The University Experience

Retention to Degree

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Lack of Progress for Women in Engineering (WIE)

Although progress has been slow, there have been advances in recruiting, retaining, and graduating women in undergraduate engineering programs. But why are we “stalled” and perhaps in need of major intervention? This paper identifies some of the key factors and trends that assist women to succeed in undergraduate engineering programs but also asks what’s missing and what’s preventing faster progress. It is intended as a discussion starter for universities to examine how much progress has been made by their engineering programs to become more diverse and how does that fit within the context of the larger university setting. With so many competing priorities for resources, factors outside as well as within engineering need to be considered. There are success stories (e.g. Harvey Mudd increasing women in Computer Science from 10% to 40%) in which institutions have significantly increased enrollment and graduation rates of women in male dominated fields. *So why has progress at most institutions been so slow?*

Questions… and more questions

How can we replicate the success that some schools are having? What is missing in the literature? Are there under-studied “breakthrough” areas? Are there promising practices that need to be researched further, built upon and disseminated (e.g. service learning, project based curriculum, experiential programs such as co-op that increase self-efficacy)? This isn’t a linear progression, but is there a tipping point? If departments or programs reach 30% or 35% WIE can they expect to rapidly achieve gender parity? These are complex questions given that some of the research and model programs have been around for a number of years (e.g. living learning communities, mentoring programs, supplemental instruction) but progress is still slow. We raise these questions in the hopes that they will be catalysts for more rapid change.

Numbers

The total number of engineering bachelor’s degrees awarded has grown over the past decade. During this same time, the percentage of women receiving engineering degrees has not yet reached 20%. It has hovered between 17% and 19% for a number of years.[1]

Figure 1 shows the percentage of bachelor's degree earned by WIE over the past four decades.[2, 3]

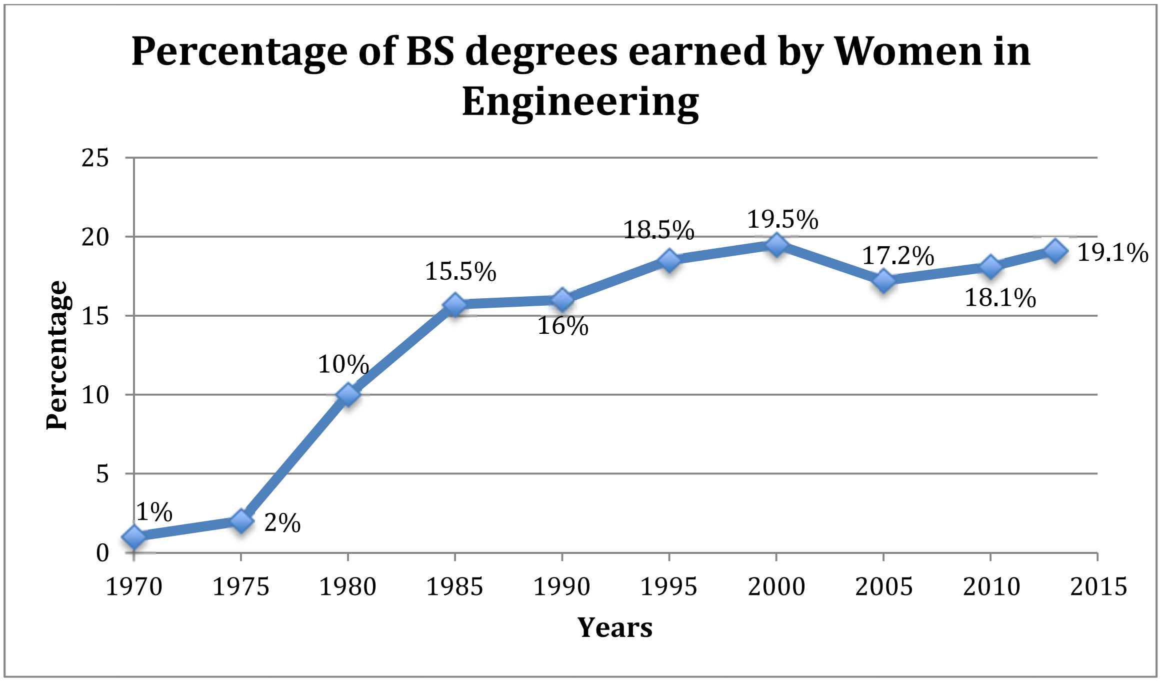

Figure 1: Percentage of BS Engineering Degrees Earned by Women

Figure 2 shows enrollment trends in undergraduate engineering from 1979 till 2014[4, 5].

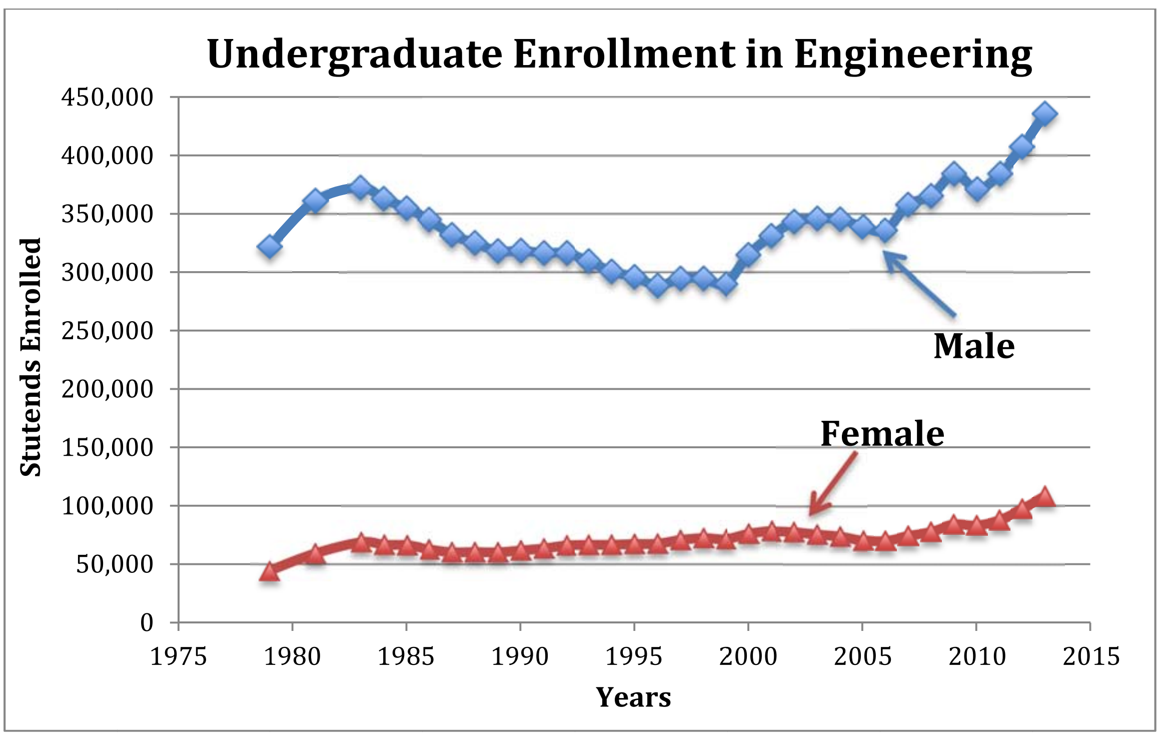

Figure 2: Undergraduate Enrollment in Engineering by Gender

Key Factors

There are a number of key factors that have been found to assist women in undergraduate engineering programs. These include: creating a welcoming environment, providing societally meaningful content, developing curriculum and classrooms that are engaging, providing contextual support, offering role models, and providing out-of-classroom opportunities for leadership and experiential learning such as co-op. In an article “Piercing the 20 Percent Ceiling” in ASEE – PRISM (2015), author Margaret Loftus points out that although the average number of females in engineering programs in the United States is under 20%, some schools have successfully increased the female student enrollment in engineering. Loftus found that these schools have succeeded by cultivating a culture in which women thrive through a combination of commitment across all departments to increase the number of female students, a heavy dose of hands-on learning, and an environment in which women feel welcome.[6]

Welcoming Environment

Creating a welcoming community for females in a college or university can start during the recruiting process. These efforts can include targeted events such as women in engineering days, brochures and materials prominently featuring females, and Open Houses that facilitate access to female faculty and upper-class women. Summer programs (such as bridge programs) before their first semester have proven to be highly successful in creating a cohort and previewing opportunities (e.g. research) and resources (e.g. supplemental instruction) that will be available when they matriculate. When new students arrive on campus, activities sponsored by student groups such as the Society of Women Engineers (e.g. SWE student-faculty welcome lunch, alumni tea, upper class mentors) can be very effective in creating a welcoming environment.

Considerable effort has been put into programs to help students with their transition into college. Students often go through both an academic and a personal transition. The academic adjustment is due to more challenging course content, classes being faster pace and requiring students to master more materials on their own; this can be mitigated by programs such as supplemental instruction. Academic support structures such as review sessions, peer tutoring, and study groups help create an environment that is collaborative rather than competitive.
The personal adjustment can be due to students entering a new community, living away from home, being given more freedom and responsibilities. In the freshman year, living learning

communities are proven to support women and provide a welcoming environment. Stassen (2003)[7] explored the effect of living learning community models on a variety of students with different experiences and academic performances. They strengthen connections between the learning environment in the classroom and the living environment in the residence hall. Learning communities have received considerable attention by higher education scholars and practitioners since they encourage student engagement in educationally purposeful activities inside and outside of the classroom. They both challenge and support students.[8] Tinto's study (2003) showed the impact of learning communities on student success, and discovered that learning communities not only help enroll a cohort of students in classes together, but they also help to involve students both socially and intellectually in ways that promote cognitive development and shared responsibility.[9]
Are we putting enough funding into sustaining and expanding these successful programs? Do we do enough to promote student involvement in these as students make enrollment decisions?

Social Relevance

A welcoming environment can provide programs to engage students in meaningful ways. For example, service learning programs that combine service to the community with student learning in a way that benefits both. Coyle et al (2005)[10] initiated a program called EPICS (Engineering Projects in Community Service) at Purdue University in 1995 to fulfill the complementary needs of engineering undergraduates and the community. Currently, more than 15 universities nationwide are participating in this program.

In a recent article in the NY Times (2015)[11], author Lina Nilsson suggests that one solution to greater female enrollment into engineering could lie in universities introducing societally meaningful content. Several universities that offer these types of programs and courses report significant increases in the number of women participating. Student organizations and clubs such as Engineers Without Borders see similar patterns. This indicates that another key factor to increasing the number of female engineers may be reframing the goals of engineering research and curriculums to be more relevant to societal needs.
A recently released report by the American Association of University Women, AAUW (*Solving the Equation*) draws on a large body of research that explores the factors underlying the underrepresentation of women in engineering and computing, including stereotypes and biases. This report also points out that a factor "that may contribute to girls and women choosing to pursue fields other than engineering and computing is the small but well-documented gender

difference in desire to work with and help other people."[12] Women make up a higher percent of the Biomedical Engineering degrees awarded (39% of BS degrees in 2011). Whereas women make up a low percent of the Electrical, Computer Engineering, and Computer Science degrees awarded (11.5%, 9.4%, 11% respectively of BS degrees in 2011). *Are female students attracted to Biomedical Engineering because of the evident applications that benefit society? What measures are other engineering fields taking to appeal to women?*

Classroom and Curriculum

When looking at the first year engineering curriculum, the AAUW report summarizes a number of key recommendations: "college and university engineering departments should emphasize the wide variety of expertise necessary to be a successful engineer. A narrow focus on math and science obscures the other areas of expertise – writing, communicating, organizing, and managing – that engineers need to be successful. Including engineering design activities in the field early in undergraduate coursework allows students to see the differences between textbook problems and the creativity and critical thinking necessary for actual engineering problem solving." [13]

Felder et al (2003)[14] listed different methods to design and teach courses that meet ABET Engineering Criteria. These methods have also helped with retention of students. The teaching methods involve problem based learning and cooperative learning. A study by Smith and Sheppard (2005)[15] that focused on classroom-based pedagogies of engagement pointed out that engineering educators had successfully implemented ways of better engaging their students through active and collaborative learning, learning communities, service learning, cooperative education, inquiry and problem-based learning and team projects.

Steinemann (2003) states that "Problem Based Learning" can help students gain practical problem solving experience, which can help students to implement projects that have benefit to the greater community.[16] Min et al examined data from 1987 to 2004 of over 100,000 undergraduate engineers from nine different schools. They studied the rates of retention as well as when students decided to leave. They determined that females tended to leave engineering sooner than their counterparts. In order to combat this, Min suggested implementing a more varied and hands-on approach to teaching the fundamentals of math and science in ways that are more engaging.[17] *Can't curriculum for required engineering and science courses be designed that feature compelling, socially relevant themes? Can't curriculum be delivered with engaging pedagogy (i.e. featuring creativity and design, skills in problem solving, and project-based learning in teams)?*

Contextual Support

Contextual support from faculty, mentors, colleagues, family and university can play a major role in helping an individual persist through challenges. It helps avoiding feelings of isolation and has been found to enhance not only self-efficacy but academic achievement as well.[18]

Lent et al (2003)[19] in their research on Social Cognitive Career Theory (SCCT) looked at the contextual supports and barriers related to the pursuit of engineering majors and found that environmental factors like family support and financial constraints were linked to choice of goals and actions (i.e., persistence in engineering) indirectly through their self-efficacy.

Raelin et al (2014)[20] in a pathways model described that academic achievement, academic self-efficacy, as well as contextual support (e.g. from mentors, advisers, financial aid, family, friends, teachers, professional clubs, campus life, and living-learning communities) were critical to retention, especially to women. This support was found to be particularly important to women in engineering and appeared to serve as an inducement to stay at the university and in the major. It was found that women took significantly more advantage of support in all forms indicating that women utilize resources if provided.

Which of the contextual support is most important to women? Do they have an “additive” effect?

Opportunities Outside of the Classroom

The pathways study[21] conducted longitudinally over three years in four universities (2 co-op and 2 non-co-op schools) also looked at work self-efficacy developed by students during their co-op work experience. Work self-efficacy measures a range of behaviors and practices affecting students’ beliefs in their command of the social requirements necessary to succeed in the workplace. It is made up of problem solving, sensitivity, role expectations, teamwork, learning, pressure, and politics. This research found that the most critical variable predicting retention was the number of co-ops taken by students. Those who stayed at the university or in the major participated in more co-ops than those who left. However, the variable of co-op participation had a unique symbiotic relationship to work self-efficacy. Co-op students developed far more work self-efficacy than non-co-op students. Samuelson and Litzler (2013) analyzed responses of women engineering students at the University of Washington who had participated in an internship or co-op. All respondents spoke highly of their opportunities, and believed that their experiences helped improve their understanding of engineering as a whole, as well as make valuable connections.[22]

Although many students in engineering have access to co-ops or internships, many still do not participate because of personal preferences or because their university has not made the sustained financial and human resource commitment to provide for a program of formal targeted placements along with counseling support. Nevertheless, the benefit in terms of retention seems to be worth the investment.

Could programs be provided that provide comparable, alternative experiences?

Leadership Opportunities

Leadership opportunities not only help women to excel in their field of interest but also provide them with the confidence to overcome challenges like gender bias in male dominated fields such as engineering, and develop technical and communication skills. Ely et al (2011)[23] discuss the implications of leadership in theory and education. The authors provided a conceptual framework by integrating insights from two streams of research, one on leader identity and another on second generation gender bias, that are subtle forms of cultural and organizational gender bias. The U.S. Department of Education released a report in 2006[24], *Test of Leadership*, which focused on bridging the gap between high school and undergraduate education. The report pointed out that teaching leadership skills in high school helped students enter undergraduate studies with greater confidence and better prospects of retention and graduation.

Undergraduates should be encouraged to take advantage of leadership opportunities both in and outside of the classroom. Faculty can play a role in project and lab work to assure leadership roles are rotated amongst team members. Student groups can also provide significant opportunities for women to take on leadership roles and hone their skills.

Can professional organizations in addition to SWE (e.g., ASME, IEEE, etc.) facilitate this through workshops and other means? Can student group advisors be trained to mentor and coach women into leadership positions in their organizations?

Role Models

In a study by Fouad and Singh (2011)[25], a third of the women interviewed who didn't enter engineering after graduation said it was because of their perceptions of engineering being inflexible or the engineering workplace culture as being non-supportive of women.

Author Joan Williams (2015)[26, 27] discusses gender bias against women of color in science in her latest article “Double Jeopardy” featured in SWE Advance. The study from the Center for WorkLife Law at UC Hastings by Professor Williams et al (2015)[28] combined in-depth interviews of women of color in STEM with survey results from both women of color and white women. The study found that there is pervasive gender bias with African American women reporting that they are more likely to have to prove themselves over and over again; and Latinas reporting of being pressured to do administrative work for their male colleagues (such as organizing meetings). *How does this affect undergraduate WIE? Do they see role models in the work place facing this gender bias and stereotyping and get discouraged? Are they worried that they will face similar bias and stereotyping? Can we do more during their university experience to prepare them (e.g. career management classes, career services offices, career mentoring programs)?*

In spite of a student's excellent academic credentials, many high tech companies include "technical interviews" as part of the screening process for hiring candidates. These can be very intimidating and may contribute to the reason diversity numbers are so low in many of these companies. *Can we influence the practices of the companies that recruit our female students?*

Parallels with Underrepresented Minority (URM) Students

There are a number of parallels between URM and the under representation of women in engineering. These include the need for role models, the success of programs such as Summer Bridge[29], bias and stereotyping, the success of minority serving institutions to women's colleges (e.g. Smith, Wellesley) in preparing students for careers in STEM, failure of high school systems to prepare URM and women for college majors in STEM.

In a paper by May and Chubin (2003)[30] the various factors that contribute to the success of minority students in engineering programs are explored. Student success is correlated to several indicators, including pre-college preparation, recruitment programs, admissions policies, financial assistance, academic intervention programs, and graduate school preparation. This review suggests that the problem of minority underrepresentation and success in engineering is solvable given the appropriate resources and collective national "will" to propagate effective approaches. This is of critical importance as URM retention rates in STEM fields are disproportionately low.[31]

In a recent article in U.S. News & World Report (2015)[32] Bidwell reported that African American men are still "one of the most underrepresented demographics" in STEM even though the field is "dominated by men." The number of black men earning science and engineering doctorates has "stayed essentially flat" in absolute numbers between 2003 and 2013, as have bachelors' degrees figures. African American students face more obstacles like unavailability of resources, role models, and relatability, as well as "systematic problems of perception and low expectations." The Executive Director of the National Society of Black Engineers, Karl Reid points out that the lack of black men in STEM is "a byproduct of a failing system for African Americans in the overall school system."

A report by AAUW (*Why so few?*) discussed the model of Historically Black Colleges and Universities (HBCUs) for creating effective and supportive departmental cultures that help recruit and retain female science majors. HBCUs produce a disproportionate number of African American women physicists with more than half of all African American physics degree holders (male and female) graduating from HBCUs. One crucial thing the report points out: HBCUs provide a path toward a degree for students who do not come to college fully prepared to be physics majors.[33]

As mentioned above, Williams (2015)[34] reported that in the workplace black women (77%) in science were more likely than other women to report having to provide more evidence of competence than others (Latinas 65%; Asian-Americans 64%; white women 63%). The report also found that black women tended to attribute "Prove-It-Again" bias to race rather than gender while others felt gender and racial bias were additive*. Do female undergraduate URM in engineering encounter these same barriers?* There is much work to be done in this area. LaMotte for example is undertaking an interpretive phenomenological study focused on African American women at predominately white institutions in engineering who despite the environment, successfully persist.[35] *Can we do more to assist minority women at the university level? Can we learn more from minority serving intuitions? Can organizations such as SWE, NSBE, SHPE collaborate more on campus?*

Summary

We have discussed several key factors critical to retention of female students in engineering programs. Contextual support from faculty, mentors, colleagues, family and university plays a major role in helping an individual persist through the challenges. Living learning communities and service learning programs nurture the culture of teamwork from the very beginning of engineering among students preparing them to thrive in any field and advance it. Providing women with experiences outside of the classroom such as cooperative education, research opportunities and leadership opportunities, increases retention and helps students to not only graduate with a degree but also to remain in the field.

Measuring progress? Colleges and universities are tracking freshmen to sophomore retention and graduation rates both at the university and at the engineering college levels. Most are tracking retention and graduation by gender, by ethnicity, by socio-economic level, by underrepresented minorities, etc. *But how do they measure success? Is it compared to their* *"match peers"? (If everyone is moving slowly, does it seem acceptable?) Is it compared to prior years? (If they make small advances each year, is that "success"?)*

Despite over 40 years of slow movement in both enrollment and graduation rates for women in engineering, there has been progress. The greatest successes have been in creating programs that enable women to thrive (not just survive) in engineering programs. However, the numbers of women in the field and the rate of change are incredibly frustrating.

Why aren't we doing better?

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