their first college-level courses in the male dominated fields of engineering, physics and computer science, and women choosing those fields as their majors. Examining data from Ohio undergraduates, they considered if the sex of the instructor influenced students' decisions to take additional courses in that area, and decisions about their majors. While young women who took their first course in the male dominated fields of mathematics, statistics or geology from a female instructor were more likely to choose these as their majors, this pattern did not hold for engineering. This leads the authors to question the importance of female role models and conclude that sex segregation in college majors cannot be understood exclusively based on the presence of female faculty.

With respect to graduate study, Neumark and Gardecki[11] also report inconclusive results on the importance of female Ph.D. candidates having women professors as role models in the male dominated field of economics. Examining data from economics graduate students, the authors find that while the presence of female faculty reduced the time to completion of the Ph.D. for female students, the effect on the likelihood of women completing their degrees was negligible. Moreover, Neumark and Gardecki[11] see no evidence that female students had better overall outcomes with women on their thesis committees or serving as their dissertation chairs.

In contrast, Lovitts'[12], Herzig's[13], and Lovitts'[14] recent studies of student persistence in Ph.D. programs point to the importance of faculty members serving as role models and socializing agents. Since women Ph.D. students in sciences face a higher degree of isolation and more barriers to integration into departmental cultures, faculty members play an especially important role in shaping the experiences of female students. Herzig's[13] examination of the experiences of graduate women in mathematics is instructive on these issues. Herzig[13] notes that students who are more integrated into the academic and social communities of their departments are more likely to persist in graduate school. Faculty play an important role as mentors and as agents of socialization for graduate students; moreover, negative interactions with faculty have pervasive effects on women in science. Women described their limited or negative relationships with faculty, including: feeling invisible, needing guidance, wanting better teaching, lacking moral support and wishing to be mentored".[13] While many male students reported similar problems with the department, "what was unique to the women was their unanimous descriptions of feeling that they do not fit into the male-dominated culture of mathematics, a feeling that presents a substantial obstacle in their path to developing a sense of belonging in mathematics".[13]

Moreover, studies of women science faculty by Kemelgor and Etzkowitz[15], Lindholm[16], Lindholm, Astin, Sax and Korn[17], and Tindall[18] suggest that quality of their experiences as graduate students influences their decision to stay in the academy. In fact, based on a study of science faculty and doctoral students at Research I and II institutions, Kemelgor and Etzkowitz[15] note that that while "women who have reached the graduate level and beyond, have usually had positive, encouraging experiences with educators," women faculty "unanimously cited at least one mentor as essential in their provision of strategies, access to professional networks, and to see themselves as bona fide scientists-to-be."

Role model theory presumes that increasing the numbers and visibility of women faculty in STEM disciplines will increase the numbers of women entering and graduating from these programs. Given the inconclusive nature of prior research on role models, in this study we examine the following: 1) changes in the gender composition of engineering colleges that received the ADVANCE IT grant in 2001; and 2) changes in the gender composition of doctorates awarded at institutions that received the ADVANCE IT grant in 2001. We then compare these results to the peer institutions for the ADVANCE schools, and examine the relationship between faculty and student outcomes.

Scope of Study

To date 37 institutions received major ADVANCE grants and 19 institutions completed their programs. Given our desire to understand the longer term outcomes of the ADVANCE program, we limited our analysis to the public Ph.D. granting engineering colleges of Cohort 1 (2001-2006) ADVANCE institutions as shown in Table 1.

Table 1. Institutions of ADVANCE Cohort 1.

Cohort 1 Institutions (2001-2006)
Georgia Institute of Technology (Georgia Tech)
New Mexico State University (NMSU)
University of California, Irvine (UC Irvine)
University of Colorado at Boulder (CU-Boulder)
University of Michigan (Ann Arbor) (Michigan)
University of Washington
University of Wisconsin, Madison (Wisconsin)
Cohort 1 Institutions Not Considered
Hunter College of the City University of New York*
University of Puerto Rico, Humacao*

*Institution does not offer B.S., M.S., or Ph.D. engineering degrees.

Method

According to Frehill et al.[19] and Kanter[20], sex ratios are useful indicators of institutional gender inequalities. Building on this idea, we examined changes in the gender composition of engineering faculty and graduating doctoral students using data from *Profiles of Engineering and Engineering Technology Colleges*[21] published by American Society for Engineering Education

(ASEE). In addition to data regarding gender composition of full-time tenure-track faculty and graduating doctoral students, we use descriptive statistics, including national and ADVANCE cohort averages.[ii]

In our analysis, we compared each ADVANCE institution to 1) other ADVANCE institutions within the same cohort; 2) the national average; and 3) the university's peer institutions. We obtained the lists of peers from the websites of the thirteen ADVANCE institutions. Table 2 shows the institutional peers for ADVANCE schools. The peers of the ADVANCE institution were based on the university and not the engineering college. To be included as a university peer, each institution had to meet the following criteria: 1) college of engineering: 2) doctoral engineering programs; 3) no ADVANCE or the start of the ADVANCE program during the time period of comparison. Specifically, five universities listed as ADVANCE peers, Michigan State University, Ohio State University, Purdue University, Rutgers, and Washington State University received the ADVANCE IT award in 2008. Given the very limited overlap between the time frame of our study 2001 – 2009 and the timing of the most recent round of ADVANCE awards (2008), we kept these institutions among the institutional peers.

Table 2. University peers for ADVANCE Cohort 1 (2001) institutions.

ADVANCE Institution	**University Peers***		
Georgia Institute of Technology	North Carolina State University Purdue University** Texas A&M University The Pennsylvania State University	The University of Texas at Austin University of California, Berkeley University of California, Los Angeles	University of Florida University of Illinois at Urbana-Champaign University of Minnesota - Twin Cities
New Mexico State University	Clemson University Colorado State University Iowa State University*** Louisiana State University Oklahoma State University	Oregon State University Texas A&M University The University of New Mexico University of Arizona***	University of Missouri-Columbia University of Tennessee, Knoxville University of Wyoming Washington State University**
University of California, Irvine	Stony Brook University University of California, Los Angeles	University of California, San Diego University of California, Santa Barbara	University of Florida University of Illinois at Urbana-Champaign
University of Colorado at Boulder	Michigan State University** State University of New York at Buffalo Stony Brook University The Ohio State University** The University of Iowa University of Arizona***	University of California, Davis University of California, Irvine University of California, Los Angeles University of California, San Diego University of Florida University of Michigan (Ann Arbor)***	University of Minnesota - Twin Cities University of Missouri-Columbia University of Virginia University of Washington University of Wisconsin, Madison***
University of Michigan (Ann Arbor)	Michigan State University** The Ohio State University** Purdue University**	Stony Brook University The University of Iowa University of California, Berkeley	University of California, Los Angeles University of Illinois at Urbana-Champaign University of Minnesota - Twin Cities
University of Washington	University of California, Davis University of California, Los Angeles University of California, San Diego	University of Connecticut University of Maryland, College Park University of Massachusetts Amherst	Rutgers, The State University of New Jersey** University of Virginia
University of Wisconsin, Madison	Purdue University** The Ohio State University** The University of Texas at Austin	University of California, Berkeley University of California, Los Angeles	University of Illinois at Urbana-Champaign University of Minnesota - Twin Cities

*Obtained from institution web site.
**ADVANCE institutions included in the analysis because they received ADVANCE grant in 2008.
***ADVANCE institutions excluded from analysis because they received ADVANCE grant prior to 2008.

Analysis of Changes at ADVANCE Institutions

Figure 1 shows the percentage of full-time tenure-track women faculty and graduating women doctoral students at the start and end of the study period, 2001-2009. Specifically, in 2001 at the start of the ADVANCE program, the average percentage of women faculty at the seven Cohort 1 institutions was just over 20% higher than the national average (10.7% versus 8.9%); in 2009, the margin of advantage declined slightly, standing at 14.2% versus 12.7%. Interestingly, in 2001, 12.6% of Ph.D.s were awarded to women at ADVANCE schools, well below the 17% national average. By 2009, the national average of women earning Ph.D.s rose almost 25% to 21.2% while the ADVANCE schools increased by over 90% the percentage of women graduating from their programs to 24.1%.

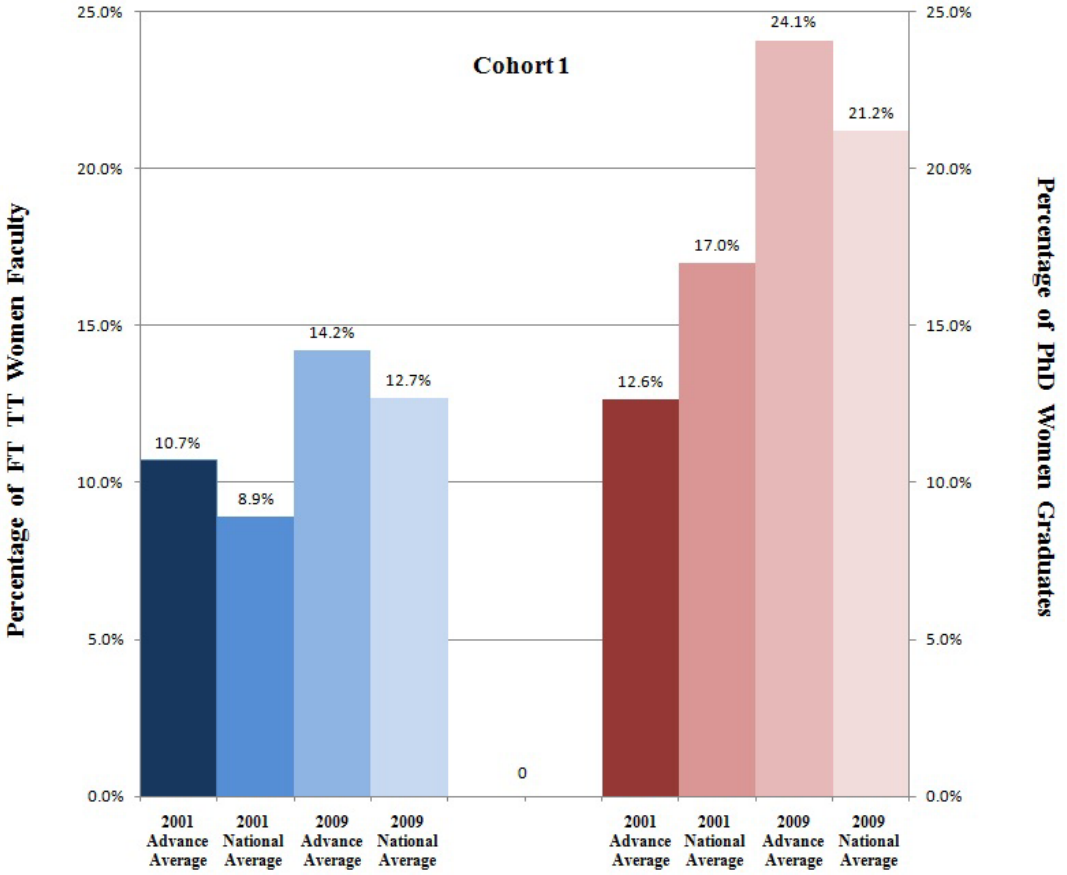

Figure 1. Percentage of full-time tenure-track women faculty vs. national average (2001-2009) & Percentage of Ph.D. women graduates versus national average (2001-2009).

Figures 2a and 2b show the percentage of full-time tenure-track women faculty and Ph.D. students at the start and end dates. Specifically, the percentage of women faculty at all ADVANCE institutions was greater than or equal to the national average at the start of the grant period. All ADVANCE institutions show an increase in the percentage of women faculty by 2009, except UC Irvine, where the percentage of women on the faculty declined from 11.1% to 10%. In addition, during this period, both NMSU and UC Irvine slipped below the national average as shown in Figure 2a. Thus, only five Cohort 1 institutions still out-performed the

national average in 2009. Importantly, among these five institutions, Georgia Tech, which in 2001 had 22% more women faculty than the national average, but only had 3.5% more women on its faculty than the national average in 2006, actually lost some of its relative advantage.

In terms of net gain in the percentage of women faculty, the CU-Boulder showed impressive increases going from 11.6% to 16.9%. Second, in terms of the overall performance, the University of Washington maintained its leadership position and finished as the top performer among all ADVANCE institutions examined here (19.8% women on the faculty in 2009).

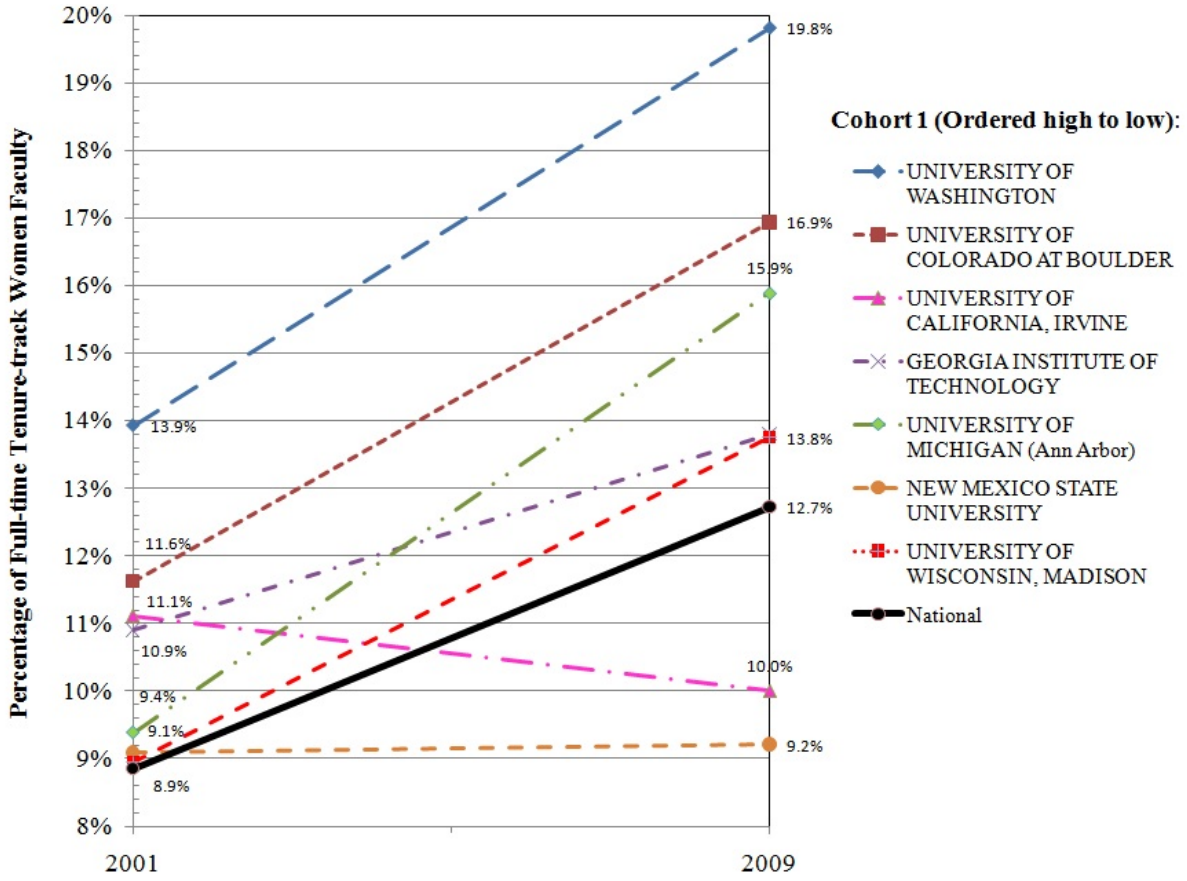

Figure 2a. Percentage of full-time tenure-track women faculty, Cohort 1 institutions and national average, 2001–2009.

In terms of the net gain in women graduates, with the exception of Michigan, all of the ADVANCE schools showed improvement, with the University of Washington, UC Irvine, Wisconsin, and NMSU showing particularly impressive increases in the percentage of doctorates awarded to women. With respect to overall performance, NMSU's small program (fewer than 20 students overall) went from graduating no women in 2001, to having 37.5% female Ph.D. recipients in 2009. Accordingly, among all ADVANCE schools, not only did NMSU have the greatest increase in women matriculating, by 2009, they also had the highest percentage of women graduating. Conversely, in 2001, Michigan's large program had the highest percentage of women graduates (19.6 %) of the ADVANCE schools. In 2009, the percentage of women graduating fell to 16.7% - the lowest percentage of all of the ADVANCE schools. Interestingly,

while the number of women graduating from Michigan with Ph.D.s in engineering increased from 36 in 2001 to 44 in 2009, the overall size of the graduating cohort increased by nearly 25%, from 184 in 2001 to 263 in 2009, resulting in a decline in women's share of Ph.D. degrees awarded.

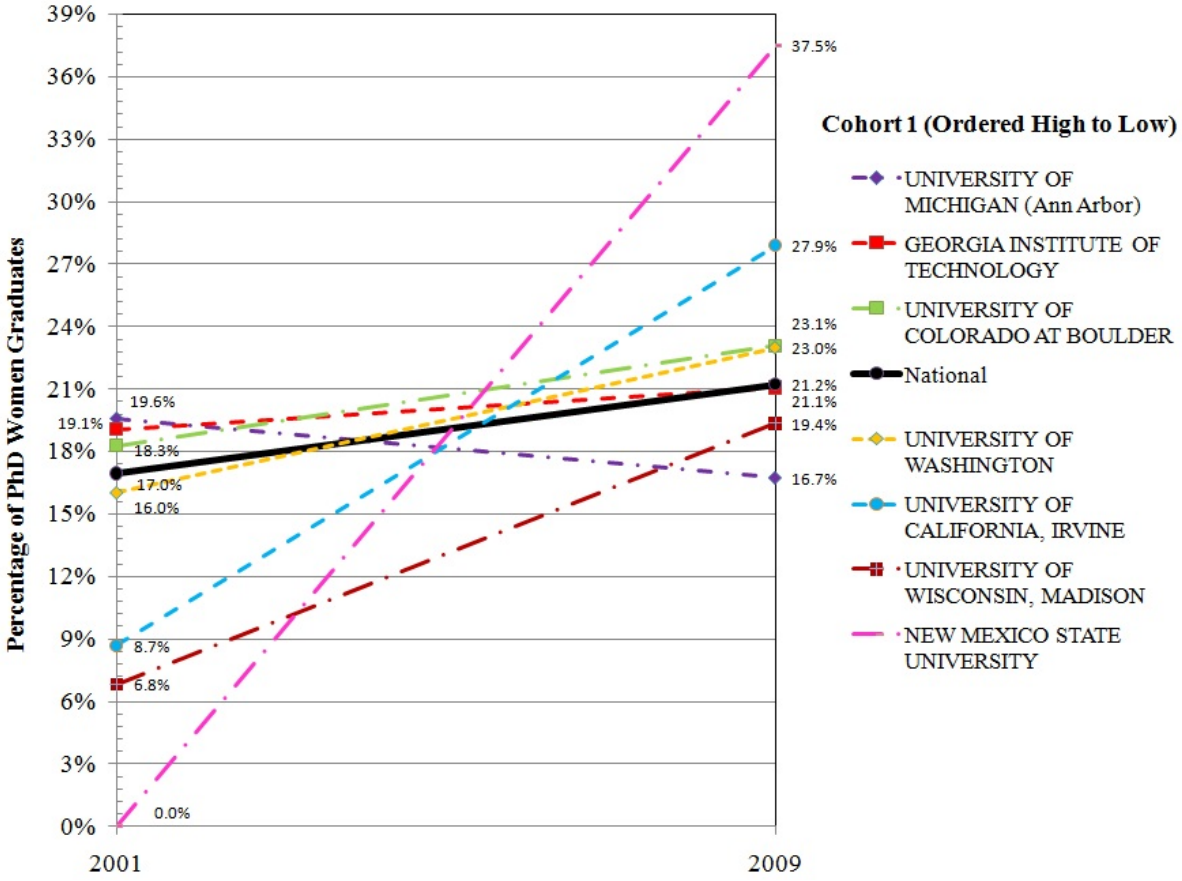

Figure 2b. Percentage of Ph.D. women graduates, Cohort 1 institutions and national average, 2001 – 2009.

Comparative Analysis of ADVANCE and Peer Institutions

Since reporting percentages does not provide a context for understanding trends, comparing ADVANCE schools to their peer groups offers a more nuanced picture of the changes during this period. Table 3 shows the rank of ADVANCE institutions with their university peer group at the start of the grant period and in 2009. Relative to their peers, with respect to both the proportions of women among both faculty and graduating students, ADVANCE schools showed mixed results.

With regard to faculty, the University of Washington maintained its top standing. CU-Boulder, Michigan, and Wisconsin performed in accordance to what would be expected of ADVANCE schools by maintaining or improving their positions relative to their peers. It is worth mentioning, however, that Purdue University, which is in the peer group for both Michigan and Wisconsin, ended the grant period with the highest percentage of women faculty in both peer groups. However, not all ADVANCE schools improved relative to their peers in the percentage of women on their faculty. For example, UC Irvine, which occupied the top position in its peer group at the start of the ADVANCE program slipped to the 6th position, with 10% of women faculty members by 2009. Accordingly, the engineering college at Stony Brook University overtook the top position at UC Irvine's peer group. A different dynamic occurred at Georgia Tech's engineering college, which declined in ranking from the 2nd to the 3rd position despite the net gain of seven women faculty members. NMSU also declined from 4th to 10th in its peer group, although the percentage of full time tenure-track women stayed roughly the same (9.1% in 2001, 9.2% in 2009).

Table 3: Rank of Cohort 1 institution with university peer group in 2001 and 2009 by percentage of FT TT women faculty and PhD women graduates.

ADVANCE Institution	Rank with University Peers by Women Faculty		Rank with University Peers by Women PhD Graduates	
	Start 2001	End 2009	Start 2001	End 2009
Georgia Institute of Technology	2/11	3/11	3/11	4/11
New Mexico State University	4/12	10/12	11/12	2/12
University of California, Irvine	1/7	6/7	7/7	2/7
University of Colorado at Boulder	2/13	2/13	5/13	3/13
University of Michigan (Ann Arbor)	4/10	1/10	3/10	6/10
University of Washington	1/9	1/9	8/9	3/9
University of Wisconsin, Madison	4/8	2/8	8/8	4/8

The patterns for relative ranking of women earning doctorates at ADVANCE schools are also mixed, but are more positive than the faculty outcomes. As discussed above, given that ADVANCE schools started significantly lower than the national average in the percentage of women earning doctorates, it is not surprising that none of the ADVANCE schools were at the top of their peer groups in the percentage of women graduates in 2001. Interestingly, however, both Michigan and Georgia Tech were third among their peers in 2001, and both slipped by

2009, with Georgia Tech 4th of the 11 in their peer group and Michigan in the 6th spot among 10. Although all other schools showed gains in the percentage of women graduates relative to their peers, none finished first in their peer groups. Even with a 37.5% female graduating class, NMSU fell behind the University of Wyoming whose 2009 graduating class was 40% women. It is worth noting, however, that relative ranking in NMSU's peer group is highly sensitive to the specific year since the graduate programs at both Wyoming and NMSU are quite small, with ten and eight students, respectively.

Study Findings

With respect to the representation of women on engineering faculty and in the granting of Ph.D.s, institutions receiving the ADVANCE grant in 2001 have exceeded national trends. In faculty representation, ADVANCE schools started above the national average, and continue to do so in the post advance period. The increase in the percentage of women graduating from ADVANCE institutions with Ph.D.s in engineering is particularly impressive. While ADVANCE schools started well below national averages in 2001, by 2009 these schools surpassed national trends, representing a 14% advantage over national averages.

Comparing the representation of women faculty and graduate students in the context of their peers reveals several noteworthy patterns. In percentage of women faculty, most ADVANCE schools started at or near the top of their peer groups, and none were in the lower half of their peer group in 2001. Accordingly, many of these schools were already doing well in faculty representation when they received ADVANCE funding. Since that time, the results have been mixed, and some *peer schools* have made great strides in attracting and retaining female faculty. Thus while some ADVANCE schools lost standing relative to their peers, others maintained or improved their position. In contrast, with respect to graduate students, the ADVANCE schools were generally performing poorly relative to their peers in 2001. By 2009, the poor performing schools improved women's graduation rates moving up relative to their peers. However, relative to their peers, no schools receiving the ADVANCE grant had the highest percentage of women earning doctorates in 2009. It is also worth noting that the two highest performing schools in granting engineering Ph.D.s to women at the start of the grant, Georgia Tech and Michigan, which both started in 3rd place relative to their peers, dropped in standing by 2009.

In terms of making engineering colleges more gender equitable, the first cohort of ADVANCE institutions tend to be improving relative to their peers by at least one of the measures discussed here. That is, CU-Boulder, the University of Washington, and Wisconsin all either maintained or improved their relative standings in both the representation of women faculty and the percentage of women graduating with Ph.D.s. While the Michigan lost ground in graduating women, they gained in female faculty representation. Conversely, while UC Irvine and NMSU gained in graduating women, they lost in female faculty representation. Only Georgia Tech lost ground both in their representation of women on the faculty and in Ph.D. graduates.

Importantly, however, we do not find conclusive evidence that increasing the proportion of women on the faculty at an institution has a direct relationship to the percentage of Ph.D.s granted to women at that institution. Indeed, UC Irvine, Michigan and NMSU reflect cross-directional trends with respect to faculty and students. Specifically, Michigan performed

extremely well in women faculty, landing in the top spot of their peer group in 2009. However, at the start of ADVANCE, Michigan was 3rd among its peers in graduating women Ph.D. engineers. By 2009, it fell to 6th place in its peer group for women graduates. Conversely, UC Irvine was the top among its peers in women faculty in 2001, but by 2009 was the second to last among its peers. For graduate students, however, UC Irvine began the granting period in last place among its peers, and ended in the 3rd spot. Similarly, in 2001 NMSU was in 4th place among its peers in faculty representation, but was second to last in its peer group in 2009. Yet, in graduate degrees awarded to women, NMSU started in 11th place, but was 2nd in its peer group in 2009.

Interpretation

The overall findings of increases in female faculty representation and especially the growth women earning doctorates at ADVANCE institutions are promising. We are careful to note, however, that during the period of our study there have been significant increases in the absolute numbers of engineering degrees. Accordingly, more women are graduating, but the rate at which women are graduating is incremental relative to the overall production of Ph.D.s. At Michigan, for example, the number of women graduating increased, but the overall graduation rate rose so sharply that the percentage of women in the graduating class in 2009 declined. While absolute numbers are, of course, important, for significant improvements in overall gender equity in engineering, which is often measured using sex ratios, increasing the percentage of women entering and remaining in the field remains a top priority.

Comparing ADVANCE institutions to their peers contextualizes our findings making them relative to other schools, and shows more mixed results. This raises important questions about the circumstances under which changes are occurring in STEM disciplines. Our inability to distinguish a clear relationship between the percentage of women on the faculty and the percentage of Ph.D.s granted at ADVANCE institutions is intriguing. This calls into question the importance of role models for women in choosing areas of study. With similar findings among biomedical engineers, Chelser et al.[7] attribute this to women leaving the academic and industrial workforce in higher numbers than men, in part due to a hostile work environment, difficulty with work-family balance, and women receiving less credit for the same achievements as their male counterparts.

Empirical literature conforms to Chesler et al.'s[7] findings and suggests that women faculty and students in STEM encounter similar issues and barriers. For instance, using the metaphor of a leaky academic pipeline, social scientists observe disproportionate female attrition at critical pipeline points including receiving a Ph.D. degree, entering the assistant professor position, receiving tenure and promotion to associate rank, receiving promotion to full professor, and advancing into academic leadership positions.[22] Factors contributing to this phenomenon include institutional climate, a sense of isolation[23], lack of role models[24], and lack of women in key academic leadership positions.[25]

We are inclined to suspect that such findings may help in explaining our results. In particular, although women's graduation rates are likely to be affected by more complex factors than the availability of roles models, even more important from our perspective is that the concept of role

models applies to *individual women* in specific circumstances rather than the overall climate or culture in an academic field. However, this also raises questions about the impact of the ADVANCE program in improving the climate for women. In particular, the goal of the ADVANCE program is to transform institutions to make the field more accessible to women at all stages of study and career, and ultimately diversify engineering. Indeed, for women to be more equally represented, more women must be present at all stages of the academic pipeline. Investigating how and why institutional transformation may only apply to either graduate students or faculty at a given institution – or how or why there is an inverse relationship between growth in these areas – could reveal what specific mechanisms account for women who are differentially positioned in their education and careers. Thus, further research on the cases where there is an inverse relationship between the percentage of women on the faculty and the percentage of women graduates is called for. Such research may also shed light on the sorting processes that lead engineers (both men and women) into industry or the academy. In this context, it is also important to note that the vast majority of studies evaluating the outcomes of ADVANCE initiatives focus on the changes in the situation of women faculty. Although the continued monitoring of progress in this area is absolutely necessary, our analysis points to the importance of on-going multidimensional assessment that includes questions related to the depth of institutional transformation with regard to its effects on women Ph.D. students.

Limitations

These analyses and questions also point to important limitations of this study. The improvements in women's representation discussed above are based on numerical outcomes without accounting for other factors that lead to changes in representation. With respect to faculty, we do not have information about the number of positions available at any given institution, the timeliness of openings, and the issues around faculty retention. Similarly, our analysis of graduate students in the pipeline does not take into account the numerous factors contributing to individual women's decisions to pursue academic versus industry positions. Further, examination of numerical outcomes does not consider the changes in the overall institutional culture and day-to-day practices at the ADVANCE versus non-ADVANCE institutions. It is possible that, in the long run, the ADVANCE institutions are more successful both with regard to numerical results and the less tangible outcomes such as institutional climate and faculty and student satisfaction. However, this is not something that we can conclude from the information here, and this caveat also points to some other limitations of our analysis.

Increasing the overall representation of women faculty is an important aspect of institutional transformation as it allows us to assess progress toward the creation of a critical mass of women faculty.[iii] And, it is also a critical *first step* toward a more prominent institutional change by creating a greater likelihood of women entering the leadership positions. Given that one of the most critical factors ensuring success of an institutional transformation is leadership support,[26] the presence of women in the leadership positions not only transforms the authority structure but also creates further opportunities for successful institutional change. However, although gender composition is an important indicator of institutional transformation,[27] our exclusive focus on this measure is also a limitation of this study. An adequate understanding of institutional transformation requires the inclusion of other quantitative as well as qualitative indicators, such as the number of women in the highest academic ranks and leadership positions or the

heightened awareness of equity issues, which are also better indicators of lasting change. Further, our analysis cannot account for factors such as international status of either students or faculty members. Such information may help explain our inconclusive findings about the importance of role models for women in the academic pipeline.

Institutional transformation is a long-term, ongoing process, which often requires a much longer time horizon than eight years.[28] A more accurate understanding of the nature and extent of transformation can be gained by expanding the time-frame for comparisons beyond the eight year period.

With these limitations in mind, we believe that in order to understand why some institutions are more successful in pursuing gender equity than others, and how success is being defined, it is important to continue comparing ADVANCE institutions across different institutional levels and over time. In addition to providing us with a better understanding of the different strategies and initiatives, such comparisons can also tell us what else may be important to look at, such as different starting points, policy contexts, and the success stories that may materialize even without ADVANCE funding.

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Endnotes

[i] In a discussion of different assessment strategies, Frehill et al.[19] suggest that using an institution's own peers for comparison purposes is especially well suited "to understand the extent of change relative to gender equity goals."

[ii] Since our main focus in this study is on sex-ratios as an important indicator of gender equity, we do not provide absolute numbers, except the instances when they offer insight into trends with implications for the issue of representation. We will gladly share the raw data used in our analyses upon request.

[iii] The concept of critical mass is related to the gender-ratio indicator. In her pioneering work Kanter[22] distinguished among four gender ratio categories: the female token category ranges from 0 to 17%, the female minority ranges from 18 to 35%, and the sex-balanced ratio stands between 36 to 64%. The critical mass indicator is typically designated at the high end of the female minority category, i.e., at 30%.