Changing Perceptions and Creating Impressions: An Overview of Theory, Practices, and Evidence for Attracting Women into Undergraduate Engineering and Computer Science

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Introduction

Concerned about the growing workforce shortage, in 1957 Gilbert McCann made an appeal to the American engineering industry to recruit more engineers (McCann, 1957). While there was an adequate supply of potential talent, he argued, the public lack of awareness of science, the importance of science to society, and the opportunities that engineering careers could afford barred competent students from pursuing engineering degrees. Fifty-seven years later, we are still grappling with increasing engagement in engineering, particularly among women and underrepresented minorities. In his call for action, McCann included both men and women, suggesting that women need only be “assimilated properly” to participate. In the 1960s, several events precipitated a rise in women’s participation in engineering, including the 1964 “American Women in Science and Engineering Symposium” held by the MIT Association of Women Students (Layne, 2009), the 1964 enactment of the Civil Rights Act, and the National Organization for Women’s demands that Congress enforce the law. Today, women’s share of bachelor’s degrees in engineering has gone from less than one percent in the 1950s (Bix, 1999) to 20 percent (ASEE Connections, 2015). Yet a great deal of unevenness persists across engineering disciplines, with women being much more likely to study some fields (e.g., biomedical, chemical, and environmental) than others (e.g., computer, electrical, petroleum, and computer science).

To reach parity, efforts are made both to recruit women into engineering undergraduate degree programs as well as to retain them. This paper focuses on recruiting. Below I discuss the barriers to entry, including perceptions of engineering and gendered experiences of educational contexts. Next, I review the practices recommended for attracting women into undergraduate engineering and types of programs that are typical. I then examine the evaluation evidence associated with intervention efforts. Finally, I present some recommendations and ideas.

Barriers to Women’s Entry into Undergraduate Engineering

Approaches to recruiting women into undergraduate engineering are responses to barriers to their entry. A very brief summary is presented here.

Public Perception of Engineering: Inaccurate, Difficult, Male

Public perception of the engineering profession and what engineers do continues to be based in misconceptions, when people have any awareness at all. A 2004 Harris poll showed that only 37 percent of adults polled believed that engineers care about the community, 28 percent see engineers as sensitive to societal needs, and a surprisingly low 14 percent thought engineers save lives (Harris Interactive, 2004). The respondents also perceived engineering as a lower status occupation than many other professions. Studies show that many elementary aged boys and girls perceive engineers as people who build or fix things and who are unlikely to be creative or to design (Committee on Public Understanding of Engineering Messages, 2008; Knight & Cunningham, 2004). It could be argued that people hold misconceptions about most occupations before they really experience one or in the absence of an important other who can give more accurate information (e.g., parent). Nevertheless, when the image is especially negative or does not align with a person's self-concept or interests, it becomes especially unlikely that a person will pursue a career in that occupation.

Students also consider engineering and computing to be occupations where one "sits in a cubicle" alone, to be difficult majors, and as gendered male (L. J. Barker, Snow, Garvin-Doxas, & Weston, 2006; Corbett & Hill, 2015; Margolis & Fisher, 2002). Teachers also hold stereotypical views of engineers, seeing them as being socially challenged and considering the occupation to be gendered male (Yasar, Baker, Robinson-Kurpius, Krause, & Roberts, 2006). Despite their training, teachers' unconscious beliefs about who is capable or suitable and who is not can be communicated in subtle ways to students (and parents) and can influence students' choices of career paths. Parents and families, a very influential group for college-bound students (Bregman & Killen, 1999), also hold gender schemas and through these, have a lifelong influence on shaping children's choices of engineering and computing majors. Girls are more likely to be turned off by engineering than boys, given pervasive cultural beliefs about what kind of people are engineers (men), as well as gender stereotyping at home, at school, and in the media (Corbett & Hill, 2015). These deep-seated beliefs become unconscious biases, seemingly the natural order of things, and are difficult to overcome.

Gendered Experiences of Educational Settings and Topics

Add to these unconscious biases about self and others a set of gendered responses to grades and confidence. Women often set a higher minimum standard for involvement in an area of study than do men (Katz, Allbritton, Aronis, Wilson, & Soffa, 2006). When they do not meet this standard (interpreted through grades, lack of encouragement by teachers, negative verbal or nonverbal communication by boys), women lose self-efficacy, believing they cannot be successful; they may then choose a different career path (Correll, 2004; Eccles, 1994). Studies have linked self-efficacy to choice of major (Lent, Brown, & Hackett, 2000; Porter & Umbach, 2006). In addition, women with a fixed mindset are less likely to take a risk with a difficult subject (Dweck, 2008). The risk of failure may also seem very real in classes where male students dominate and are considered the "standard" type of student. Female students are marked as different in many high school and college classes, such as computer science and engineering. Girls experience these classes under different conditions than their male peers, constantly feeling that they have to prove they are as good as the boys, yet suffering a variety of intended and unintended micro-inequities that continue to chip away at their confidence or their tolerance of the situation.

Life Interests

Empirical studies suggest that women more than men pursue careers in which they can make a societal contribution (Corbett & Hill, 2015; Katehi, Pearson, & Feder, 2009). It is important to note that this is not the same as saying that women care about society and men don't: both care. However, it may be that men are more likely to tolerate less interesting lectures and assignments because they are still judged by society on the basis of their ability to be breadwinners and unemployment or underemployment may lead to shame (Haywood & Mac an Ghaill, 2003). It has been argued that the image of engineering as not serving humankind or being connected to human concerns works against women's participation. To the extent that engineering is made interesting to students, it appeals more to men's than to women's interests. This would make sense, if one considers that faculty target their lectures and assignments to the interests of their predominant audience, men. Sanoff compares engineering to women's participation in law and medicine, citing a 35 percent growth in women's enrollment in law schools since 1963 and growth in medical schools from 10 percent in 1970 to 50 percent today (Sanoff, 2005). He argues that the reason medicine and law are more attractive than engineering to women is their perception that in these fields a person can make a difference for people and society.

In the next section, I describe the recommended components of programs intended to overcome, deny, or reverse perceptions of girls and women about engineering. Then I review support for creating effective messaging, as well as program leaders' inconsistent use of recommendations for creating their programs.

Practices Recommended for Attracting Women into Undergraduate Engineering

Engineering societies, universities, and other organizations create and implement interventions to change public perception and increase motivation for youth to become engineers. Audiences that are targeted for intervention include children, from pre-K through high school, parents, and teachers. Programs often make special efforts to appeal to women and underrepresented minority students.

Recommended Program Components

Components of programs to reach girls and underrepresented minority students are generally based on the research about barriers (above) as well as on empirical tests of theories. Chapter 10, “What Can We Do?” of the AAUW’s recently released Solving the Equation report (Corbett & Hill, 2015) includes a set of recommendations for attracting women into engineering and computer science.[1] These are presented below (with my own comments in italics).

- Reduce the influence of unconscious biases in society at large. The authors recommend using role models to accomplish this in order to change the beliefs of both boys and girls about what kind of people are engineers/computer scientists. *This approach may only change the biases in the girls’ and boys’ heads, and possibly only temporarily, since society at large is a powerful influence. It is difficult to “deprogram” a lifetime of belief.*
- Use affirmative action policies. *This is illegal in some states, though one might argue that funding initiatives to broaden participation is itself a kind of affirmative action.*
- Encourage girls/women to become well prepared in high school, especially in their mathematics course-taking (i.e., calculus, physics).
- Teach women/girls about stereotype threat and how to counteract it through self-help mechanisms (e.g., “self-affirmations” and reappraisal of negative thoughts).
- Make engineering and computing more socially relevant, demonstrating that these pursuits serve people, fit into a broad range of application areas, and support community. They suggest creating degree areas or specializations that combine engineering or computer science with other fields (e.g., digital humanities, biomedical engineering).
- Show that engineering and computing are not solitary occupations, but that professionals work with others. *(This is probably not always true, however, so we as a community should be careful of bait and switch.)*
- Provide role models with whom young women can identify.
- Encourage interaction to reduce sense of difference between boys and girls.
- Emphasize that women and girls belong in engineering and computing. *The authors suggest introducing engineering and computer science at an early age, though people should be careful to repeat the messaging and activities rather than use a “drive-by” approach, because there will be competing messages for many years.* Similarly, demonstrate through words, images, and actions that the environment into which they are being recruited values the social identity of girls and women. *Be sure that this is not just a recruiting illusion, but genuinely true. I once heard an*

[1] The chapter also presents recommendations for workplace practices for recruiting and retaining women engineers (including academic workplaces), practices of university faculty for interacting with women students, and policy recommendations for governments and public agencies.

African American PhD student warn underrepresented prospective PhD students that they should "check out the institution for more than one day to try to get a feel for whether they really want you, will support you" and "there are places where they recruit you, but once you get there, it's not as welcoming as you think."[2]

- Encourage a growth mindset to increase sense of belonging and to emphasize that technical knowledge and ability can be learned through practice.
- Encourage girls to "tinker and build confidence and interest in their design and programming abilities." *This recommendation appears to emphasize tinkering over building confidence. Tinkering is something that is described by some men as activities they engaged in with their father, but it's far from the only way to build confidence and unlikely to be part of every engineer's upbringing.*

Other recommendations in the literature include changing admissions policies, making performance standards explicit, explaining the source of spatial skills and providing training for spatial skills (though this might also backfire, when spatial skills testing is part of the introduction to an engineering curriculum), encouraging girls to play with relevant toys, and making early coursework relevant to students' life goals.

[2] Tapia Symposium Morning Graduate Panel October 18, 2001. I was the evaluator.

Early coursework should be considered part of a recruitment period, not just retention, because students still have the opportunity to walk away either to other types of engineering or to other majors altogether. In other words, faculty should be on board with recruiting goals and be taught to give encouragement, make lectures and assignments relevant, etc. Other things an undergraduate department can do is to have activities and student spaces visible during tours, so that potential recruits see students engaging in normal social activities (Whitten, Foster, & Ducombe, 2003). Finally, another recommendation is to establish and nurture a feeder system that includes preparing students for college (either through direct outreach or through teacher professional development), creates and maintains awareness, and builds and maintains a relationship with the schools and support of administrators (Chubin, May, & Babco, 2005). These recommendations can be integrated into programs that directly target girls or can be emphasized to parents and other influencers.

Recommendations for Messaging

Several sources provide suggestions for creating messages for girls about the nature of engineering and engineers. *Changing the Conversation* (Committee on Public Understanding of Engineering Messages, 2008) makes recommendations for talking about engineering to engender public understanding and to promote diversity. The National Academies provides an accompanying toolkit that includes “dos and don’ts.” The National Academy of Engineering’s EEES project also

National Center for Women & IT (NCWIT) Undergraduate Recruiting

NCWIT works to build capacity for others to recruit women. The NCWIT Extension Services for Undergraduate Programs (NCWIT ES-UP) provides resources for developing a strategic recruiting plan. Often, little thought is given to the return on investment of this nontrivial use of scarce resources (money, time), the time frame of possible benefits (i.e., how soon will you see results in your classrooms?), the message provided to the particular audience, or to tracking the outcomes. NCWIT ES-UP encourages users to adopt an approach underpinned by a philosophy of getting the greatest return on investment, in the shortest time to bring benefits, with the least cost. This means strategically targeting “low-hanging fruit” (asking, “who could be in your courses next year?”), taking advantage of the influencers of students to spread the word further, finding and leveraging existing programs, controlling the message by providing potential message-givers talking points, and evaluating what works and what doesn’t. An example of a commitment that doesn’t fit this model is an outreach program that brings middle school kids to campus for a thorough summer camp. Such a program may only reach 20 or 80 kids a year and it will be years before they show up in on campus, if they do at all. After all, they will be pummeled with four to six years of competing messages during the lag.

Being strategic also means developing a plan. Most academic departments have outreach efforts to inform the public and potential students about their discipline and participate in a variety of events and produce materials to communicate with students, teachers, parents, and employers. Often, however, event attendance is opportunistic, resulting from chance awareness an event will occur and chance availability of someone who can attend. It may be selected because of the motivation and time of a particular faculty member or may be completely dependent on a funding solicitation (and thus not sustained after the funding period).

supports faculty with practical suggestions for recruiting women. NCWIT (see sidebar) also provides messaging advice.

Messaging has to be done carefully, however. The messenger has to decide whether to state the inaccuracies and misconceptions that are held by the listeners. On the one hand, people talk about what something is not when they need to overcome an existing belief. In order to do so, they have to state that belief, which brings it into the social milieu, potentially reinforcing it as a possibility. Once that is done, it is possible that the messenger creates awareness of that issue or belief where it did not exist before or even reinforce the belief, even though it is being denied. Research on consumer messaging demonstrates that even when a belief is being presented as false, people can end up believing it as true, because it has been repeated ("I've heard that before, it must be true") (Begg, Anas, & Farinacci, 1992; Gilbert, Krull, & Malone, 1990; Skurnik, Yoon, Park, & Schwarz, 2005). Research on changing perceptions of fourth through sixth graders about engineering is consistent with the consumer research. In one study, many children still believed that what engineers did was construct things, even after being told about their design of robots (Reeping & Reid, 2014).

Inconsistency in Use of Recommendations

Publications about programs demonstrate that some people integrate the recommendations described in scholarship and reports, and some do not. Some are better at describing in detail how a program is accomplished at a level of detail that can be replicated (What did program implementers say or do to integrate this feature? How often?). For example, one program reviewed literature on barriers to entry noting that students perceive engineering as difficult, do not have engineering-related hobbies, and may believe that the profession has poor social status (Zywno, Gilbride, & Gudz, 2000). They created a program in which girls could meet role models, build confidence, gain information about career options, and learn the social value of engineering. Another program targeting Latino youth for recruitment to engineering used teaching approaches that were more personal and integrated social networks, mentors, and role models (Camacho & Lord, 2013). A program based in scholarship showing that African American undergraduates will be successful in math classes if they have the same access to study groups as White and Asian students (Fullilove & Treisman, 1990) used pair programming to support African American students (Williams, Layman, Slaten, Berenson, & Seaman, 2007).

Not all programs actually use the components that are recommended. In a meta-analysis of the practice-oriented STEM intervention literature, Creamer and colleagues found that "most publications provided three or fewer references to evidence-based practices to justify the selection of an activity or program. About one-tenth of the articles they evaluated "either made no reference to literature supporting the choice of the activity, or provided only one reference" (Creamer, Mutcheson, Sutherland, & Meszaros, 2014, p. 86). I found many examples consistent with these findings. For example, a residential summer bridge program of four weeks was intended to help students succeed in calculus in the following semester, because the authors argued that math skills were an important predictor of success. They used no other practices in their program. To their credit, the authors discussed the poor outcomes. Another program (funded at $2M), begins with a two week summer bridge in which students assess their abilities and come up with a personal development plan for improving their math skills. The project mentions “other” activities, but they are apparently not important enough to list.

Program Types

Direct Outreach with Girls and Women

Nearly every university in the U.S. with an engineering major has an engineering outreach program with various components. These can take the form of summer camps, bridge programs to make up for missing knowledge or experiences, Ambassadors or Roadshow programs in which students or faculty visit schools to change the perception of engineering and create awareness of the careers and opportunities, attractive websites, and development of relationships with teachers. Many universities are also using robots in their introductory courses in order to appeal to women. This seems to have some positive impact. For example, when Bryn Mawr required that every girl have a robot to program in the introductory course, the number of women attempting to enroll in the course skyrocketed, resulting in a lottery to get in. Women would showcase their robots’ abilities in dormitories and other locations, which served as an unintended recruiting mechanism.

In-school intensive programs (e.g., Project Lead the Way engineering and computer science, STEM magnet schools, etc.) become regular classes for thousands of high school students across the country. Project Lead the Way (PLTW) Engineering and PLTW Computer Science, have explicit diversity goals and provide schools with curriculum, professional development for teachers, and assessment tools. Magnet schools often have diversity as a core mission and many are all-girls or all-boys schools. The degree to which these promote true workforce diversity is not known. That is, to go to a magnet school, a student has to hear about it and be able to get to school. They have to go outside of their neighborhood schools, which may not be comfortable to students or parents, or go to a school that does not have “regular” sports and other social activities. It can also happen that these activities are in place, but the students or parents do not realize they are part of a mainstream high school. While PLTW participation appears to greatly increase the likelihood of students pursuing engineering and computer science degrees (Project Lead the Way, 2013), the extent to which they are reaching their gender diversity goals is not clear. Females participate in PLTW in general at much lower rates than their male counterparts and although it is hard to find data, appear to be a small proportion of students in the engineering and computer science classes.

Extracurricular experiences are also made available on a large scale. Robots are huge with K12. Not only do many organizations have robotics as part of their activities (e.g., Boy Scouts and Girls Scouts have badges and programs on robotics; 4H, NASA, and universities sponsor programs), but there are even books on how to integrate and teach it (B. S. Barker, 2012). Perhaps the largest program is FIRST Robotics. FIRST has not been particularly successful at increasing the number of girls who participate (though it is difficult to find data). Awards programs like the NCWIT Award for Aspirations in Computing connect girls to corporations, each other, and to potential scholarship providers. The Society for Women Engineers allows girls to be members, and provides posters, grants, and programs (including parallel programs for parents). Many schools have after-school programs that teach computing and engineering to girls and boys. Nonprofit organizations are part of every city, and usually have STEM programming (e.g., GirlStart).

Websites that target girls with computer science and engineering information abound. For example, The National Academy of Engineers provides EngineerGirl, which presents information on engineering, allows girls to ask real engineers questions, and compiles information for girls about contests, activities, clubs, and scholarships. Danica McKellar, an actress and UCLA math major, maintains a website called “Math Doesn’t Suck,” which is too bad, because by saying it doesn’t suck, surely she plants the seed that maybe it does. After all, there is no need to defend something that is valued. Many girls like math, but just don’t know what to do with it. NCWIT offers a Latinas & Tecnología de la Información website, targeting primarily parents in the U.S. who are more conversant in Spanish as well as Puerto Ricans.

Outreach through Teachers and other Influential Adults

Many universities and other organizations provide professional development to teachers and other school personnel. For example, NCWIT has the Counselors for Computing project, providing training and resources to school counselors (e.g., posters, talking points cards describing pathways through university, community college, the military and the different relevant majors). NCWIT also offers the Tapestry workshops for teaching teachers (and trainers of teachers) how to get girls into their high school computer science advanced placement classes. The National Academy of Engineering, the Society of Women Engineers, and corporate sponsors have developed websites with resources for teachers. For example, Engineer Your Life (“Engineer Your Life,” n.d.) includes resources to support teaching, messaging, and reaching out.

Media

In addition to the websites mentioned in the sections above, there are recent attempts to get females in engineering in the media. The National Academy of Engineering, the University of Southern California’s Viterbi School of Engineering, and the MacGyver Foundation are putting on a competition for a television series in which a female engineer is the star. The underlying theory to this approach is that media can engineer beliefs and socialize people. This is often disputed in communication scholarship. Some argue that the relationship between media and culture is not one-way, but instead more like a dialogue of mutual influence, reflecting cultural values and (re)producing them (Bandura, 2001). For example, many people believe that a reason for the popularity of biology among women is because of television programs like CSI. Others would argue that the requirement by universities and colleges for a biology course along with the availability (and requirement) of biology courses in high school is a better explanation for girls' apparent high self-efficacy and degree seeking in biology. Regardless, one must hope that the sponsors can keep Hollywood from creating a sexualized, eccentric, or otherwise non-standard female engineer character, as is done with most female characters in the media—especially those whose role is anything but supporting (Smith, Pieper, Granados, & Choueiti, 2010).

Evaluating Outcomes of Interventions for Recruiting Women

It was originally my goal in writing this paper to report on which interventions work and which do not to improve engineering outreach community efforts. However, the quality of evaluation of efforts described in published literature is uneven and many evaluations suffer from serious problems. Below I describe what might count as higher standards for evaluation and common shortcomings in the hopes that evaluations can be improved and more learned about programs and messaging.

Evaluation Criteria and Quality

To what extent do the practices recommended by theory and empirical studies result in women's increased representation in engineering? From a scientific viewpoint, this is difficult to say because the quality of evaluation is uneven. An intervention should use rigorous criteria to demonstrate its outcomes. The best evaluation should also demonstrate that the outcomes found were caused by the intervention and cannot be explained by another rationale. This is extremely difficult and unrealistic in everyday practice. Even if randomized, controlled studies could be used, demonstrating cause is difficult because most interventions combine multiple approaches (e.g., multiple messages, more than one activity, multiple role models, building self-efficacy, etc.) and because the nature of the settings is probably unique in some way. A conclusion that an approach is "effective" should therefore be made with caution. NCWIT's social science team attempts to make recommendations in a way that avoids such a solid endorsement. The team avoids the label "best" and is even hesitant to label practices "effective," defining an effective practice as one that transfers: it has been evaluated in more than one setting with similar and demonstrable results. Instead, the team uses "promising practice," defining this as a practice that has been evaluated using rigorous data collection and analytical methods that demonstrate successful accomplishment of goals in at least one setting. A good evaluation report looks not only at outcomes, but links them to the processes by which the outcomes resulted and describes the conditions. In other words, a report provides enough description of processes that someone else could adopt/adapt and have similar results and the description should highlight the essential features (as opposed to optional ones). Most reports of programs and their evaluation do not meet these high and perhaps unrealistic standards (funding for evaluation would need to be much higher, for one thing).

In contrast to the high standards described above, many of the reports found in outreach literature are closer to the opposite extreme. A meta-analysis conducted by Creamer and colleagues at Virginia Tech (Creamer et al., 2014) investigated the spread of evidence-based practices (EBP) related to gender and STEM using articles published from 1995 to 2009 in three major venues frequently accessed by engineers and computer scientists (FIE, ASEE, and the *Journal of Women and Minorities in Science and Engineering*). The authors found that articles/papers that include EBP comprise less than 25% of the total articles published in all of these venues (ASEE = 32.6%, FIE = 30%, JWMSE = 12.2%). In addition, they found that on a six-point Likert scale, the overall quality of EBP publications is low (as measured by each article's use of literature and theory) and that the quality did not improve over the 14 years of the study. Thus, finding good rationales for choosing interventions for recruiting in these venues may be difficult. Similarly, in a meta-analysis of summer bridge program articles, Sablan found that the majority are descriptive (not correlative or experimental) and that program processes and components are not well connected to the most important outcomes (Sablan, 2013). In addition, the majority of articles discussed one-off programs or single-site programs, so understanding the degree to which it might transfer to another setting is problematic. A reader trying to decide whether summer bridge programs work and under what circumstances is not served by the literature because the empirical support is poor. If practitioners are seeking and choosing approaches in these venues, it could partly explain persisting problems with recruitment. In the next sections typical problems are reviewed.

Typical Evaluation Problems

Many people do not report how their participants were selected. Therefore, it is impossible to know whether the intervention caused positive outcomes (e.g., enrollment) or if the participants were already predisposed to participate. In one study, surveys with 760 female students who had attended a summer camp found that more than half, 400, were studying engineering. Although the authors claimed that the camp was the motivation for pursuing engineering, there is no way to know if it had that effect. After all, the recruitment of girls into the camp was based on whoever signed up first and students self-selected into the camp. Another study similarly targeted minority girls, but was competitive, accepting only students with high math and science grades. Grades are not the only indicator of intelligence or ability; in fact, many aspects of life can keep a student from performing well on assignments and tests, such as the need to support parents in taking care of younger siblings. These authors acknowledged that the students in the program may have been "predisposed" toward engineering. This result is in line with the results of another evaluation that tracked the women into the engineering major and looked at one-year retention (which was promising), but then showed that more than half of the participants surveyed had a family member who was an engineer. Another program presented similar results: students enjoyed their campus visit, and many intended to major in engineering. Yet 40 percent of the participants had family members who were engineers. Another study, obviously recognizing that the selection details had not been procured when students entered the program, conducted a retrospective survey, asking about impacts as a result of participation. They report that students thought their involvement led to the desired outcomes (becoming an engineer), but we can't be sure this is not retrospective sensemaking (Weick, 1995) or a reflection of how much they enjoyed the program.

Many programs claim that they are effective in getting girls into engineering, yet the outcome they present is an interim goal, not an outcome goal. Being able to link a summer camp, stereotype threat training, or confidence building to a bachelor's degree in engineering or computer science would be powerful. Even being able to link program participation with intention to complete the major or remaining in a major after the first-year experience would be good evidence of success. Unfortunately, however, many programs look only at whether the intervention was effective in an immediate or near-term way. For example, in one project studying a bridge program that incorporated activities to build self-efficacy, a sense of belonging, and academic and social skills, all that was measured were these very constructs, and only in the short term. In the article, the author did not report on tracking students even into a first semester experience.

Some papers are very vague in terms of the description of design components of programs. One residential two-week summer camp for sophomores and junior high school girls included non-specific engineering-related activities expected to appeal to girls and somehow "exposed" the girls to campus life and extracurricular activities. Taught by faculty and graduate students, the program was reported to engender self-efficacy, science self-concept, and "empowerment" of students (based on a survey). The authors claimed that the successful outcomes were in part due to the girls' involvement with role models and information, but alternative explanations are easy to generate, such as girls establishing a positive relationship with faculty and graduate students. Not only did these authors not report whether the students pursued engineering degrees, but the evidence taken for supporting change was not credible.

Finally, few papers report negative results. The results of these studies are needed for making evidence-based decisions about what to do and what not to do. I applaud those who both describe their programs in detail and discuss their negative outcomes, such as Berenson, Slaten, Williams, & Ho, 2004 and Reisel, Jablonski, Kialashaki

, Munson, & Hosseini, 2014.

Recommendations and Ideas

One might ask why, if efforts began more than 50 years ago, progress has been so slow with respect to women's participation in engineering. Perhaps the combination of issues described in the section above on barriers is especially difficult. On the other hand, perhaps we as a community could be doing some of what we do better, such as doing a better job of evaluating and communicating what we learn. Perhaps also there are avenues that are not well traversed or studied. Below is a list of questions and possibilities.

Exploring Evaluations and Improving Them

Meta-analysis of ultimate goals. Are there features of recruitment programs that are effective for short-term participation (enrollment in the major, finishing the major) or that could be linked to long-term participation, such as staying in the field? This latter is the real goal. One way to find this out would be to perform an extensive meta-analysis of articles and reports across the many fields that might report on such topics.

Limit what gets published. The field could stop accepting papers published as conference proceedings that do nothing more than rehash the program components without conducting good evaluation, describing the processes in detail, or linking processes and features to outcomes. In soliciting and rejecting papers, program committees should point authors to a set of expectations for do-it-yourself evaluation. Some projects don't work and these should be reported.

Untapped Audiences

***Two- to four-year transfer*.** The National Academy of Engineering is conducting a study to understand transfer between two- and four-year programs. Community colleges graduate many minority students. To the extent that it is difficult or impossible to get an engineering or computer science degree from an accredited four-year program after starting out in community college, the system is creating barriers for students. Understanding how to make this work will be valuable.

Beyond girls and "young" women. What counts as a woman who can be attracted into computer science and engineering? The traditional "pipeline" view seems to predominate: messaging is created to appeal to middle or high school girls and the noun "women" is modified with the adjective "young." If building the workforce is so important, why aren't we targeting grown women? Is it because girls are not a threat to the status quo? Beth Quinn, a sociologist of law and NCWIT social scientist, asks, "much research shows that it's not until women get older and more experienced that the sexism really kicks in. It's 'easy' to push for girls' and young women's participation. (Aren't they cute? So unthreatening.) It's another thing entirely to talk about giving middle-aged women job training and pushing for more women to be in management and the C-suite. Are we taking the easy route?" There are alternative pathway programs ripe for study and evaluation. Women with existing bachelor's degrees can pursue post baccalaureates (e.g., at Stevens Institute of Technology). Several organizations offer "boot camps," intensive instruction that lasts up to a year and connects participants with jobs (e.g., Linux for Ladies, Open Cloud Academy). Karen Chapple's study of nontraditional entry points into found that among those without a bachelor's degree, participants hadn't advanced beyond the entry level in four years of study. However, those with a nontechnical college degree were more successful (Chapple, 2006). Much more could be learned here about program components that are effective and ineffective. In addition, "return to work" or "re-entry" programs bring women engineers back into the workforce after a hiatus. Such women often suffer from low confidence and mainly need to bring their knowledge and skills up to date to regain it.

How Might Research Help or Hinder our Efforts?

Early curriculum as part of recruiting. I believe that the introductory semester or even year in a major must be considered part of the recruiting process, because students can still opt out with little cost. Most studies are about courses in a major, but don't take into account courses that students have to take but that are outside of the major (e.g., computer science and engineering majors have to take physics, chemistry, etc. in their first year). There could be an accumulation of micro-inequities in these other courses that we are unaware of. Also, it is often the case that students will not get to take courses in the topics that interested them in the first year or two, which could lead to attrition. Yet messaging is likely to cite topics in later courses to attract women. How does the delay in doing something interesting affect continued enrollment?

Consumer research approach? Is it really possible to change the public perception of engineering and computer science as well as the implicit biases about occupational gender? What can our community learn from marketers? For example, how do corporations manage public opinion when something goes terribly wrong with their products, services, or public image? (think: listeria in ice cream, automobile recalls, poison in soft drinks, big pharma). How did Mothers Against Driving Drunk accomplish their goals?

***Are researchers, faculty, and program leaders subtly creating and/or maintaining biases*?** Is it possible that outreach efforts, by virtue of their labeling as for "girls" but not "boys," themselves communicate beliefs that engineering and computing are not really appropriate for women? Do they communicate that you have to be a pathbreaker to pursue a man's career? (c.f., Silverman & Pritchard, 1993, who found that most girls did not want to be pathbreakers).

That is, do programs implicitly convey a belief that females won't really fit in? Perhaps there is an analogy to support groups and networks that are women-only. Perriton argues that women's networks not only reflect existing gendered inequalities, but reinforce or create them (Perriton, 2006). Despite the good they can do for women who participate, women's groups are shown to have negative unintended outcomes. Studies suggest that the presence of corporate women's groups imply to many men and women that women need "extra help" or are victims of discrimination and are perceived by men as women talking about motherhood and recipes (Bierema, 2005; McCarthy, 2004). Research could be conducted to find out ways to enable girls' and women's involvement without at the same time creating an image of women as deficient. Finally, researchers and evaluators should ask whether the questions they use in interviews and surveys actually plant the seeds of difference and not belonging. Perhaps the research itself is so heavily underpinned by preconceived notions of girls and women that respondents merely confirm stereotypes. It may be that the girls and women who are studied are reenacting societal beliefs about gender when participating in studies, in line with the "looking glass self" theory of identity (Cooley, 1912; Corti, 1973). In other words, instead of reporting on the women, we may be reporting societal beliefs about women.

These are a few ideas about how we as a community could improve the knowledge of what works and what doesn't as well as the reports that guide practitioners in outreach efforts. With better knowledge of programs and messaging, perhaps we can reach the goal that WEPAN has stated, that the enrollment of engineers be equal among women and men, leading to parity in the ratio of graduates by 2050.

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