BRIDGING THE GENDER GAP IN ENGINEERING AND SCIENCE: THE CASE FOR INSTITUTIONAL TRANSFORMATION

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Abstract
For the past several decades, intervention programs for women and for minorities in engineering and science have mushroomed. Most programs have focused primarily on helping individuals develop the skills necessary to survive and thrive in the academy. Now, after decades of experience, many groups are calling for an institutional change. Though many barriers to creating a fully diverse workforce appear early in informal and formal education, higher education must remain a focus of this change. Higher education remains the true gatekeeper to careers in engineering and science: higher education defines the criteria for entry and the required credentials to be a scientist or an engineer.

In October 1995, Carnegie Mellon held a participatory conference, *Bridging the Gender Gap in Engineering and Science*, bringing together 150 stakeholders—researchers on gender issues in engineering and science, deans, department heads, faculty members, students, elementary and high school teachers, parents and colleagues from foundations and industry. The participants discussed the changes required in higher education to assure more equitable opportunities for all women in those fields.

Bridging the Gender Gap came at a critical time in the many on-going discussions on equity in engineering. For the past decade, groups such as the American Association for the Advancement of Science, the Association for Women in Science, Cross University Research in Engineering and Sciences, the National Academy of Sciences, the National Science Foundation and the Women in Engineering Program Advocates Network have held meetings on increasing diversity. Thanks in part to their work, intervention programs for women and for minorities in engineering and science have mushroomed, focusing primarily on helping individuals develop the skills necessary to survive and thrive in the academy. And now, after decades of experience, these groups and others are calling for an expanded approach: a

focus on institutional change. Though many barriers to creating a fully diverse workforce appear early in informal and formal education—from parents' attitudes in the home and toys given to children, to the implicit and explicit curriculum from preschool through high school—higher education must be a major focus of this change. For higher education remains the true gatekeeper to careers in engineering and science:

- Higher education defines the criteria for entry and the credentials required to be a scientist or engineer.
- Higher education teaches the teachers who work in kindergarten through 12th grade.
- Higher education impacts attitudes of many of yesterday's, today's and tomorrow's parents.

With affirmative action under attack, research budgets in jeopardy and the role of the traditional Ph.D. in question, this shift in attention towards the institution comes at a particularly challenging time. Yet many reasons exist to encourage women to enter these fields and at the highest levels. Despite the current challenges, science and engineering present greater rewards than most traditional fields for women. Equity requires that women—as well as men—have the full range of career choices available. And, our country desperately needs a scientifically and technically literate population of teachers, parents, and citizens. Equally important, the nature of the worldwide economy requires that we draw on the best resources of our total population if we are to remain competitive. The *Bridging Conference* and this paper are based on several assumptions:

- There is a problem of under-representation. The dramatic increase in women's participation in engineering and scientific fields that occurred in the 1970s and early 1980s has leveled off. In the mid 1990s, women earn circa 15% of all bachelor's degrees, 14% of all master's degrees, and only 9% of doctorates from U.S. engineering schools. Women's lower salaries, higher unemployment rates and slower opportunities to advance and achieve tenure are consistent throughout all disciplines, but particularly in engineering, computer science and the physical sciences. Women faculty and professionals in engineering are so underrepresented at all institutions in the U.S. that they often find themselves the only woman in the department. Currently, women comprise circa 3% of the faculty in engineering and circa 9% of the working engineers.

- Under-representation has costs. When women are in the minority, they have less opportunity to speak and to offer opinions and are less likely to participate. Research has shown that women benefit from experiences when they are involved with a "critical mass" of women. Once they

experience success and establish confidence in their ability, they are more able to be equally visible in situations where men typically overshadow women's contributions. Studies suggest that graduates of women's colleges or colleges with a high number and/or percentage of women faculty attain a higher level of career achievement.

- Women are not a monolithic group: diversity matters. At all educational levels, girls and women have dramatically different educational experiences than boys and men, but this is true in different ways for majority women and women of color. A full appreciation of women's experiences requires a still larger understanding of diversity: race, ethnicity, social class, sexual orientation and disability. Also, if we are going to understand women in science and engineering we need to desegregate by individual sub-disciplines. When too little is known of diversity, it is impossible to create appropriate responses.

- Changing higher education can make a difference. While higher education cannot reverse the influence years of socialization have had on girls' and women's career decisions, higher education can have an impact in several critical ways—by maintaining the aspirations of women who come to the academy committed to the fields, and by opening doors for others to be recruited during the college years. This may require re-thinking entrance requirements and financial aid policies; it may require changing the traditional curriculum, academic support structure and reward systems.

- Much of what is wrong reflects unconscious bias. Whether we examine women as undergraduates, graduate students or faculty, institutionalized barriers to full participation in these fields arise in large measure from practices which are unintended. Even benign looking practice can be biased: when you use GRE scores for screening awards and fellowships, men do better; when you use the GPA, women do better. Achieving equity for undergraduates, graduate students and faculty members requires that we both uncover these practices and change them appropriately. This requires carefully crafted, systematic and quantitative and qualitative research. Again, we may need to review access, funding, climate, curriculum, the nature of scientific inquiry and the traditional reward structure. Institutional transformation in any of these areas will require continuing careful evaluation so that we can understand what works and what does not.

- The responsibility for creating a more diverse community in engineering belongs to all the stakeholders—to K-12 teachers, to parents, to students,

to faculty members, to department heads, deans, professors and presidents, to the foundations and to industry.

The strategic recommendations emerging from the *Bridging Conference* may be grouped in three categories: those that involve the interaction of the academy with other institutions or the society at large; those that involve modifying existing practices through critical examination; and, those that involve collecting data for understanding and decision-making.

<u>Interactions outside the academy:</u>
- Get girls interested in science and engineering at a young age.
- Provide early mentoring, role models, and research opportunities for young women.
- Help the public overcome the assumption that engineering is an inherently "male" field.
- Emphasize that there is room for social responsibility and good work within the field of engineering.
- Promote academic/industry diversity partnerships. Because it is currently the leader in diversity, industry can teach the academy what it knows about creating equitable climates.
- Communicate to teachers, counselors, and school boards the importance of high school mathematics.

<u>Practices and behavior in the academy:</u>
- Create multiple points of entry into the pipeline so that one need not take a required series of classes in high school in order to become an engineering major in college.
- Examine entrance requirements that may discriminate against qualified women: for example, consider the integrated profile of applicants over standardized test scores.
- Create less competitive environments that foster cooperation among students.
- Change scientific and engineering texts, examples, homework and test problems to reflect subjects of interest to a broader population of current students.
- Increase faculty sensitivity to different ways of promoting and evaluating learning and to the implications of their interactions with women students and among students in classroom and laboratory settings.
- Ground changes in the departments, courses, and in reward structure such as merit increases, promotion, and tenure.
- Create gender equity in engineering faculty and increase accountability for the hiring and promotion of female faculty.
- Reconfigure tenure policies to allow for childbearing and childrearing.

<u>Recommendations for data collection and analysis:</u>

- Use tracking systems to determine if differences exist in the retention of female and male students and faculty, and to identify specifically where and why such differences occur.
- Conduct regular alumnae surveys for internal quality assessment.
- Examine the experiences and participation of subsets of women -- by race, ethnicity, social class, sexual orientation, and disability -- instead of as a single, monolithic group.

A Framework For Systematic Transformation

These recommendations will require that institutions change their values and behaviors. They require that institutions internalize the value of inclusion when they define policies for external interactions, "gatekeeping" practices, and creation and sustenance of a healthy educational environment. In discussing curricular transformation, Doug McAdams notes that there are "unexplained assumptions that reinforce and lend scientific legitimacy" to the way we conduct an institution. (McAdams, 1988) Two of these assumptions are particularly relevant to transforming institutions to be inclusive for gender in engineering and science. One is the distinction between the private and the public with women restricted to the private realm. The second is the belief that views discussed and considered in the academy should be based only on reason and should be disinterested and disengaged to be legitimate. Joan Tronto has argued that such unexamined assumptions provide boundaries that shape the morality of an institution and in turn lead to widely accepted social values that "constitute the concept with which we interpret all (moral) arguments. Some ideas function as boundaries to exclude some ideas (of morality) from consideration." (Tronto, 1993)

Transformation will require a planned, deliberate change in the ethos of the academy. The active projection of the image of science and engineering as an instrument of service and the acceptance of social responsibility is one key to this new ethos. Engineering has always been a profession of service. Historically, the discipline of engineering was first marshalled into social service as an instrument of the military. As Taft Broome noted in his paper for the *Bridging Conference*, the first engineering school in the U.S. was at West Point. Only later did it enter the "civil" realm. (Broome, 1996) An acceptance of social responsibility now would require an examination of our social contract and commitment to ethics as a routine part of the curriculum and other aspects of the academy. Ideally, this would make a process of self-reflection inherent in the teaching and learning processes, and in the

conduct of all matters. While it would take significant effort to activate this process of reflection, it could significantly change the environment to one of mutual respect and support once it is in place. Once the environment has changed, one would expect universities' outreach programs to mirror its ethos. Rather than being an image-building or advertising effort, outreach programs would then serve as responsible providers of mentors, advice, and experience. This might include a spectrum of entry points and modes to the study of science and engineering, and enable people at various stages of their life make informed decisions about education and careers in science and engineering. With the current upheaval and restructuring of all institutions, this kind of outreach would help all people, not just women, orient or modify their education for a changing world.

Another critical component of transformation will be a continuous process of active and conscious analysis and enunciation of policies for entry and retention of students and junior faculty. This would include active establishment of mentoring and networks for young faculty as well as for non-traditional students. Accountability of the institution would require an examination and correction of the disparities between stated expectations and actual assessment of performance. It would require an explicit consideration of life cycle needs of students and faculty of different ages and stages of life. Keeping track of alumni and asking them explicitly for suggestions could help in redefining the environment and paying attention to their suggestions should be a part of the process of evolution of the institution.

The new ethos will also require that we examine the existing compartmentalization between "education" and "work," beginning with the redefinition of our relationship with our industrial colleagues. We must begin to appreciate the industry as a learning place and the academy as a workplace. While, it is well-accepted that Cooperative Education programs provide us with the best strategies for retention in engineering, there has not been an appreciation of how much we can learn from industry about strategies for designing an inclusive environment.

A transformed institution must make an active effort to design inclusive practices and material for the classroom and for research guidance. Faculty workshops that raise issues of classroom pedagogy for a diverse audience should be as important as those for various cognitive details of learning, currently the norm for such workshops. An institutional initiative would be required before traditionally trained faculty would consider legitimate—the discussion of different ways of learning as a constructive approach to teaching.

In the book, *To Engineer is Human,* Henry Petroski points out that engineers can learn more from failed designs than from successful ones. (Petroski, 1985) This is an important fact to keep in mind as we re-engineer the academy. Examining what happened in "failed" cases of students and faculty may yield more valuable insights than looking at the models of success as we normally tend to do. Ideally, this would include not only the examination of one's failure, but factoring the case to see how and why they succeeded elsewhere. At least an analysis of the institutional processes that led to a student or junior faculty failing after she or he was selected carefully to fit the expectations may make explicit, the implicit norms that led to the failure.

We have posited that for institutional transformation to begin the academy must examine its ethos. The University defined as a service institution—the provider of education and "habits of the mind" for the future professionals—and not as the keeper of a closed crucible of exclusive knowledge is crucial to this process. From the realizations of the classroom as "participating spaces for the sharing of knowledge" to the design of the intellectual as someone who seeks to be whole, the academy provides endless possibilities to provide what Paolo Freire has called "praxis"—action and reflection upon the world in order to change it.

<div align="center">REFERENCES</div>

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