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Implementing Institutional Change to Increase Engineering Diversity

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Abstract

The barriers to gender equity in engineering are daunting in an environment where boys and girls only 9 years old have internalized gender stereotypes that dictate that physical-science and technology are for boys and that life science is for girls. In a world where minorities are projected to make up more than 40% of new workforce entrants by 2008, it is unacceptable that white high school students are four times more likely than African American students to take pre-calculus or calculus. The reality is that girls graduate high school with skills and knowledge comparable to boys, but are far less likely than boys to pursue engineering. In contrast, while comparably few minorities graduate high school with the skills and knowledge necessary to successfully enter engineering studies, they do so in numbers representative of their participation in college education as a whole, but are far less likely than whites to graduate.

In the absence of institutional change to rectify the unintentional inequities preventing equal access to engineering education by underrepresented groups, isolated recruitment and retention programs have had only modest success in generating real growth in the numbers of women or minorities entering engineering. If engineering educators are to succeed in attracting and keeping the diverse engineering students so desperately needed by today's technology workforce, they must take the lead in working towards the institutional change necessary to turn the tide towards parity in engineering education. The latest research and successes from institutions such as Carnegie Mellon University and the Massachusetts Institute for Technology illustrate key areas for institutional change shown to be effective in recruiting and retaining greater numbers of women and minorities in engineering education. These areas include: effective K-12 outreach programs, K-12 teacher training, curriculum realignment, admissions policy reform, faculty recruitment and student leadership. This paper will outline suggested strategies for implementation by engineering educators ready to serve as leaders at diversifying engineering.

Overview of the Under Representation of Women and Minorities in Quantitative Fields

It is estimated that over the next ten years, the U.S. will need an additional 1.9 million workers in science, technology, engineering, and math (STEM).[1] Traditionally, the STEM workforce has consisted of mostly white, non-Hispanic men, who made up 70% of the STEM workforce in 1997.[2] In the same year, underrepresented minorities - African-Americans, Hispanics, and American Indians - comprised just over 6% of the general STEM workforce.[2] This reliance on a predominately white, male workforce is troubling in the face of the changing demographics of

the U.S. population. The proportion of white students in undergraduate enrollment fell from 80% in 1978 to 70% in 1997. During the same period, the proportion of underrepresented minorities (URM) in undergraduate enrollment increased from 15.7 to 21.7%.[3]

The Advisory Committee to the National Science Foundation Directorate for Education and Human Resources has expressed concern that the facts that the majority of Americans are women, and that the proportion of Americans aged 18-22 who are URM is expected to rise above 40% by the year 2015, have profound implications for STEM education. It concluded that unless STEM education becomes much more inclusive than it has been in the past, the U.S. will be denied the STEM talents of the majority of its population.[4] In order to remain competitive, the U.S. must reinvent STEM education and employment to attract, educate and employ those who have been traditionally underrepresented in STEM.

Approximately 25-30% of all students entering college in the U.S. intend to major in STEM fields.[3] Unfortunately, 50% of all students intending to major in STEM change majors within the first two years,[1] and fewer than 50% actually complete a STEM degree within five years.[3] Women are much less likely than men to intend to major in STEM fields.[5] In 1999, women were only 20% of total undergraduate enrollment in engineering programs in the U.S., and were only 19% of full-time first-year engineering undergraduates.[5] In 1998, women received 56% of bachelor degrees overall, but only 37% of STEM bachelor degrees. They earned only 35% of the bachelor's degrees in astronomy, 33% in chemical engineering, and less than 20% in aerospace engineering, electrical engineering, mechanical engineering and physics.[5] Underrepresented minorities received just 12% of the total STEM bachelor degrees awarded.[1]

The participation and retention profiles of white women are different than those of URM males and females. Women are generally more likely to go to college and to graduate than their male peers, but they are far less likely to choose to major in a STEM field. URM males, on the other hand, are less likely to attend college at all and are less likely than whites to graduate if they do attend college. Among those who were 25 to 29 years old in 2000 and had completed high school, only 21% of African Americans and 15% of Hispanics, compared to 36% of whites, had earned bachelor's degrees or higher.[5] Underrepresented minority males select STEM fields in rates comparable to their representation in overall enrollment. Roughly equal percentages of whites, African Americans, Hispanics, and American Indians intend to major in STEM.[5] In contrast, women from URM are less likely than their male URM counterparts to select a STEM major, but are more likely to do so than white female undergraduates. In 1999, African American women were 34% of African American engineering enrollment, and Asian, Hispanic and American Indian women were between 23 and 25% of the enrollment of their respective racial/ethnic groups, while white women were only 18% of white engineering enrollment in the same year.[5]

The percentage of engineering degrees going to URM has increased steadily from 2.9% in 1973 to 9.2% in 1995. However, 9.2% is still less than half of the combined representation of URM in the US population.[8] While the 2000 Census showed that almost 25% of Americans are African American or Hispanic, only about 10% of engineers are from those ethnic backgrounds. Women constitute half the U.S. population, but are less than 10% of its engineers.[9]

National Imperative to Increase Diversity in STEM

Today the U.S. is the world leader in the global STEM enterprise, but other countries stand ready to challenge this economic strength. One of the main reasons is a shortage of U.S. citizens with the necessary education to fill STEM jobs in the U.S.[2] The U.S. is suffering from a shortage of a skilled STEM labor force. From 1998-2008, employment in all STEM occupations is expected to increase by about 51% or 1.9 million jobs.[3] Employment for all engineering occupations is expected to increase by an average of about 20%.[3] According to a report by the U.S. Dept. of Commerce, "severe shortages of workers who can apply and use information technologies could undermine U.S. innovation, productivity, and competitiveness in world markets."[10] The report identifies the under-representation of women and minorities as a major contributing factor to this shortage. A principal conclusion of a report by President Clinton's National Science and Technology Council was that it is imperative that members of all ethnic and gender groups participate at increasing rates if a strong STEM workforce is to be ensured.[11]

In September, 2000, a Report of the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development came to the same conclusion. "An increasingly large proportion of the workforce consists of women, underrepresented minorities, and persons with disabilities – groups not well represented in STEM fields. Unless the STEM labor market becomes more representative of the general U.S. workforce, the nation may likely face severe shortages in STEM workers."[12] The National Science Foundation, a major source of government funds for STEM research, has set as one of its strategic goals to "strive for a diverse, globally oriented workforce of scientists and engineers" and includes broadening the participation of underrepresented groups as one of only ten criteria that must be addressed by every grant proposal it receives.[13]

While gender and racial equity is seldom on the agenda of mainstream business and government, the critical shortage of a skilled STEM workforce in the U.S. is generating substantial interest in ways to increase the recruitment and retention of women, underrepresented ethnicities and persons with disabilities in STEM education and employment. There is a growing consensus among government, education and industry leaders that if the U.S. is to remain competitive, it is imperative to increase the number of women and URM in STEM. Many major corporations have come to realize that diversity in the workplace enhances creative thinking, improves decision-making, increases worker retention, recruitment and productivity, and increases competitiveness in an increasingly diverse consumer market.[4] The engineering community has identified the need to increase the recruitment of women and URM into the engineering profession.[9] This need has been formalized by government institutions like the Directorate for Education and Human Resources at the National Science Foundation, which lists equal access to STEM fields for URM, women and persons with disabilities as one of its three funding priorities.[2]

There is clearly strong national impetuous for diversifying the U.S. STEM workforce. This call for diversification at the highest levels of national leadership is based upon economic imperitives, not social justice. It is an opportune moment to create systemic change towards equity in STEM by leveraging the labor shortage to build partnerships between government,

labor, industry and academia to increase the representation of women and other underrepresented groups in STEM.

Strategies to Diversify STEM

Women have the academic skills to pursue STEM education, but are four times less likely than men to intend to major in STEM. Research has found that pre-college exposure to STEM careers and to women in STEM encourages female students to pursue STEM.[14] Strategies to expose girls to STEM include outreach initiatives that teach girls and their teachers and guidance counselors about STEM. Outreach to elementary, middle school, and high school girls that introduces them to women who are majoring in engineering and to women in engineering careers can play on important role in helping expose girls, and those who influence them, to STEM. Other recommended recruitment strategies include: forming collaborations where high school students are encouraged to take courses not offered at their high school by attending local colleges tuition-free; provide for professional development of middle and high school teachers in STEM by setting up collaborations through which they can take courses at local colleges for free; and increase visibility of women in STEM to students by supporting school visitation programs that include female students and faculty.[15] Given the important role that they play in female students' decisions to enter STEM[15], it is particularly important to educate teachers, guidance counselors and parents that STEM subjects provide intellectual skills valuable across many disciplines[16]. Teachers and faculty must be involved in actively recruiting female and URM students to study STEM subjects and to remain in STEM fields. [16]

In *Unlocking the Clubhouse: Women in Computing*, Jane Margolis and Allan Fisher share strategies from Carnegie Mellon University, which succeeded in increasing its enrollment of female undergraduates in computer science from 7% to 42% in five years and increasing its retention of women to nearly match that of men.[16] Fisher is the former Associate Dean for Undergraduate Education in the School of Computer Science at Carnegie Mellon University (CMU), and implemented the institutional changes that made the dramatic increase in female enrollment and retention at CMU possible. A key element of the CMU strategy was curricular reform that provided first-year students with four different ways to enter the curriculum depending on their level of prior experience. [16] The rest of the curriculum is neither tightly scheduled nor deep in prerequisites, so that all students get an equal opportunity to take advanced courses. This was accomplished by designing a course that combined discovery-based, real-world orientation with an introduction to programming that would prepare students for a more advanced programming course. Another, more advanced course was designed for incoming students with a greater level of prior experience. [16]

Research indicates that introductory courses and simulated research experiences that allow students to experience STEM as researchers experience it can both entice and engage students. The Advisory Committee to the National Science Foundation Directorate for Education and Human Resources recommends that STEM faculty build inquiry, the processes of STEM, knowledge of what STEM practitioners do, and the excitement of cutting edge research into every course, and that faculty adopt pedagogy that develops communication, teamwork, and critical thinking skills. [4] Curricular reforms to engage a more diverse student body by engaging students in hands-on assignments that include real-world applications have had a positive impact

on both recruitment and retention at Smith College and Rensselaer Polytechnic Institute.[17] Curricular reform has been facilitated by the recent changes to accreditation standards by the Accreditation Board for Engineering and Technology.

In addition to reform that restructures the first-year engineering curriculum to engage the students through inquiry, real-world applications, and social relevance, admissions reform is starting to reshape the face of the engineering student body. Carnegie Mellon University adjusted its admissions criteria to reflect its research that prior computing experience did not predict academic success by removing its strong preference for highly experienced applicants. In 2001, the University of California system adopted an admissions plan that guarantees provisional University admission to all students in the top 12.5% of every high-school class in the state, regardless of grade-point average and standardized-test scores, if the students complete two years at community college first. It is estimated that this new policy will produce an additional 3,500 transfer students a year, and that 36% of them will be URM, compared to the 18.6% that URM comprise of traditional admissions to the University.[18]

If institutions of higher education are to engage and retain women and URM into STEM, they must first assess the quality of the student experience. Poor teaching, unapproachable faculty, and peer hostility disproportionately affect women and URM. The freshman experience is critical to the persistence of women, who are most likely to leave STEM after the freshman year.[14] Large lecture courses that take a weed out approach can have a devastating effect on otherwise able students.[18] The curriculum and academic culture must contextualize the work that students are asked to do and provide students with role models and career information. Faculty and staff must be made aware of unintentional gender and other inequities, such as assignments and teaching examples that reflect male-dominated interests, textbooks that focus on technical detail and fail to reflect the application and impact of the material. [18]

Conclusion

Workforce demands and demographic trends dictate a new imperative to increase the recruitment and retention of women and URM into STEM fields. While outreach and support activities for women and URM in STEM play an important role in increasing participation and persistence[14], systemic change is necessary to implement the move toward equal representation of women and URM in STEM. Curricular reform that integrates inquiry, real-world applications, and team work in a format that demonstrates the relevance of coursework has shown documented success at moving participation and persistence rates for women and URM towards parity. [17, 18] Admissions reform that compensates for lack of prior experience, that includes a mechanism to reach able students in underserved school systems, and that allows for a qualitative assessment of student abilities is vital for assuring equal access to higher education in STEM.

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