The Under-representation of Women in Engineering and Related Sciences: Pursuing Two Complementary Paths to Parity

A Position Paper for the National Academies' Government University Industry Research Roundtable Pan-Organizational Summit on the U.S. Science and Engineering Workforce

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Despite some concerted attention and resources devoted to recruitment and retention of women in engineering over the last couple of decades, they are still woefully under-represented in engineering and many related sciences. This under-representation is problematic from several perspectives: From the point of view of the U.S. science and engineering workforce, nearly half the potential talent for the technical workforce is missing. There is also cause for concern on the part of those seeking quality, talent, and creativity for the engineering and scientific disciplines and professions. And women themselves are missing out on opportunities to leverage learning and skills in interesting and rewarding careers, explore new fields, develop new knowledge, design new solutions, and benefit from the rewards of financial independence and economic equity.

Data

When we consider why there are so few women in science and technology fields, it's important to consider a few facts. Women represent more than half the population, and 46% of the U.S. workforce, but just 24% of those working in science and engineering combined, and only 10% of the engineering workforce (NSF, 2002). Since 1980, the percentage of women receiving bachelor's degrees in engineering has slowly increased from about 10% to nearly 20%. But in some of those years, the percentage remained flat, and in recent years, even when the percentage increased, the total numbers remained the same or decreased.

Those less engaged with developing the scientific and technical workforce may be lulled into complacency. Since the social changes of the women's movement and legislation removing barriers and addressing gender equity changed the landscape for women's opportunities 30 years ago, women have made considerable progress in participation a variety of professional fields. National Science Foundation data put the percentage of women receiving bachelor's degrees in science and engineering combined at 50% of the total in 2000. At first glance, one would think equity had been achieved, but upon closer scrutiny one sees that the definition of "science" in this case includes social and behavioral sciences, including psychology (in which women represented 76% of bachelor's degree recipients in 2000) and other fields where women are over-represented. In 2000, women earned about 20% of bachelor's degrees in engineering, 33% in mathematical and computer sciences, and 56% in biological and agricultural sciences.

Furthermore, the apparent "gains" in percentages are more reflective of the lower percentages of men entering these fields than increases in percentages of women: In 1980, 1.3% of women earning bachelor's degrees majored in engineering vs. 11.1% of men. In 2000, 1.7% of women earning bachelor's degrees majored in engineering vs. 8.8% of men. The numbers of women beginning majors in science and math are much smaller than those for men, but once in these fields, women's attrition is not appreciably different from men's (Campbell et al, 2002), except at highly selective institutions (Strenta, 1993). Attrition and differential retention for women may still be a concern, however, since we would expect even stronger retention among women than among men, given their higher average academic performance (Seymour and Hewitt, 1997).

The gap in participation of minority groups is not as large as the gender gap (Campbell et al, 2002), but race and ethnicity are also key factors in understanding the full spectrum of women's participation in science and engineering. While the gender gap in preparation for higher education has closed, a gap in preparation persists for students of African American, Hispanic, and Native American background compared with their white and Asian counterparts.

Most of the data reported, however, is not disaggregated by gender and race/ethnicity. Potentially even more problematic for educational equity is the lack of data on the relationship of socioeconomic status to entry and persistence in science and engineering education and workforce participation. The development of policy and practice to ameliorate the under-representation of various kinds of students and later, workforce participants, is impeded by these limitations of available data. Because of the strong correlation, it's often not at all clear when differences in preparation, for example, reflect differences in socioeconomic status and when they reflect institutional or individual racism.

The situation of women's considerable under-representation in science and engineering cries out for remedy, but remedy is complex. Dramatic gains have proven elusive over the last three decades since overt barriers to women's participation in these fields have fallen.

Examining explanations for gender differences

Differences in aptitude, achievement, or preparation do not appear to explain women's lower rates of participation in engineering and science. Some may assume that women leave scientific and technical fields of study because they find them too difficult. Yet the achievement gap in mathematics between boys and girls is less than 1% (Campbell et al, 2002), and research suggests that women switching out of science and engineering majors in college have higher GPAs in these fields than those of the men who stay in such majors (Seymour and Hewitt, 1997; Adelman, 2000). Girls and boys appear to be taking math and science classes in high school at about the same levels.

The remaining area of gender difference as students prepare to enter college appears to be interest, with girls even less interested than boys in pursuing engineering and science in college and beyond. Women, to a somewhat greater extent than men, are apt to choose fields of study they believe will contribute to the social good, and engineering and related sciences are not widely perceived as professions making such contributions. Though examples abound of discoveries, inventions, and solid engineering work and scientific research that contribute to the health and welfare of people all over the planet, to environmental protection and improved quality of life, the links between this work and engineering and science are not obvious to those outside these fields, and the perception remains.

Lack of interest or misperceptions on the part of students are not the responsibility or domain of any one institution or system. They are prompted by a social fabric that pervades our society, represented not only within our educational systems but in homes, within families, and in popular culture, which by and large stereotypes engineering and scientific fields as "geeky" and particularly inappropriate for girls and women. Targeted programs frequently attract only a portion of the students who could benefit from them, due to stigmas attached to participation, including peer backlash and harassment of those who participate.

We should be cautious about overemphasizing gender differences in seeking explanations and remedies for women's under-representation in science and engineering. Men and women are more alike than they are different. Women, like men, are not monolithic in nature; they choose to pursue or leave certain fields of study or employment for a wide variety of reasons. As a result, there won't be a "one size fits all" solution to increasing women's participation in scientific and technical fields, and many of the same strategies that work to encourage men's participation will encourage women's, and vice-versa.

At the same time, we need to recognize that societal beliefs, attitudes, and behaviors still lead to differential perceptions of and expectations for women (see, for example, Valian, 1998). Expectations, in turn, strongly influence learning and behaviors (Steele, 2002). Mitigating differential expectations through deliberate encouragement of women, provision of mentoring, role models, internships and scholarships, and related strategies can be helpful.

Good educational practice, focused on improving the learning of all students without a particular focus on gender, frequently results in greater gender parity. Similarly, when special effort is put into understanding the causes and providing remedies for women's under-representation (e.g., through examination of institutional policies and practices, faculty development, or providing a stronger community of support), the resulting changes often benefit all students.

Lessons Learned: Strategies for Change

Solutions to increase participation of women in science and engineering often initially focus on the problem of "How can we persuade more girls/women to enter/stay in these fields?" These interventions have been characterized as efforts that focus on a "deficit" model, in which it is assumed that these individuals lack something – ability, experience, interest, inspiration, motivation – that they need in order to succeed. In this model, attention is paid to mitigating that deficit, typically by providing programs – summer camps, internships, remedial courses, special study groups, mentoring programs, social opportunities, seminars, evening programs, etc.

Program evaluation suggests that well-designed intervention programs can definitely make a difference in increasing the numbers of women in science and engineering, at least for some portion of the population in some environments. But even on college campuses with longstanding, comprehensive programs focused on women in engineering and/or science, the representation of women does not rise to parity. Some have criticized this approach for its development of "band-aid" efforts that address symptoms rather than tackling the roots of the problem.

In the last decade, juxtaposed to the program intervention approach, many have suggested that the question to be addressed instead ought to be "What needs to be changed in these fields, disciplines, and institutions so that more girls/women will be attracted to them?" Within this framework, greater attention is paid to institutional and "systemic" features of the fields of study, modes of instruction, organizational policies, cultural practices, and structural elements that may impede women's full participation and success. Under consideration in this model, for example, are admissions policies, teaching practices, faculty rewards and incentives, faculty development, grading, testing, and other forms of assessment, curricular structure, and program and degree requirements. The appeal of this approach is strong. In theory at least, systemic change will address root causes and solve the problems so that they will not recur and will not need recurring treatment. It's also a bold, transformative approach with appeal to change agents who recognize and appreciate the serious limitations of program intervention.

At the same time, however, systemic change requires long-term investment to create measurable shifts in values, beliefs, attitudes, and behaviors, as well as structural changes in complex, interconnected organizations, professions, and practices. These changes are frequently challenging, complex, and time-consuming, particularly if a comprehensive shift is desired, with measurable impact on the participation of currently under-represented groups. There is a need to address inter-related systems and organizations in ways that are not under the control of any one single group of change agents.

Making a distinction between these two approaches is not always easy, and valuing one over the other is not altogether helpful, either. We need to focus on changing systems, practices, and institutions, not on "fixing" the individuals who aren't choosing engineering and scientific fields, but support programs should not be tossed out even as we focus on critical systemic change. An analogy to consider is the treatment of disease: There are diseases for which the cause and cure are still unknown, but while research scientists are investigating the cause and cure, we don't withhold treatment to ameliorate the symptoms of the disease, improve quality of life and extend life. Similarly, as we pursue systemic change, it is important to continue to measure the effects of good intervention programs, and offer those which are effective as widely as possible.

Programs that support and encourage individual girls and women, helping them to understand and thrive even within current flawed systems and organizational structures, are valuable. Such programs may also seed the process of longer-term shifts in institutional practices and culture. For example, in situations where men who are professional engineers and scientists serve as mentors to women students, they may learn more about the barriers women face in ways that lead to changes in their own beliefs, attitudes, and behaviors. In another example, faculty sponsoring research internships may have their erroneous assumptions about women students' abilities or other stereotypes dispelled.

There are already many strong programs in place, innovative as well as "tried and true," local, regional, and national, that help spark interest among young women, help to mentor students and emerging professionals at every level, provide "hands on" opportunities to explore the fun, challenge, and excitement of engineering and science, and offer role models and communities of support. Too often, however, these programs exist at the margins of our institutions, short on infrastructure for sustainability and scalability, the first to be cut when budgets are tight, vulnerable to leadership burnout or personnel changes. Leadership is needed to recognize the importance of this work, bring it into the mainstream of everyday educational practice, and create more ways to institutionalize, replicate, and scale effective efforts. Often, resources are needed to provide appropriate infrastructure for organizations or programs to ensure their sustainability, stability, and growth.

Too, the endless appetite of funding agencies, the media, and creative individuals who develop programs for the "new new thing" in programs for women and girls in engineering and science, may contribute to an over-investment in "startups" at the expense of sustaining high-performing but more seasoned operations.

Lessons Learned from MentorNet

Mentoring is a frequently employed strategy for retention of women in engineering and science. The power of mentoring is sometimes poorly understood, and mentoring is not always effectively practiced (Zachary, 2000). At its weakest, mentoring is viewed as a somewhat offhand strategy to address deficits, providing some needed encouragement and advising of weaker and less confident students. Once in college, women are somewhat more likely than men to doubt their ability to succeed in scientific and technical fields, yet lack of confidence frequently influences women's decisions to persist in studies or postgraduate opportunities in these fields (Seymour and Hewitt, 1997). Mentoring appears to be a strategy that helps increase women's confidence in their abilities (MentorNet, 2002).

At its strongest, however, mentoring is understood as a powerful learning process, which assures the intergenerational transfer of knowledge and "know-how" on an ongoing basis throughout one's life (Clutterbuck, 2001; Zachary, 2000). Mentoring helps make explicit the tacit knowledge of a discipline and its professional culture. Whether or not such individuals are labeled "mentors," nearly everyone has one or more mentors in the form of more experienced guides and advisors as they grow and develop as individuals and professionals.

Both protégés and mentors learn from mentoring relationships (Zachary, 2000). Well-deployed mentoring can be highly effective in supporting systemic change and in creating positive, productive, equitable learning environments (Clutterbuck, 2001). When mentoring is understood as a serious and powerful learning process, complete with the need to establish learning objectives, measures, and discipline to achieve results, its potential can be realized (Zachary, 2000). Policymakers, funders, and program developers, however, need to understand better the elements of effective mentoring and to consider how best to construct mentoring experiences that can be valuable and powerful in their transformation of individuals and organizations.

MentorNet was specifically designed to take advantage of newly emerging widespread use of Internet technologies to create mentoring opportunities where they couldn't previously exist due to constraints of time and geography. It was also designed to leverage technology in support of scale of programs that can otherwise be very time-consuming to manage well. Research-based program design, continuous improvement and feedback loops, and clever adaptation of technology-supported solutions have enabled an electronic mentoring program linking students with professionals in industry that is both scalable and cost-effective.

Summary of Recommendations

- Disaggregate data by sex, ethnicity, and socioeconomic status to ensure that program and change design will be influenced by data appropriate for all within the targeted population.
- Measure the effects of intervention programs, and offer those that are effective as widely as possible.
- Bring effective programs into the mainstream of everyday educational practice, and create more ways to institutionalize, replicate, and scale these efforts.
- Invest in infrastructure for effective programs to ensure sustainability, stability, and growth, creating high-performance organizations.
- Invest in both treatment (support under current systems) and cure (systemic change).
- Use research and practice to inform the development of effective mentoring programs for specific learning objectives for individuals and to support systemic change, measuring results against objectives.
- Explore ways in which technology can support scale and achieve efficiencies.

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[i] MentorNet (www.MentorNet.net), *the e-mentoring network for women in engineering and science*, is a nonprofit organization. MentorNet's mission is to further women's progress in scientific and technical fields through a dynamic, technology-supported mentoring program and to advance women and society by developing a diversified, expanded and talented workforce. The vision is three-fold: to establish excellence in large-scale e-mentoring, to create the e-community of choice for women in engineering and science through online mentoring and networking, and to leverage that community for positive social change.

MentorNet leverages technology to build large-scale impact for women and positive social change, scale which has increased over its five year history. During 2001-02, more than 3,000 undergraduate and graduate women studying engineering and related sciences at more than 100 colleges and universities across the U.S., and in several other nations, were matched in structured, one-on-one, email-based mentoring relationships with male and female scientific and technical professionals working in industry and government.