TUEE

Transforming Undergraduate Education in Engineering Phase III

Voices on Women's Participation and Retention

Workshop Report

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ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

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ASEE engages with engineering faculty, business leaders, college and high school students, parents, and teachers to enhance the engineering workforce of the nation. We are the only professional society addressing opportunities and challenges spanning all engineering disciplines, working across the breadth of academic education, research, and public service.

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- We support engineering education across institutions, by identifying opportunities to share proven and promising practices.
- We support engineering education locally, regionally, and nationally, by forging and reinforcing connection between academic engineering and business, industry, and government.

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Transforming Undergraduate Education in Engineering Phase III: Voices on Women's Participation and Retention

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Voices on Women's Participation and Retention

Workshop Report

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AMERICAN SOCIETY FOR ENGINEERING EDUCATION
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The meeting participants, a list of whom can be found in Appendix B, are to be lauded for their energy and effort during the project's two-day workshop. Their contributions provide the intellectual substance on which the report is based.

The meeting planning committee, listed on page i, helped us develop an agenda that made best use of limited time, asking the right questions and guiding participants to concrete outcomes.

We are grateful for the contributions of Lecia Barker, Amlan Baneerjee, Daryl Chubin, Clemencia Cosentino, and Rachelle Reisberg. They wrote four commissioned papers (included on appendices E—H) that stimulated conversations during the workshop gallery walk.

The following ASEE staff made contributions: Rocio C. Chavela Guerra, Director of Education and Career Development, served as project director; Ray Phillips, Program Assistant, coordinated meeting logistics; and Ashok Agrawal, Managing Director of Professional Services, provided conceptual guidance to the project. Mark Matthews, Editorial Director, wrote the first draft of the report and edited and proofread the final document. Alexandra Longo, Program Manager, and Austin Ryland, Senior Research Associate, conducted background research. Nicola Nittoli, Creative Director, and Francis Igot, Junior Graphic Designer, provided report layout and design. Brian Yoder, Director, Assessment, Evaluation, and Institutional Research, and Rossen Tsanov, Senior Research Associate, conducted data collection and analysis for the pre-workshop survey.

This report underwent an external review process by two members of the planning committee. Reviewers provided comments and feedback but were not asked to endorse the content of the report. We thank the following reviewers for their input: Beth Holloway and Adrienne Minerick.

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Executive Summary

Voices on Women's Participation and Retention served as Phase III of the American Society for Engineering Education (ASEE) project Transforming Undergraduate Engineering Education (TUEE). This multi-year, multi-phase project, supported by the National Science Foundation (NSF), consists of a series of stakeholder meetings intended to develop a framework for transforming the undergraduate engineering experience.

The Phase III workshop took place over two days in June 2015 in Seattle, Washington. In the course of the workshop, participants developed the main elements of a comprehensive strategic action plan to fulfill a key aspect of the transformation of undergraduate engineering education: *reducing the gender gap in engineering.* This action plan is composed of of several components including accountability standards, measurement and evaluation of results, incentivizing measures, and encouraging engagement of *everyone* in reducing the gender gap. A central pillar of the action plan is an online dashboard that shows the composition of engineering schools according to gender, race, and ethnicity. Constructive roles are to be strategically assigned to all ranks within academia, as well as to stakeholders in government agencies, industry, and professional societies. University-industry alignment would be strengthened under a shared understanding that "diversity equals value," resulting in improved teamwork and better products.

Recommended actions:

- **Creating an online dashboard that shows the composition of engineering schools according to (minimally) gender, race, and ethnicity (ASEE).**
  - Data already collected by government agencies and ASEE would be expanded to include admissions and faculty demographics.
  - Schools would be categorized depending on their success in diversifying the undergraduate student body, with those showing the most year-to-year progress gaining special recognition.

- **Identifying gender diversity as an institutional value that must be implemented in a multiple ways across campuses (campus administrators).**
  - Each institution is responsible for outlining the process of implementing diversity initiatives across campus.
  - ASEE can host workshops that highlight promising practices for diversity initiatives across campuses.

- **Promoting equity by reflecting such values in grant policies, providing further incentive to comply (sponsoring agencies).**
  - Government agencies could provide equity-incentives in their grant policies.
  - Include discussions of modern equity frameworks and the changing equity landscape.

- **Bringing leaders together to focus on diversity and inclusion data management and training (professional societies).**
  - ASEE can continue to provide forums for dissemination and discussion of research results and current trends.
  - Collaboration across university, government, and industry can foster relationships which will enhance the ability to address the gender divide in engineering.

Background

The Transforming Undergraduate Education in Engineering (TUEE) Initiative

Transforming Undergraduate Education in Engineering (TUEE) is a multi-phase initiative that seeks to identify the critical components of engineering curricula, pedagogy, and educational culture necessary to support the education of engineers over the next decades of the 21st century. This initiative also seeks to create a shared vision on the future of engineering education by (a) bringing together diverse and varied members of the engineering community for brainstorming workshops, (b) identifying the steps needed to achieve the shared vision outlined by the community, and (c) practicing continued coordination among engineering education stakeholders to ensure these steps are being taken. Funded by the National Science Foundation (NSF) and led by the American Society for Engineering Education, the project is composed of five distinct phases:

- Phase I: Synthesizing and Integrating Industry Perspectives
- Phase II: Insights from Tomorrow's Engineers
- Phase III: Voices on Women's Participation and Retention
- Phase IV: Views of Faculty and Professional Societies
- Phase V: Mobilizing the Community for Change

As of this report's publication, workshops for Phases I, II, III, and IV have been completed. This report focuses on Phase III of the project, specifically on the events and results from the June 2015 workshop *Voices on Women's Participation and Retention.*

The first workshop of the TUEE initiative (Phase I), *Synthesizing and Integrating Industry Perspectives,* was held May 9-10, 2013. This workshop brought together 34 representatives from the engineering industry, four staffers and officials from the National Geospatial-Intelligence Agency, and eight representatives from academia to explore and discuss the knowledge, skills, and attitudes[4] (KSAs) needed in engineering today and the near future. Workshop participants identified the core competencies that have proved integral to engineering performance, and also added a number of new skills and professional qualities needed to craft a functional "T-shaped" engineering graduate – one who brings broad knowledge across domains, deep expertise within a single domain, and the ability to collaborate with others in a diverse workforce. Participants found current training to be inadequate and out of sync, both to meet present industry needs and fulfill future industry requirements (American Society for Engineering Education, 2013).

A "T-shaped" engineering graduate is one who brings broad knowledge across domains, deep expertise within a single domain, and the ability to collaborate with others in a diverse workforce.

[4] The three initial phases of the TUEE initiative defined KSAs as knowledge, skills and abilities. In phase IV, we adopted a competency model to frame KSAs, switching the definition to knowledge, skills and attitudes.

The second workshop (Phase II), *Insights from Tomorrow's Engineers,* was held April 10-11, 2015 and was attended by 41 engineering students (54% female), with the goal of brainstorming the most effective ways to acquire the 36 KSAs identified in the Phase I workshop. Overwhelmingly, the student participants concluded that schools were paying insufficient attention to many of the KSAs needed to create a T-shaped professional. While supporting a strong foundation in math, science, and engineering fundamentals, they were critical of how these subjects were taught. Participants expressed their sentiments that lessons in calculus, physics, and chemistry should include examples of real-world engineering problems, and curricula should feature design-based projects and open-ended problems. Traditional lectures and lessons should be supplemented by extra-curricular activities, competitions, and hands on experiences. Participants conveyed that teaching format should be part of the basis for securing tenure and salary increases and called for greater faculty diversity (in gender, ethnic background, and industry/academe experience) and more mentoring opportunities, whether with older students, faculty, industry professionals, or peers (American Society for Engineering Education, 2017).

Women in Engineering: From 1970s to Today

Since the 1970s, U.S federal policy – backed by funding – has sought to engage and retain more women and minorities in science and engineering. As America began to disengage from the Vietnam conflict, the attention of policymakers and the public turned to domestic issues that had risen to the surface in the previous decade, including poverty, environmental protection, and the treatment of minorities and women. The campaign for African American civil rights and a growing feminist movement made a significant impact on federal education policy. (Lichtenstein et al., 2014). In 1972, Congress enacted Title IX of the Education Amendments of 1972, later known simply as Title IX, which mandated equal access to federally funded education activities (United States Congress, 1972). Advocates such as Janet Welsh Brown of the American Association for the Advancement of Science, president of the Federation of Organizations for Professional Women, persuaded lawmakers of a need to correct the dearth of women and minorities in science and engineering. Congress responded with the groundbreaking Science and Technology Equal Opportunity Act of 1980, which "made promoting scientific and engineering talent among women and minorities a federal priority" (Lichtenstein et al., 2014). The measure authorized a number of steps by the National Science Foundation to increase the participation of women in scientific and technical fields as well as a comprehensive effort to increase the participation of minorities in science and technology.

In 1982, NSF began publishing a biennial report, *Women and Minorities in Science and Engineering,* containing data and research on the participation of underrepresented groups in these fields. Later retitled *Women, Minorities, and Persons with Disabilities in Science and Engineering,* the report now has an accompanying website with available data (National Science Foundation, 2015c). Increased attention to female and minority participation coincided with growing national concern about foreign technological competition and weaknesses in U.S. math and science education. An influential 1983 report, *A Nation at Risk: The Imperative for Educational Reform. An Open Letter to the American People* (Gardner, 1983), cited "a redistribution of trained capability throughout the globe," and documented numerous measures of decline in U.S. student attainment, including fallen math and science scores. NSF addressed both educational reforms and equal opportunity in a 1983 examination of ways to improve science and math education, *Educating Americans for the Twenty-First Century.* The study devoted a chapter to successful interventions to prepare women and minorities (Lynch, 2011). The following decade saw a growth in standards encompassing equity and quality, including the 1996 National Science Education Standards (National Research Council, 1996).

However, despite greater attention at the federal level, low retention rates for female and minority STEM students persisted through the 1980s and 1990s. A search for explanations included a seminal 1997 study, *Talking About Leaving,* which pointed to "perceptions of and attitudes towards the culture and climate of science and engineering classrooms and majors" and "faculty styles and other environmental factors" (Lichtenstein et al., 2014, p. 313-4). Various researchers noted that women and minorities were found to experience a chilly climate, characterized by "unsupportive institutional policies and negative classroom environments" that lead to consistent reporting of "isolation, self-doubt and questioning about [staying in engineering]" (p. 321). Research supports the negative impact of a chilly climate on women in STEM. Other barriers cited at the time and since include a lack of role models for women and minorities in science and engineering and a lack of community support. High turnover among female faculty has been attributed to the culture of STEM fields (Xu, 2008). These departures, in turn, remove female faculty role models. Women faculty are noticeably less satisfied with their career work in STEM fields (Deemer et al., 2012).

Techniques to promote retention and persistence of women in STEM in academic settings have been researched in recent years, including:

- learner-centered teaching strategies (co-operative, program-based, project-based, hands-on, and service learning);
- highlighting peer-peer interaction;
- fostering an environment of mutual respect;
- strong faculty-student relationships in and out of the classroom, and
- high-impact practices like seminars and capstone projects, and participating in extra-curricular educational experiences like student organizations or conferences.

Over the past several decades, retention and persistence statistics for females have slowly risen. Women went from earning 0.3 percent of STEM doctorates in 1966 to 20.2 percent in 2006 (American Association for University Women, 2010). Additionally, a K-12 gender gap in math and science performance has effectively closed—with males and females now performing comparably (Lichtenstein et al., 2014). However, the rate of progress has flattened recently. A recent study cited by Lichtenstein et al. (2014) found that the U.S. "ranked 30th out of 35 countries in the proportion of female Ph.D.'s in engineering, manufacturing, and construction and 24th out of 30 with respect to growth in the proportion of female Ph.D.'s in these sectors" (p. 311).

With continued low numbers of women in STEM occupations generally, the period 1986 to 2008 saw a 3 percent increase in the proportion of women obtaining bachelor's degrees in engineering, a proportion lower than biology and computer science (American Association for University Women, 2010). In 2016, women accounted for 20 percent of the total number of bachelor's engineering degrees awarded at U.S. institutions. At the doctoral level, women earned approximately 23 percent (2,721) of engineering doctoral degrees (11,650) awarded by U.S. institutions (American Society for Engineering Education, 2016).

Compared with medicine, business and law, science and engineering fields continue to lag behind in gender equity (American Association of University Women, 2010). In order to significantly increase female participation in engineering for the long-term, more research must be conducted, more stakeholders must be engaged, and new programs, projects, and actions must be implemented.

Introduction to Phase III: Voices on Women's Participation and Retention

Phase III of TUEE addressed the chronic problem of low female participation in U.S. engineering undergraduate programs. As part of this phase, ASEE held a workshop, *Voices on Women's Participation and Retention* on June 12 and 13, 2015, in conjunction with the Society's annual conference in Seattle, Washington (workshop Agenda is detailed in Appendix A). The goal of the workshop was to develop and refine a set of recommendations and actions to reduce the gender gap in engineering, including changes to undergraduate curricula, pedagogy, and academic culture. An eight-member workshop Planning Committee invited participants with a range of experience and expertise. The 40 attendees (75 percent female) represented academia (administration, research, and teaching), industry, funding agencies, the marketing sphere, professional organizations, community colleges, and high schools (Appendix B provides the complete attendee list). Participants were instructed to engage in productive dialogue and discussion directed at finding solutions to the gender gap issue. They were urged to provide recommendations that could be implemented using existing resources and, in the words of Planning Committee member Diane Matt, former Executive Director of Women in Engineering ProActive Network, "envision a roadmap to reach full parity of diverse communities of women in engineering."

In his welcoming remarks, ASEE Executive Director Norman L. Fortenberry called increasing women's participation "an engineering imperative." ASEE, he added, has adopted "one of the strongest diversity statements [he has] ever seen," and was striving to live by it. Diane Matt, who spoke next, noted that progress is currently taking place in reducing the gender gap, citing eight schools with high proportions of women engineering students that could serve as "leading indicators of a new normal." While this information is encouraging, Matt emphasized that as of June 2015, "there are few incentives, no accountability structure, and the knowledge and expertise [needed to close the gender gap] is not fully resident in engineering higher education." The task ahead for the workshop, Matt said, was to "to identify the sequences of strategic pressure points and actions . . . that will propel us toward the full inclusion of diverse communities of women in engineering."

Christianne Corbett, then a senior researcher at American Association of University Women (AAUW) and currently a Ph.D. student in sociology at Stanford University, elaborated on the reasons for low numbers of women in engineering in her keynote talk, *Solving the Equation: Variables for Women's Success in Engineering and Computing.* While acknowledging the growing number of colleges and programs with high female involvement, Corbett emphasized the hurdles that must be overcome to ensure sustained increased female participation.

Solving the Equation: Variables for Women's Success in Engineering and Computing

In 2015, AAUW released the report *Solving the Equation: The Variables for Women's Success in Engineering and Computing* by Christianne Corbet and Catherine Hill.

Solving the Equation "asks why there are still so few women in the critical fields of engineering and computing — and explains what we can do to make these fields open to and desirable for all employees" (AAUW, 2015). The main resource Web page includes ancillary materials, including slides, a factsheet, executive summary and full report. on *Solving the Equation* for gender equality in STEM. All materials can be found at: *http://www.aauw.org/research/solving-the-equation/*

Addressing Primary Barriers: Results from the Pre-Workshop Survey

Prior to workshop implementation, 38 workshop attendees completed a three-question survey, which afforded them an opportunity to provide open-ended comments on what they perceived to be the primary barriers to female participation in engineering, what they have done (or can do) to address and overcome such barriers, and what type of institutions are best equipped to address these barriers. Participants were also given the opportunity, anonymously, to share personal experiences of gender-related challenges in engineering.

Brian Yoder, Director of Assessment, Evaluation and Institutional Research at ASEE, shared the survey results with the group. Asked what they perceived to be the primary barriers to female participation in engineering, the majority of respondents cited culture and gender bias. Respondents also cited limitations in female opportunities in K-12 education, lack of role models and mentors, and generic female isolation in engineering. In response to the second question on what they have done (or can do) to address and overcome barriers, the majority of respondents cited publishing research and conducting lectures related to diversity and gender gap issues. Other respondents spoke of working within their organizations to encourage diversity and with those in leadership positions to implement diversity efforts. In response to the third question, which asked what type of institutions are best equipped to address the barriers they had identified, most respondents cited academic institutions. Other respondents mentioned nonprofit organizations, government, the engineering industry, and everyone, in the sense that everybody is responsible for addressing these barriers.

In analyzing the survey responses, Yoder pondered the larger question of how we think about change, and the ways in which we can effect change to reduce the gender gap in engineering. One theory of change is the “thousand points of light” approach, that “[a] thousand small things that we do…locally will have an effect on engineering education and engineer[ing] as a profession naturally.” A related idea is the expectation that as more women enter the engineering profession, engineering will become more accommodating. Change can also be stimulated from above – for instance, by a shift in ABET accreditation criteria – and can be triggered by “disrupters,” which blow up existing systems and make way for new ones. (These disrupters could be changing industry skill demands, shifting nature of engineering/industrial jobs, and increased economic independence for women). Yoder’s remarks helped set the stage for discussions throughout the workshop about ideas and theories of change, and for brainstorming to come up with suggestions, recommendations, strategies, and concrete action plans to reduce the gender gap in engineering. Pre-workshop survey results are described in Appendix C.

Conversations on Four Workshop Themes

The Planning Committee structured the workshop conversations around the Four Frames Model developed by the Simmons Center for Gender in Organizations. The four frames are: (a) equip the women/prepare women for success; (b) heed policy and lay; (c) value differences; and (d) re-envision work culture (see Appendix D). In preparation, four papers were commissioned to serve as "discussion starters." These papers focused on four topics: (1) an empirical description of the state of women in engineering, (2) public perception of the field, (3) the undergraduate experience, and (4) promising practices. Authors discussed their papers during a four-station gallery walk. Following the gallery walk, participants formed groups, each focusing on one of the presented paper topics, to share insights and propose improvements in the way engineering students are recruited and taught. Comments and questions posed in the discussions reflected the wide range of participants' backgrounds, perspectives, and experiences.

The State of Women in Engineering

Clemencia Cosentino (Mathematica Policy Research) and Amlan Banerjee (ASEE) made their presentation based on a joint paper, *More Women are Pursuing Engineering Degrees, but Vast Disparities Remain* (see Appendix E). Of all the STEM fields, engineering ranked lowest among intended majors for women entering college, with men three times more likely than women to report intending to major in engineering. Nonetheless, women's enrollment is growing in most engineering disciplines, and in two, mechanical and mining engineering, growth is evident at all three degree levels (undergraduate, graduate, and doctoral). Further, once having entered engineering programs, women are more likely than men to graduate.

What percentage of women represents a tipping point that can prompt cultural change in an institution?

A case study of doctoral STEM disciplines at a university in the southern United States revealed that programs in which 33 percent or more of the students were female exhibited a 39 percent lower rate of female attrition (Lott, Gardner, & Powers as cited in Ryland, 2013).

Comments from the Pre-workshop Survey: The State of Women in Engineering

"The mix of cultural conditioning that directs women away from engineering careers at an early age, and insufficient academic preparation and counseling at the middle school and high school levels, presents a big obstacle to attracting, involving, and retaining young women in engineering and engineering education."

"There are still some faculty members who do not embrace diversity in engineering."

"There is an accumulation of subtle, complex, multi-factored and systemic challenges for women in engineering that are typically not recognized, often denied, or written off as unchangeable—either because they are not a priority or because of lack of knowledge about strategies for change."

During the breakout session on this topic, participants first discussed the issue of equality versus equity. Equality emphasizes sameness (everyone starts in the same place, and gets the same thing) and equity emphasizes fairness (everyone, no matter where they start, has access to the same things). Equity is a prerequisite to achieving equality. As part of this discussion, one participant said that while numerical diversity is a gateway to gender equity, it does not ensure meaningful interactions among groups, which can mitigate implicit bias; students can still find themselves segmented from the majority. Although participants agreed that meaningful interactions are key to increasing both equity and equality, they also asked what percentage of women represents a tipping point that can prompt cultural change in an institution. Is it 35 percent? A case study of doctoral STEM disciplines at a university in the southern United States revealed that programs in which 33 percent or more of the students were female exhibited a 39 percent lower rate of female attrition (Lott, Gardner, & Powers as cited in Ryland, 2013).

Discussion at the breakout session went beyond strictly gender issues to include minority participation, language, accessibility, and income. Reflecting on minorities' struggles, one participant observed that Latinas had to develop "a critical consciousness of forces against them" and become resilient. Students can learn "healthy resistance strategies" to confront racism, but scaling up these strategies is difficult.

Several pressing questions emerged as a result of this group's discussions: What fosters cultural change? To what extent should we adapt instead of trying to impact large-scale change? Do we first prepare women to be successful in the current system or instead work to transform the system? Responding to the first question, one participant pointed to *A Whole New Engineer* by David E. Goldberg and Mark Somerville (2014) as a guide to systemic change. Other participants suggested that the engineering education model should be redefined, and that in order to transform the system, there needs to be a critical consciousness amongst all stakeholders. Relating to the first two questions, participants acknowledged the importance of working within the current system to try to effect change while also working towards transforming the system and removing barriers to diversity and inclusion. K-12 students should become acquainted with strategies to overcome diversity challenges, and special "resilience" skills training should be offered to young women throughout their education, continuing into college. In colleges and universities, role models should be emphasized (including both male and female role models and mentors). Regarding administration and faculty, accountability measures, including rubrics and established diversity procedures, should be introduced and enforced at a university-wide level to ensure that faculty members take diversity issues seriously, and also to encourage the creation and development of faculty diversity champions.

Public Perception of the Field

Lecia Barker, from University of Texas at Austin, gave a presentation based on her paper *Changing Perceptions and Creating Impressions: An Overview of Theory, Practices, and Evidence for Attracting Women into Undergraduate Engineering and Computer Science* (see Appendix F). She focused primarily on efforts to bring women into engineering undergraduate programs and retain them in the field. Barker noted the unevenness of female representation across engineering disciplines, with many more women in biomedical, chemical, and environmental engineering than in computer, electrical, petroleum, and computer science engineering.

Barker drew a connection between barriers to entry for women in engineering and public misconceptions about engineering. Engineers, she said, are widely seen as insensitive to societal needs, thus discouraging women who seek careers that help others. Additionally, engineers are not recognized as lifesavers; nor are they considered creative. Engineering is perceived as difficult, "gendered male," and isolated within the workplace. Gendered experiences in educational settings also play a role in low female participation in engineering. Women who enter the engineering field are likely to hold themselves to higher standards than men, and to lose confidence in their ability when they fail to live up to those standards. Another challenge that women face is that faculty tend to gear their lectures to the majority of their audience—that is, men.

Women who enter the engineering field are likely to hold themselves to higher standards than men, and to lose confidence in their ability when they fail to live up to those standards.

Comments from the Pre-workshop Survey: Public Perception of Engineering

"The images of women they see don't support it and academic environments often fail to illustrate aspects of engineering that interest girls. Society, culture, and the profession itself too often reinforce, subtly or overtly, the male ideal of an engineer."

"While a lack of awareness and understanding is not the only barrier to women's participation and retention, it is often the first barrier."

"It extends to the subtle messages students receive from their peers and from media sources about who engineers are and are not, and to the public's perception of what engineering really is. The messages boys and men receive from peers and the media don't always teach them to value a smart, technically competent woman as a potential mate. Naturally, girls and women who perceive this may not choose such a path because they fear it will hinder their ability to attract a mate. Young girls are not necessarily encouraged to consider fields such as engineering."

The breakout group that discussed perceptions of engineering formed a number of recommendations and suggestions for how to educate the public in a way that would bolster recruitment of women in undergraduate engineering programs. The group agreed that training is necessary to affect both perception and recruitment. Schools (both higher education and K-12 institutions) should introduce gender bias and cultural awareness training; engineering faculty in colleges should have specific skills training to encourage female participation in all engineering disciplines. Barker's paper, while acknowledging the powerful role of educators and faculty in impacting change, noted that "parents and families…also hold gender schemas [and] have a lifelong influence on shaping children's choices" (Appendix F, p.41). It is therefore worth thinking about training programs or efforts that reach not just educators, but parents and families as well.

In addition to the importance of training, the group also suggested that marketing efforts be more attuned to the gender and diversity gap and provide more information to those who are unfamiliar with the engineering field and its different disciplines. The engineering community should stand up against marketing that alienates women from the field or that discourages them from entering engineering programs. Marketing efforts should also seek to explain what engineering is all about and make sense of its various disciplines. Research efforts focused on gender equity and inclusion in media can provide insight into the gender divide in engineering education as well, especially images of women in engineering. Barker's recommendations for improving female participation in engineering disciplines with the widest gender gaps are to better communicate "engineering and computing [as] socially relevant, demonstrating that these pursuits serve people…and support community" and "show that engineering and computing are not [exclusively] solitary occupations" (Appendix F, p.42). These recommendations can be translated to marketing efforts.

This breakout group also discussed how to engage non-traditional students in engineering and how to re-think the educational gateways to undergraduate engineering programs to encourage more diversity. Noting that engineering excludes a large number of students, participants suggested that the engineering community come up with a way to reach non-traditional students (i.e. those with different ways of knowing and doing that may be disadvantaged by traditional measures though they would perform well as practicing engineers) and encourage them to pursue engineering degrees. The group also suggested that math and science no longer be considered the exclusive gateway into engineering and that instead, engineering be introduced early on in students' K-12 education.

The Undergraduate Experience

In the third "discussion starter" presentation, Rachelle Reisberg (Northeastern University) summarized her paper *The University Experience: Retention to Degree* (see Appendix G), which examined a variety of successful efforts to recruit, retain, and graduate women in engineering. Noting an increasing number of these success stories, she questioned why most institutions have seen either slow progress or none at all, and whether the methods used by successful institutions can be widely adopted. Reisberg identified key factors and actions that help women advance in undergraduate engineering programs. These included: creating a more welcoming environment during the recruitment process, highlighting social relevance in curricula and lessons, including service learning opportunities, acknowledging skills that go beyond the purely technical, introducing cooperative learning experiences to enhance student self-efficacy, and providing both leadership development and mentoring opportunities for female students.

The breakout group that discussed the points raised by Reisberg agreed that creating a welcoming environment during recruitment is important to get more initial female participation in engineering programs. Yet they felt that creating such an environment would require a student perspective.

Highlighting social relevance in engineering curricula and lessons may be a challenge, the group found, especially in certain engineering disciplines or lessons that are often perceived as offering little opportunity for real-life social connections. If

Comments from the Pre-workshop Survey: The Undergraduate Experience

"In that sense, universities should partner more closely with industry to provide practical opportunities for students. This would also allow for academia and industry to share promising strategies for shifting norms and expectations in both classrooms and organizations, and to design course experiences that support marginalized students and create environments in which diverse students can establish a sense of belonging."

"That means shifting slightly away from the narrow focus on science and math, and including more multidisciplinary studies outside of engineering such as business, humanities, arts, and social sciences."

"Engineering colleges need to revamp and modernize their curricula to make it more interesting to women, more connected to the challenges they face, and better geared towards real social impact."

social relevance is to be highlighted, along with incorporating service learning and emphasizing business-preparedness skills, the responsibility lies with the engineering faculty. The group agreed that faculty development can play a pivotal role in enhancing and improving the undergraduate experience for female engineering students. They cited three qualities faculty should possess: resistance (that is, resisting traditional gender biases and misconceptions), awareness, and empathy. Faculty should be trained both professionally and through consistent reflective practice. Professional training should be focused on pedagogical techniques – how to deliver compelling, engaging, and socially relevant engineering lessons. In order to encourage faculty members to receive such training, they should be granted total involvement in reshaping engineering curricula. This, in turn, would foster more leadership and advancement opportunities for particularly engaged faculty.

Importantly, the undergraduate experience is not solely about the student, this group noted; rather, it is a systemic issue. When seeking to improve the undergraduate experience for engineering students, the school should be treated as an ecosystem, with all parts (both internal and external) interacting with and depending on each other for continued progress and sustainability. In order to truly impact change related to gender and diversity gaps in the engineering field, a systems approach must be taken.

Promising Practices

Daryl E. Chubin, an independent consultant, shared insights about his paper *Promising Practices in Engineering Education (as Viewed through Four Frames)* (see Appendix H). Addressing organizational change to increase more female participation in engineering undergraduate programs, he adapted a "four frames" framework traditionally used in organizational management literature. Chubin asserted that these frames "help to categorize what has been tried – and worked – in changing the engineering education experience" and serve "as a lens for viewing practices that reflect healthy, welcoming, supportive, and evolving environments for women in engineering." The four adapted frames are: 1) Equip the Student, 2) Enforce Policy and Law, 3) Embrace Difference, and 4) Evolve Organizational Culture. All of these frames must be employed thoughtfully in order to effect organizational change, the emphasis being "on transforming organizations to be a continuing source of production both of skilled professionals and new knowledge – the hallmarks of discipline."

Participants expanded on Chubin's adapted frames in discussing ways to effect change on an organizational scale. The group agreed that rather than attempting to "tweak" organizational culture, the engineering community should seek to transform it. In order to do so, attention must not be paid merely to individuals, but to all stakeholders (including faculty, institutional leaders, PreK-12 teachers, students, professional societies, and industry representatives). This is certainly a tall order, and the group acknowledged that the various stakeholders form a complex ecosystem and that it will be challenging to implement significant and lasting change on a large scale. Change takes time, and it is important that minor successes be recognized and applauded. Before trying to effect organizational change, there needs to be concrete data that shows the root causes of the gender and diversity gap. Once this data has been collected, measures of evaluation and success must be defined, and researchers and organizations must be held accountable for carrying them out. Engineering faculty members bear a large responsibility to encourage lasting organizational change. As a group, faculty must seek to change the ways of "dinosaur" instructors, revitalize curricula to make engineering relevant, change the learning environment to add power and self-efficacy in learning outcomes, bring in more diverse representatives to the teaching body, and adopt a team mentality.

Participants agreed with Chubin that enforcing policy and law is an important key to encouraging organizational change. The group noted that institutional leadership is necessary but not sufficient; strategic plans and practices to close the gender and diversity gap must be codified in policy to gain traction. Addressing diversity should be approached as a national imperative and acknowledged as essential for the future good of the engineering profession.

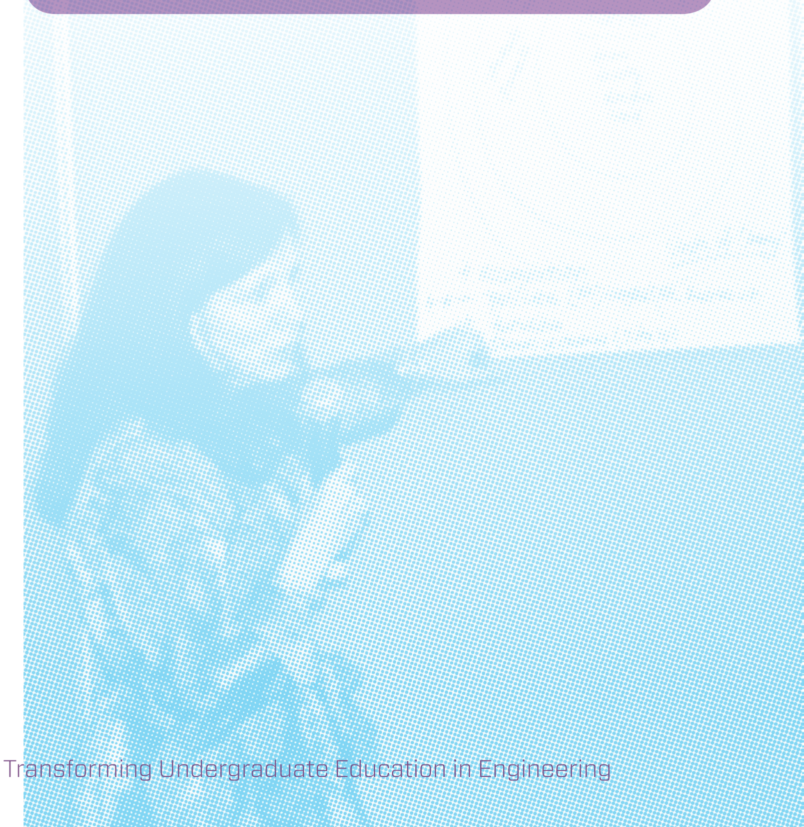
Comments from the Pre-workshop Survey: Promising Practices

"National messaging campaign like Engineering Your Life designed to change the way girls think about engineering and how engineers talk about engineering."

"Programs like Black Girls Code, COMPUGirls, and NSBE's all-girls Summer Engineering Experience for Kids (SEEK) camps in Jackson, Miss. and Atlanta, Ga. should be replicated elsewhere to encourage more girls' engineering aspirations."

"The National Academy of Engineering, through its website EngineerGirl! (*www.engineergirl.org*) is engaging middle school and high school girls in understanding how engineering and other technical fields can provide them the tools to pursue rewarding careers and make a tremendous difference in their communities."

"The first UNESCO Engineering Week in Africa in 2014 exposed youth, especially young women, to careers in engineering."



Envisioning an Action Plan

Planning Committee member Teri Reed, currently Assistant Vice President for Economic Development at the University of Cincinnati, opened Day 2 of the workshop with a call to action, emphasizing the need for "accountability, ways of tracking, ways of communicating, [and] ways of messaging." A central pillar of this action plan would be creation of an online dashboard that shows the composition of engineering schools according to gender, race, and ethnicity.

Participants broke into groups to brainstorm four topics: determining the necessary metrics in an online dashboard, accountability, incentives, and engaging men in addressing the gender gap. The four groups presented their findings and action items. These items are detailed below.

"We need to turn the data into actionable information."

- Darryll Pines
Dean, A. James Clark
School of Engineering
University of Maryland

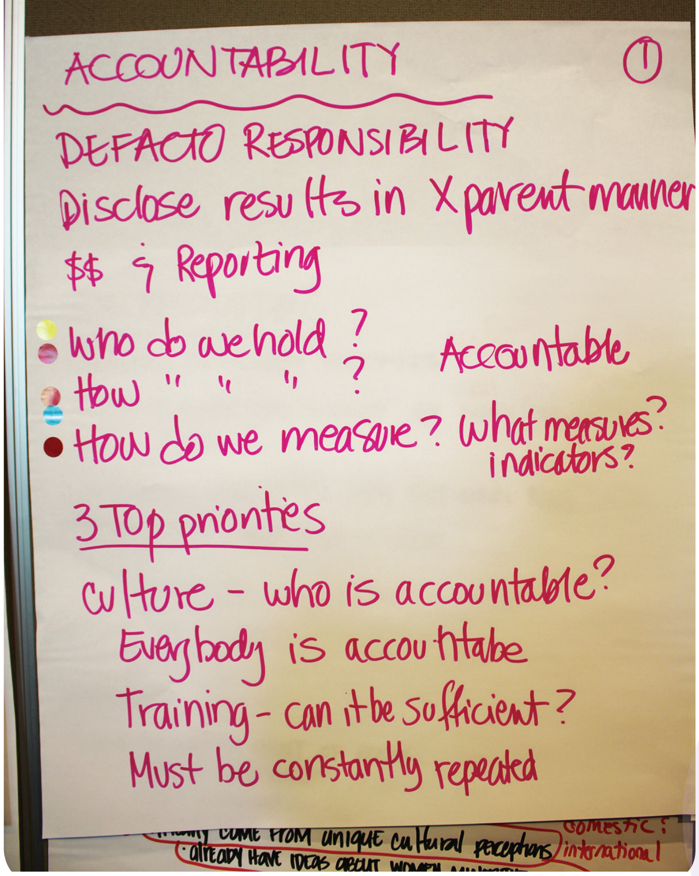
Creating an Online Dashboard

The group that brainstormed dashboard metrics acknowledged the wealth of data that already exists on gender, race, and ethnicity at engineering schools, collected by both ASEE and the Department of Education. While graduation data is already collected in these parameters, there is a distinct lack of admission-related data that an online dashboard would need – "who's applying, who's been admitted, who's been confirmed and then who's enrolled." Participant Darryll Pines (University of Maryland A. James Clark School of Engineering) also suggested collecting more demographic data on both tenure-track and non-tenure-track faculty, including "leadership data, deans, department heads, [and] associate deans [who were] never ever categorized in terms of race, ethnicity, and gender."

This group also proposed adding a ranking or scoring system to the dashboard, to indicate how well a school is doing at incorporating diversity and diversity efforts, factoring in regional demographics. Schools would be scored as gold (excellent), silver (reasonably good) or bronze (needs improvement). The group's final recommendation was to find a way to "turn the data into actionable information," as Pines put it. They suggested awards and other forms of recognition, both for schools that are consistently doing well with diversity efforts and those that have made significant improvements year-to-year. Partnerships with organizations like NSF and ABET could help with funding for awards and recognition. To make dashboard information more accessible and actionable to a wider audience, the data and university rankings would be published.

Assessing Accountability

The group that discussed this topic agreed that accountability means both 1) de facto responsibility and 2) disclosing results in a transparent manner. Those who should be held accountable include ombudsmen, provosts, deans, chairs and department heads, faculty, students, technical societies, and corporations. In order to assess accountability, models must be adopted. As to what drivers and incentives are needed to persuade someone to embrace accountability, Diane Matt suggested "reputation and public image." The online dashboard, she said, should include something that reflected these drivers, like a "diversity index."



Among further efforts that could be taken to ensure accountability, the group said technical societies could conduct site visits, following the example of the American Philosophical Association's examination of university departments. Funding agencies could set expectations for diversity for both grant suppliers and grantees. Accountability could be applied as well to hiring practices in colleges and universities, with those that don't comply with certain diversity standards and guidelines risking nonrenewal of contracts. Likewise, state governments could exert pressure on admissions departments. Further discussion is needed to brainstorm the best sets of criteria and aspects of retention.

Establishing Incentives

This group focused on establishing incentives for academic institutions and those working within the academic realm, including deans, faculty, and administrative staff. Personal incentives for college and university staff to become champions of change need to be established, perhaps in the form of stipends, recognition or awards. Incentives for universities as a whole can include research funding, regional or national prestige, and exposure to a potentially larger student body. Incentives should also be considered at regional, state, and national levels, taking into account local industries, parents, students, and federal agencies. The group noted that recognition is often overlooked as a powerful incentive, especially for faculty. Some policies intended to serve as incentives actually act as disincentives and "work against what we're trying to achieve," in the words of participant Catherine Didion (former senior program officer at the National Academy of Engineering). The group also explored the role that funding can play in creating diversity incentives.

This group emphasized that a successful incentive strategy requires planning, thoughtful messaging, and both external and internal levers. Professional engineering societies and the National Academy of Engineering may assist in establishing such levers.

Engaging Men

This group, composed of three men and one woman, spent considerable time discussing the discomfort this topic can cause. Members of the group concluded that, in order to effect change, we must learn "how to be comfortable in being uncomfortable." Participant Stacie Gregory (former ASEE post-doctoral fellow) noted that the topic produces uneasiness among both men and women; men are often unsure of what terminology to use, and how to advocate for women properly without overstepping boundaries, while women may at times make men feel uncomfortable in engaging with this issue. The group explored the idea that maybe this discomfort is not solely related to gender, but also involves other issues, like cultural differences. When brainstorming how to engage men or other groups, it would be wise not to narrow the conversation to gender alone.

As an action item, the group suggested that a framework document be created to institutionalize cross-gender and cross-cultural knowledge in the engineering curriculum. Suggestions for organizational funders and project leads included ASEE and the National Academy of Engineering. This framework could potentially be tailored to different schools, but a general framework would be a good starting point. The group explored the idea of crafting a four-step model to engage men in the engineering gender gap issue, involving assessing awareness, brainstorming methods to garner interest, and implementing and managing change across the board. Such a framework would need to be researched further in order to be executed with any degree of success.

Leveraging Stakeholder Impact

Forming separate groups, participants assumed the roles of four different sectors (stakeholder groups) that have the ability to improve the current state of affairs for women in engineering: faculty, university administrators, industry, and government and professional societies. These groups were instructed to synthesize the recommendations and strategies discussed during the workshop thus far and focus particularly on the results from the previous brainstorming session on components of an action plan. Participant Karl Reid (National Society of Black Engineers) noted that while these four groups can be differentiated, and have different roles in closing the gender gap in engineering, they should also be thought of holistically; he urged fellow participants not to get carried away with four different sets of strategies, but to "think about the synthesis" of all the groups and action plan components.

Faculty

In order to effect institutional change at colleges and universities, faculty must recognize that they are the "soldiers on the ground" in the fight for increased diversity, and realize the power they have to promote change. There must be a shift away from "victim language" among faculty that has sometimes led to "petty bickering" and ends up having "a negative influence on the climate for students." Faculty should adopt a sense of agency, through collaboration, team exercises, or university-organized leadership and empowerment workshops. Faculty must realize the unique position that they hold as individuals, and as a group, to "contribute to the entire university…step up to the leadership role and be able to organize and take things forward."

We Need More Mentors!

Mentoring can be an especially powerful mode for increasing retention and promoting diversity. There is evidence that conversations outside of class may benefit female STEM students more than males (Gayles & Ampaw, 2011). Unfortunately, while prior findings indicate the significance of critical mass related to mentoring and degree attainment, faculty of both genders have shown a bias towards students of their own gender (Tidball, 1976). Given the lower rates of female faculty, female students are at a disadvantage when finding these quality mentoring relationships (Girves & Wemmerus, 1988).

Academic Administrators

University administrators can assist with this shift by working to adopt university-wide models that seek to improve diversity. Orientations, evaluations, and ongoing conversations among university stakeholders would offer opportunities for faculty to engage in these initiatives. Involving faculty in organizational initiatives to improve diversity will give them an incentive (both individually and as a group) to contribute and work toward more inclusive classroom climates and curricula. Administrators should also work with students to ensure they are receiving rewarding and inclusive educations, through student-completed teacher evaluations that focus on classroom climate and culture. Students should feel that their opinions carry weight for the institution as a whole. These evaluation and student engagement efforts should be ongoing. University administrators can help set the tone for engineering deans to follow by establishing institutional values that are espoused by the university president and provost.

Deans can issue value statements to enable change, and show commitment through introducing diversity incentives, striving for best practices, instituting diversity training for engineering faculty, and hiring more diverse faculty members. Other recommendations for academic administrators include promoting mentoring programs, monitoring the climate for female faculty, and establishing work-life balance policies (American Association of University Women, 2010).

Industry

For industry stakeholders to stimulate increased female participation in engineering, they will need to align themselves more closely with academic institutions. Both groups already share the goals of increasing student diversity and student retention. Industry benefits from diversity and retention by having a wider pool of qualified job applicants to choose from; schools benefit by improving their graduation rates, maintaining strong revenue streams, and bettering the engineering profession as a whole. Companies can further align themselves with colleges and universities through more established collaborations and partnerships. Industry can help set competency requirements and expectations for students entering the engineering profession.

Colleges and universities can require that engineering courses incorporate real-life applications. They can work with industry to introduce new ways to assess workforce readiness that rely less on strict numerical grade requirements and avoid procedures and tactics not demonstrated to correlate with workplace performance and success. In return, industry can make a public commitment to students by offering internships and sponsoring student leadership conferences. Industry and universities will need to work together consistently and maintain an open dialogue to ensure student retention, job readiness, and possibly determine a new framework for evaluating student understanding and preparedness to enter the engineering field.

Government and Professional Societies

Government and professional societies have key roles as conveners. They can influence university leaders' thought and actions by establishing pro-diversity messaging and encouraging cross-cultural dialogue across different spheres. Professional societies can implement projects and activities that encourage inclusion, such as creating teaching modules for faculty. Societies can also enlist their members to initiate pro-diversity programs individually or in their various organizations. Government agencies can offer grants and funding opportunities to spur implementation of pro-diversity policies and initiatives. They can also be instrumental in creating guidelines, compliance reviews, and educational benchmarks. Professional societies could work together to engage students, in the process creating student councils that work towards creating professional competency standards in engineering. Government agencies and professional societies can use their convening power to set up pro-diversity committees, enlist legal counsel, elect official liaisons to work with universities and colleges, compile promising practices, and widen the diversity of member associations.

Putting the Pieces Together: Recommendations and Actions

During the concluding session of the workshop, Planning Committee member Adrienne Minerick reiterated the event's key intended outcomes: "to define a set of recommendations and actions that have the potential for reducing the gender gap in engineering," with the main focus of "provid[ing] guidance on necessary changes to undergraduate curriculum, pedagogy, and academic culture to achieve gender-inclusive engineering education." Guiding the recommendations below is a shared belief that "diversity equals value." This notion, as one participant put it, needs to be "embed[ded] into our thought, our action, and our going forward…at all levels within the institution." The group acknowledged that, while this workshop focused on closing the gender gap, efforts to increase diversity must be broader and seek to garner more engagement and varied supporters.

The following set of recommendations and actions is informed by the visions, and strategies discussed throughout the workshop and will take into account the potential interconnected influence of multiple sectors and stakeholders "engag[ing] and partner[ing] with others…in order to gather momentum."

Create a Comprehensive Online Dashboard

One necessary action discussed in detail during the workshop is creation of an online dashboard that shows the composition of engineering schools according to gender, race, and ethnicity. Participants agreed on the essential components: comprehensive data that is comparative, frequently updated, and actionable, an evaluation metric, and accountability metrics. While a significant amount of data already exists on diversity within engineering schools, mostly related to gender, there is a need to gather more data on admissions and different classes of faculty. Comparative data, as one participant noted, would serve as "a scorecard that actually measures stuff" and shows institutions where they stand in relation to the overall playing field. Currently available data would be included at the outset, but a conversation should begin on what specifics are envisioned for a dashboard "scorecard." Evaluation and accountability metrics go hand in hand; the data must be valuable, correct, and meaningful, and certain parties should be assigned responsibility for the input, correction, and continual updating of this data.

The group determined that the first step in creating this dashboard should be to come together and put forward a vision of the ideal pro-diversity, inclusive college/university campus. The group could then decide what metrics would best capture the characteristics that serve the vision.   Once these metrics have been identified, a scorecard will be possible. The group should envision how this data can be used by people in everyday life in actionable ways. In order to do so, there will need to be a cross-section of dedicated dashboard stakeholders from various sectors and backgrounds (i.e. students, faculty, government, professional societies, and industry). It was suggested by Adrienne Minerick that the group seek funding from NSF to assist with data collection for the dashboard. Participants were encouraged to submit a proposal focused on datamining, which would not require a large amount of funding.

Reframe Engineering Marketing and Messaging

The topic of engineering marketing and messaging was discussed throughout the workshop. Participants agreed they must become more informative, more socially relevant, more comprehensive in addressing the many engineering disciplines, and more attuned to the gender and diversity gap. Significant change in marketing and messaging will require the engineering community to partner with industry and universities. Industry partners can emphasize the economic value of greater diversity as leading to more innovation and better products. University partners can emphasize the educational and social value of different engineering disciplines. Students can also contribute to new marketing messages, since they are close in age to the cohort universities are seeking to recruit. The question of how to engage students has yet to be answered, but the group agreed there is a great advantage in drawing students' attention to the importance of diversity in engineering. It was suggested that one participant take on the role of marketing "champion" and create a basic one- or two-page flyer that can be adapted to different audiences and institutions. This marketing champion needs to be identified.

Improve K-12 Engineering Education

Though TUEE focuses on undergraduate education, workshop participants frequently touched upon the importance of a strong K-12 educational foundation to encourage and prepare students to pursue engineering degrees and careers. Participants felt that K-12 engineering education lacked real-world examples and opportunities for practice and did not adequately emphasize inclusivity and diversity in lessons and curricula. Participant Charles Hickman (ABET) spoke about the unique responsibility and opportunity professional societies have to impact K-12 engineering education. He noted that ABET, as a federation of multiple professional technical societies, has the ability to bring societies and stakeholders together to discuss strategies for "trying to get the societies to start talking to each other about their K-12 outreach." As currently taught, K-12 engineering education is frequently redundant, inefficient, and ineffective, in his view.

Some professional societies currently offer workshops and programs focused on improving pedagogical techniques, but there needs to be a bigger effort to work with K-12 schools to "incorporate curriculum modules that reflect on the interests discussed [at the workshop]." To do so, societies must collaborate both with schools and with each other. Societies should think of these activities as opportunities to increase membership, diversify their leadership, and reach new audiences. Many societies offer student memberships or have student organizations, which should be leveraged to promote diversity within their institutions and offer insights into impactful educational programming. Hickman encouraged participants to contact him after the workshop to arrange actionable discussions on this topic.

Create an Education Framework Document

The idea for creating an educational framework, introduced during Daryl Chubin's presentation, was discussed throughout the workshop. In Chubin's paper and presentation, he adapted a "four frames" organizational management approach to create an engineering education framework that encourages increased female participation. The group expanded on this idea and recommended that a framework document be created to institutionalize cross-gender and cross-cultural knowledge in the undergraduate engineering curriculum.

Christianne Corbett (former senior researcher at the American Association of University Women) offered specific recommendations for this framework document: Institutions should revise their introductory courses, provide more research opportunities for undergraduates after their first year of college, and facilitate interactions between female students and individuals or groups of successful women engineers, either by assisting with mentor matches or organizing trips to female-centric engineering societies, workshops, or conferences. Suggested organizations to assist in the creation of this framework were ASEE and the National Academy of Engineering. While a framework like this has the potential to make a significant impact on the engineering field, it should be developed with an economic calculation in mind: what the perceived benefit is related to the cost of adoption, and what factors would encourage a college or university to adopt it.

Continuing the Conversation

The group agreed that reflection time following the workshop would be beneficial to process the discussions and come up with additional suggestions and recommendations. One participant offered to host brainstorming conference calls, and suggested that additional in-person contacts like working groups or conference meet-ups would be a great way to foster working relationships among participants, and encourage additional development of an action plan. At the culmination of the workshop, each participant was instructed to write a commitment statement, beginning with "I vow/commit to" and listing their first steps toward action following the workshop.

Leading the Charge: New and Upcoming Initiatives

Along with TUEE and the workshop *Voices on Women's Participation and Retention,* other programs and efforts are under way to reduce the gender and diversity gap in engineering. In its 2011–2012 *Biennial Report to Congress,* the Committee on Equal Opportunities in Science and Engineering (CEOSE) called on NSF to "implement a bold new initiative, focused on broadening participation of underrepresented groups in STEM, similar in concept and scale to NSF's centers, that emphasizes institutional transformation and system change; collects and makes accessible longitudinal data; defines clear benchmarks for success; supports the translation, replication, and expansion of successful broadening participation efforts; and provides significant financial support to support individuals [in need]" (CEOSE, 2012, p. 1). CEOSE is a congressionally mandated group that advises the foundation on policies and programs to encourage full participation of women, minorities, and persons with disabilities in STEM fields.

The CEOSE call to action led NSF in 2014 to reactivate a Broadening Participation Working Group, with a representative from each directorate. This group prepared a series of options for the foundation ranging from "those very easy to implement quickly…to large-scale high investment activities such as Centers devoted to the science of broadening participation, or to broadening participation itself" (National Science Foundation, 2015b, p.2).

NSF's preeminent agency-wide initiative for broadening participation is INCLUDES (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science). The long-term goal of this six-year program is "to fund new research, models, and partnerships that lead to demonstrable progress…in meeting the challenge of broadening participation in science and engineering, with special attention [paid] to the cross-cutting areas of inclusion, relevance, scalability, and sustainability" (National Science Foundation, 2015a, p.52). NSF envisions a number of alliances across the country, backed by a central organization, looking to find or develop projects that can be scaled up and achieve nationwide impact. Funding began in the fall of 2016 with 37 Design and Development Launch Pilots, aimed at supporting projects with the potential to deliver prototypes for new models that broaden participation in STEM, and 11 grants for conferences to explore development of backbone organizations to support a national network of alliances and partnerships (National Science Foundation, 2016). By the summer of 2017, the number of INCLUDES awards had climbed to 80. In order to "achieve significant impact at the national scale within the next 10 years in transforming STEM so that it is fully and widely inclusive," all members of the STEM ecosystem must join together, "leveraging state-of-the-art knowledge on scaling of social innovations" and developing "collaborative alliances, spanning education levels, public and private sector, and including new partners" (Córdova, 2016).

The Science of Broadening Participation program (SBP), an NSF initiative begun in 2011, seeks "to better understand the barriers that hinder and factors that enhance our ability to broaden participation in science, technology, engineering, and mathematics (STEM)" (Lomax Cook & Ferrini-Mundy, 2015). CEOSE urged that its further development be supported (CEOSE, 2015). In an April 2015 Dear Colleague letter, NSF announced a new round of funding by the Directorate of Social, Behavioral, and Economic Sciences and the Directorate of Education and Human Resources to stimulate SBP research. The letter called for research proposals on factors underlying lack of diversity in STEM, including institutional factors, cultural and community factors, psychological and social factors, and economic and policy-related factors. Research proposals were also encouraged to study the potential outcome of broadening participation in STEM fields, related to "scientific productivity, innovation and the national economy industry" (Lomax Cook & Ferrini-Mundy, 2015).

Initiatives like NSF SBP, and NSF INCLUDES are just a few of the NSF programs either explicitly directed at or that emphasize broadening participation. These programs, which altogether total more than $600 million a year (CEOSE 2015), illustrate a continuing commitment to diversity dating from the Science and Technology Equal Opportunity Act of 1980 referenced earlier. Continuing efforts to engage all stakeholders in the larger STEM ecosystem, including university faculty and administrators, students, K-12 teachers, industry representatives, professional societies, and government agencies, have the potential to diversify participation and encourage both persistence and retention in STEM fields, and specifically, to reduce the gender gap in engineering. Efforts to increase diversity in these fields should be ongoing, and continuously assessed, evaluated, and strategized to ensure their effectiveness and success rate. There is still a long road ahead on the pathway to inclusion, but the combination of innovative initiatives and varied engaged stakeholders can offer a promising vision for the future of STEM diversity.

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Appendix A: Workshop Agenda

Friday, June 12, 2015

1:30 PM – 2:00 PM	**Registration**
12:00 PM – 2:25 PM	**Welcome and Setting the Stage** *Norman Fortenberry,* Executive Director, American Society for Engineering Education *Diane Matt,* Executive Director, Women in Engineering ProActive Network
2:25 PM – 2:45 PM	Keynote *Christianne Corbett,* Senior Researcher, American Association of University Women
2:45 PM – 3:45 PM	**Panel: Discussion Starters** Empirical Description of the State of Affairs *Clemencia Cosentino,* Senior Researcher and STEM Area Leader, Mathematica Policy Research *Amlan Banerjee,* Senior Research Associate, American Society for Engineering Education Perception of Engineering *Lecia Barker,* Associate Professor, University of Texas at Austin The Undergraduate Experience *Rachelle Reisberg,* Assistant Dean for Engineering Enrollment and Retention & Director of Women in Engineering, Northeastern University Promising Practices *Daryl Chubin,* Independent Consultant
3:45 PM – 4:00 PM	**Break**
4:00 PM – 5:30 PM	**Breakout Session I** Facilitated small group discussion. Breakouts by Discussion Starters themes.
5:30 PM – 6:00 PM	**Break**
6:00 PM – 8:00 PM	**Dinner** **Report from Breakout Groups** Facilitated large group discussion

Saturday, June 13, 2015

7:30 AM – 7:50 AM	**Breakfast**
7:50 AM – 8:20 AM	**Welcome and Setting the Stage** *Teri Reed,* Assistant Vice Chancellor of Academic Affairs, Texas A&M University *Brian Yoder,* Director Assessment, Evaluation and Institutional Research, American Society for Engineering Education
8:20 AM – 8:30 AM	**Break**
8:30 AM – 10:00 AM	**Breakout Session II** Facilitated small group discussion. Breakouts by sector of influence.
10:00 AM – 10:45 AM	**Report from Breakout Groups** Facilitated large group discussion
10:45 AM – 11:00 PM	**Break** (Refreshments Served)
11:00 AM – 12:30 PM	**Breakout Session III** Facilitated small group discussion. Breakouts by sector of influence.
12:30 PM – 1:00 PM	**Lunch**
1:00 PM – 2:00 PM	**Overall Discussion of Visions and Actions** Facilitated large group discussion

Appendix B: Attendee List

More than thirty individuals, representing an array of institutions and organizations, attended the *TUEE Phase III Voices on Women's Participation and Retention* workshop. The affiliations listed below are those at the time of the event.

Stephanie G. Adams
Virginia Tech

Lecia Barker
University of Texas at Austin and NCWIT

Tony Chor
Amazon

Daryl E. Chubin
Independent Consultant

Yolanda Comedy
American Association for the Advancement of Science

Christianne Corbett
American Association of University Women

Clemencia Cosentino de Cohen
Mathematica Policy Research

Catherine Didion
National Academy of Engineering

James Dorsey
Washington MESA

Wendy DuBow
National Center for Women & IT

Alejandro J. Gallard
Georgia Southern University

Roger Green
North Dakota State University

Charles Hickman
ABET

Beth M. Holloway
Purdue University

Diana Kardia
Kardia Group LLC

Russell Korte
Colorado State University

Diane Matt
Women in Engineering ProActive Network, Inc.

Barbara McAllister
Intel

Sylvia McMullen
Blinn College

Lorelle Meadows
Michigan Technological University

Keith Moo-Young
Washington State University

Adrienne Minerick
Michigan Technological University

Veronica L. Nelson
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Appendix C: Pre-Workshop Survey Results

Experts from academia, professional societies, and industry were invited to participate in the *Voices on Women's Participation and Retention* workshop. Each participant was asked to complete an online registration survey. Along with bios and contact information, participants provided open-ended feedback on what they perceived as primary barriers to women's participation in engineering; what they have done/could do to address and overcome such barriers; what type of institutions are best equipped to address these barriers; and their personal experiences of gender-related challenges in engineering. Forty-one attendees filled out the registration survey. Of these, 38 provided responses to the open-ended questions to further shape the workshop agenda and discussions. This appendix summarizes that open-ended feedback. Overall, the pre-workshop survey provided a high degree of overlap with the discussion and themes of the workshop, while allowing for the deeper contextual feedback from participants.

The short nature of the pre-workshop survey lent itself to qualitative analysis by a single researcher without the use of coding software. The open-ended survey data were coded inductively and grouped/indexed into emerging common themes and subthemes. Conventional content analysis was then used to analyze the coded data and to derive findings, conclusions, and recommendations around the emerging themes.

Primary Barriers to Women's Participation in Engineering (n=38)

Survey participants expressed the view that there is no single barrier to women's participation in engineering, but rather a mix of factors that contribute to such barriers. Among the most prevalent and pressing factors cited were biased social perceptions, the lack of an inclusive culture and environment for women in engineering in a broad sense, and a narrow, technically focused engineering curriculum. An environment of cultural conditioning directs women away from engineering careers at an early age. The pattern persists because of inadequate academic preparation and counseling, from middle school through high school and into college. One participant summarized the situation with an excerpt from a white paper in process.

Culture, environment, and societal perceptions (n=20)
Gender roles and expectations are endemic in our society and inculcated in children almost from birth. There are widespread beliefs about what kinds of things boys and men do and what kinds of things girls and women do, as well as a human desire to be seen as fitting in socially. Feeling like outsiders, women leave engineering – and other STEM academic programs and occupations – at a higher rate than do men. The dominant image of white men as successful engineers remains a key challenge to women's participation and marginalizes the diverse contributors needed to address the challenges of the 21st century.

STEM Education in K-12 (n=9)
Early education and the K-12 system do little to inspire young girls about STEM as a creative, innovative, human-oriented field or to encourage their pursuit of science, math, and other educational paths to engineering. There is a little bit of an engineer in every girl, but it is hard for kids to recognize. The K-12 community needs to make deliberate efforts to spark interest in engineering at an early age (as early as first grade), and to improve the image of engineering, showcasing for girls and the general public what engineering is and how it is making a positive difference in people's lives.

Higher Education (n=7)
Participation of women in engineering education is hindered by the restrictive culture and institutional practices of engineering programs. Male faculty members, who constitute the majority and the dominant group in engineering education, need to become aware of the ways that they, consciously and unconsciously, create barriers to women. Women's persistence may also be affected by a narrow first-year curriculum that silos students in majors instead of exposing them to the broad applications of engineering in meeting important societal and global needs.

Role models (n=4)
Being underrepresented and undervalued in engineering and engineering education means that women who surmount the hurdles and persist in engineering majors find fewer role models and mentors and, because of their low numbers, less peer support. This only compounds a systemic problem. Engineering academia has not invested sufficiently

in leadership development and organizational know-how when it comes to representation of women.

Industry Practices (n=3)
Beyond K-12 and academia, industries themselves suffer from an unwelcoming culture toward women on many fronts. Women (and increasing numbers of men) want to be more than a cog in a wheel. They want to identify with a career that will have an impact and make a difference, to be respected, and to be treated and paid equally.

Efforts to engage women in the engineering workforce have mostly focused on recruitment, not on retention and career advancement. Furthermore, too often career pathways do not provide "off ramps" or "rest stations" for women (and men) who are talented yet have personal obligations that they are not willing to ignore.

Strategies and Best Practices to Address Barriers to Women's Participation (n=38)

There was a broad range of best practices aimed at overcoming barriers to participation. Raising awareness was key, followed by training and mentoring after awareness was gained, as well as a focus on supportive environments. The pathway into STEM fields at the K-12 level was also key, since it provided a way to emphasize recruitment and retention at engineering colleges. Overall, these strategies provide a framework for moving forward with increasing participation of women in engineering.

Awareness Raising & Advocacy (n=21)
When asked what they do personally to address the identified barriers to women in engineering, many respondents mentioned engaging in awareness-raising and advocacy on their campuses or within organizations, as well as externally with industry and other partners. They do that through lecturing, conducting meetings, publishing, and presenting research, blogging, advising, and mentoring to principals (faculty, students, administrators, and employers) to promote broader-gendered participation. Research in particular was frequently mentioned as a means to investigate, explain, and address both problems and solutions surrounding inclusion and retention of women in engineering.

Several respondents reported that they chose to work directly with pre-college students to help change their perceptions of engineering and engineers. For instance, the National Academy of Engineering, through its website *EngineerGirl!* (*www.engineergirl.org*) is engaging middle school and high school girls in understanding how engineering and other technical fields can provide them the tools to pursue rewarding careers and make a tremendous difference in their communities. Reaching out to parents to demystify careers in the STEM field was also mentioned as an important and effective practice.

Training & Mentoring (n=12)
Several people reported that they serve as mentors, counselors, sponsors, and role models for younger women and minorities in STEM undergraduate and graduate education, with one person having reached 5,000 students to-date. They run substantial mentoring programs, career and professional development workshops, academic support, and tutoring sessions for undergraduates. Others conduct regular training for male faculty (particularly in STEM) interested in becoming allies for gender equity.

Creating Environment and Opportunities (n=7)
Several people described dedicated efforts to create a more inclusive environment for women in engineering. WEPAN (Women in Engineering ProActive Network), for instance, is entirely focused on gender equity in engineering. The organization mobilizes research on gender, diversity, and inclusion and practical, targeted initiatives to achieve sustainable, systems-level improvement in the higher education-to-workplace pathway. Others have created professional development and leadership support groups to empower and create opportunities for women within their organizations. Male allies for gender equality said they consider encouragement of senior women on their teams to be the single best driver of change.

Youth and K-12 Initiatives (n=5)
Many survey respondents have been involved in various initiatives to bridge the gender gap at the K-12 level. Examples were many and varied:

- Created a national messaging campaign like *Engineering Your Life* designed to change the way girls think about engineering and how engineers talk about engineering;

- Co-created a national television show, Design Squad, to show middle school students what engineering is all about and how they can use the engineering design process to tackle various challenges;
- Launched a social media campaign around the idea that there's a little bit of engineer in each girl and it's our job to #BringItOut.
- Oversaw an engineering competition, Future City, that engages 40,000 middle school students each year (50 percent of them girls) to explore engineering as they create a city 100 years in the future;
- One university engineering department established FIRST Lego League teams at all the elementary and middle schools in surrounding districts;
- Developed summer engineering and robotics camps to have more girls experience engineering at a young age and see how engineering helps people;
- A university professor taught students in grades 6-9 in the Youth, Engineering and Science (YES) program, which introduces students to engineering while improving their math and science skills;
- Offered summer engineering experiences at MIT and the National Society of Black Engineers (NSBE) to provide positive experiences for girls as early as the third grade (8 years old);
- Counseled parents on how to choose schools and co-curricular opportunities for their young girls (and boys).

Recruitment & Retention at Engineering Colleges (n=4)
The approaches to increasing recruitment and retention for women in engineering provided insight into the unique approaches campus leaders took. The following are highlights of the manner in which schools approached recruitment and retention.

A community college developed an Engineering Academy – a living-learning environment that aims both to broaden diversity within the student population and to offer more opportunities and pathways to four-year institutions and eventual careers in engineering.

In another example, an engineering college has abolished its traditional and ineffective Women in Engineering and Multicultural Engineering programs and launched an entirely new, nontraditional diversity-focused organization. The results have been dramatic in terms of access, performance and retention of women and under-represented minority engineering students.

At another university, the College of Engineering actively recruits women through overnight visits by high school students hosted by the Society of Women Engineers and through strategic outreach and communication. The admissions process has been reevaluated to ensure that all women with the potential to succeed in engineering program are being captured.

Stakeholders Responsible to Address Barriers to Women's Participation in Engineering (n=38)

The issues that women face in engineering represent a systemic problem that needs to be tackled from all angles and involve women and allies from all spheres of engineering. In order to effect change, everyone has to accept responsibility for including more women. First, academia, industry, government and professional societies all need to deeply reflect on and study their own culture and make changes to mitigate gender bias and promote inclusion of women in engineering.

A very important factor is persistent, high-level leadership across sectors and organizations that activates and pursues a range of integrated strategies with a high potential for impact. For example, both ABET and industry stand in a unique position to dictate and model what inclusive environments in engineering should look like. Similarly, academia and industry need to work together actively to change the career planning tools on the market, which are currently not all that adequate.

Academia (n=18)
In academia, it is important to raise awareness through self-education and open dialogue. For instance, academia can become more vigilant about monitoring women's representation and adjusting its own climate. Faculty and graduate students could also be trained on ways to create more inclusive classrooms and structures that can be instituted to reduce bias. There has to be a support system in place to ensure academic success and retention of the student.

Faculty

Faculty members in particular were often perceived as the biggest hurdle to gender equity in engineering education. Respondents suggested a variety of measures that engineering colleges can take to facilitate that and initiate change:

- Hold faculty accountable and ensure that workloads and resources are distributed equitably;
- Include diversity efforts as a component of faculty appraisals;
- Insist on diverse applicant pools in faculty searches;
- Financially support diversity efforts such as invited lectures that address gender;
- Ensure that service obligations, large-section lecture classes, and other time-consuming assignments are not given disproportionately to women;
- Increase the share of female math and science faculty to serve as role models and mentors who can inspire young women by their presence, their words, and their work;
- Adopt family-friendly policies.

Academia should give faculty a problem to solve that has meaning to them, and the skills and resources to solve it.

Curriculum

Engineering colleges need to revamp and modernize their curricula to make it more interesting to women, more connected to the challenges they face, and better geared towards real social impact. That means shifting slightly away from the narrow focus on science and math, and including more multidisciplinary studies outside of engineering such as business, humanities, arts, and social sciences. It is also very important to implement practical hands-on experience in the curriculum. In that sense, universities should partner more closely with industry to provide practical opportunities for students.

Industry (n=10)
Leaders in industry should make it clear that they want more women in technical roles, and should create environments that welcome and support women. They can do more to hire, retain, and promote women into senior positions. This can lead to many benefits, such as cultural change, role models, and mentoring. Programs like Black Girls Code, COMPUGirls, and NSBE's all-girls Summer Engineering Experience for Kids (SEEK) camps in Jackson, Miss. and Atlanta, Ga. should be replicated elsewhere to encourage more girls' engineering aspirations.

Youth and K-12 (n=7)
Engineering colleges also need to work more closely with K-12 partnerships to develop a pipeline of students continuing on to higher education, and to make STEM and engineering in particular a priority for women and minorities. Attracting and retaining women in engineering needs to start at the secondary education level. After K-12, research training and preparatory classes in math and science must be offered at community colleges to advance females' critical thinking skills.

Professional Societies (n=2)
Professional societies should address barriers to women by identifying more opportunities. Moreover, the various engineering technical and professional societies would be well advised to consolidate overlapping outreach programs directed toward pre-college women students and their teachers.

Media (n=2)
The media represent a powerful stakeholder that could steer the conversation and affect the outcome, in respondents' view. While public television now provides examples of girls solving engineering problems (e.g., SciGirls), such programs need to incorporate more diverse subjects and be pushed out to channels that reach broader audiences. Those images would also encourage males to value women for their intelligence.

First-Hand Experience Highlighting the Challenges to Women in Engineering (n=17)

Participants provided numerous first-hand accounts of the barriers women face in engineering. Highlights of these experiences are included below in subsets. Emphasis was placed on whether or not the experience focused more on an academic setting or an industry setting. Within academic settings, subsets included the following: unconscious/subtle bias, student, and faculty/administrative experiences. Industry settings included subsets focused on women persevering in the face of inequitable treatment, as well as instances of chilly climate/harassment.

Academic Settings

Unconscious/Subtle Bias

"High schools and colleges are increasingly using career planning software tools to help students figure out majors in college. These tools may contain biases that direct students away from engineering. One of the instructors of one of the freshman academic planning WiE classes noticed an alarming trend while reviewing student results from the MyPlan tool. In a class of about 35 students who have declared engineering as their major and expressed a strong interest in science and math, the most common career suggestion from this tool was nursing. Engineering did not even appear on many of their reports."

"When I began as an engineering professor, I assigned my few female students to different laboratory groups with the good intention of increasing group diversity. It was not until a female colleague spoke to me that I recognized that this policy just further isolated an already marginalized group, likely impeded the success of these female students, and could actually reduce long-term gender diversity in my department. This is a simple example where intention did not align with outcome, and helps illustrate the need to engage men early in education and skills development."

"My knowledge of research on gender bias gives me great insight into my own academic experiences. I now understand that the opportunities for a career in science that did not come my way were in some part due to systemic biases about women in science. Consider this quote from a major engineering college from the 1950s, "Our engineering program is officially coeducational, but doesn't welcome women, since admitting too many will waste faculty time, distract serious male classmates, and undermine our professional reputation." The ways I have encountered bias in STEM educational and career settings have been subtle, diffuse and continual over time - nearly imperceptible unnoticeable unless one is well-informed about micro-messages. The personal adjustments I made to fit in with other students are a testament to my intention to succeed. It turns out that being able to cuss like a sailor, smoke cigars, and order 100 beers can be helpful in many career and life settings. All these personal experiences inform my commitment to increasing the number and advancing the prominence of women in engineering."

Student Perspective

"Hearing countless testimonials by women engineering undergraduates who left engineering due to social pressures and outright hostility from faculty and peers. The common denominator is being alone or one of a very few, i.e., the lack of a critical mass, in a class or a major. Recognizing this as a problem for engineering, and not for student admission, is imperative for any change to occur."

"From my research, I have collected several accounts of women students being marginalized in male-dominated classes. A common complaint was that professors dismissed their questions and treated them as inferior to the men in the class. This was a common perception among the women students and thus is a real motivation for leaving the program and the field."

"While an undergraduate student, I had a male professor who would treat me in a disrespectful manner. He would call me someone else's (another minority female's) name and when I would inform him that was not me he would say it was "close enough." On more than one occasion he implied that I was a lesser student. Conversely he would shower attention on certain white males in the class and it was clear he was interested in their success. He treated women in a condescending manner. I know a number of women who were all treated the same way by him. Unfortunately, none of us felt like we had anyone to turn to – even if we had banded together as a group. I left graduated with a vow not to provide any financial support to the Engineering department until that professor was gone (which I figured would happen through retirement). I support my university and my degree has provided wonderful career opportunities. However, I felt like I was an outsider and had to figure things out on my own if I was to survive."

Faculty/administration perspective

"In my previous position, I was passed over for promotion into a higher-level administrative position. I was told that the reason was that I was not a tenured faculty member. However, there had been men in the past who had held similar positions who did not hold tenure. When I chose to leave the institution, no attempt was made to retain me. Nobody discussed with me my motivation for leaving. It was all based on gendered assumptions."

"Women's voices are still not heard enough. The gender bias at our engineering college is disgusting. For instance, while establishing an important college-wide committee recently, I was encouraged by our dean to invite the prior Chair of our top-ranked department (a man) to serve on the committee ("because we need someone who is respected and has influence"), rather than the current Chair, a woman who was unanimously elected Chair by her department and earned engineering degrees from Stanford and MIT. Apparently her accomplishments and credentials were not significant enough to balance her chromosomes. This not-so-subtle, but incredibly damaging, gender bias pervades our engineering college."

Role models (education & industry)

"Many women don't have access to roles or opportunities that their male counterparts have unless they have a sponsor. Unfortunately, I have seen many capable women passed over due to the lack of exposure and image. As an engineering student, I was one of three women in the program. There was a lack of support and resources from the male students and faculty members. I was excluded during most of my undergraduate program. This type of isolation was difficult to deal with and was reflected in my grades. I was able to finish my degree because of the strong support I had from family and friends. I knew I was the first and needed to see it through. This is why I am dedicated to helping and supporting students."

"My sister was an engineer and she inspired me to become one. She married and five years into her career she had twins and decided to leave the workforce to raise her children. This was her personal decision, but a dilemma I'm sure is faced by many women in engineering."

Industry Settings

Perseverance & Creativity

"My position requires making many decisions every day that are often challenged by my male counterparts. It takes critical thinking skills and self-confidence, not arrogance, to continue along the path that makes the right decision. This has often been challenging through my social and education process, as well as in in my career decisions, as I have always been in a male-dominated environment. It took longer hours and more commitment to outcomes for me to accomplish the same as my male peers."

"A former advisee and mentee, a female Civil Engineering graduate chose to enter the workforce in the restaurant construction business for a major national construction firm. She repeatedly spoke about the hostility of having to function and thrive in a male-dominated environment, amidst cat calls and other visible signs of disrespect. Despite her experiences, she thrived and led several successful projects, forming a tough skin in the process, only to eventually leave the field to earn a law degree."

"Data show that women commercialize their academic research at a much lower rate than men. We brought my husband onto the team to complete a technical subtask. When he attends networking events with us, the dynamics change entirely. After initial introductions, others will seek him out to ask questions about the technology/product, while my female business partner and I are still not being approached. He, of course, doesn't know the answers and so he'll direct the person to me. He serves as the lure and in this stage of the business; this has been essential for our business to move forward."

Chilly climate/Harassment

"As a new college engineering grad hired at a major corporation, I initially worked the night shift with a group of technicians and was sexually harassed. After speaking with my family and brothers, I found the courage to report it and it was resolved."

"As a young engineer working in a laboratory with all men, listening to their male-dominated conversations was extremely difficult."

"In the mining industry, many women engineers do not have bathrooms available to them and have to walk miles, back to the secretary block to use the restrooms whereas the men have toilets right outside their offices."

"While working as an engineer, my project manager called me "sweetheart" at a meeting in front of our client."

Appendix D: Four Frames Model

The Four Frames in Brief: Changing Organizational Culture A Distillation of Kolb et al. (1998)

A. Equip the Women/Prepare Women for Success

The most traditional and popular approach to achieving gender equity is equipping participants with the resources to compete as equals. In practice, this means remediating women through training programs and skills development. It recognizes that organizations are flawed, but offers opportunities for individual women to acquire the skills to compete without changing the policies and structures in place.

B. Heed Policy and Law

The second frame focuses on structural barriers, with the "deficiencies" of individual women no longer viewed as the source of the problem. Rather, structures of opportunity create an uneven playing field, with interventions introduced from outside the institution that are both legalistic and policy-based .Implementation of organizational accommodations reduce structural disadvantages to promote recruitment, retention, and graduation of women. But such actions are directed to the formal organization, not the informal rules and practices that govern behavior. Therefore, they are insufficient for achieving lasting gains because they do not change campus culture.

C. Value Differences

The third frame places gender equity within the context of broader diversity. It is thus more systemic about valuing differences of all kinds and focuses on practices anchored in evaluation criteria. But it fails to break down gender stereotypes and challenge the hierarchical valuing of what is "masculine"—assertiveness, decisiveness, competitive—over what is "feminine"—people skills—in producing desired organizational results. In short, valuing differences, even celebrating them, does not penetrate the culture or change the behavior of those who dominate it.

D. Re-envision Work Culture

The fourth frame integrates the first three frames and sees the organization as inherently gendered. In other words, the organization is unconsciously biased by privileging traits socially and culturally ascribed to men while devaluing or ignoring those ascribed to women. This frame is difficult for many to acknowledge because what has always appeared neutral and inconsequential is now re-conceived as an unearned advantage that differentially impacts men and women inhabiting the organization. To operate on the organization at its most fundamental level of practices requires an ongoing and iterative process of examining, experimenting, and learning. This takes time, demands commitment, and may sacrifice short-time organizational strife for enduring gender equity. It ties policies to their use in practice, entertains alternative strategies for success, and lays bare conceptions of ideal workers, exemplary managers, and strong leaders. Most organizations are not ready for such a cultural transformation, but the fourth frame imagines the possibilities that will benefit women, men, and the organization as a whole.

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Appendix E: More Women are Pursuing Engineering Degrees, but Vast Disparities Remain

By Clemencia Cosentino & Amlan Banerjee

Introduction

The underrepresentation of women in engineering continues to be a national problem. In 2013, women comprised about 12 percent of practicing engineers and 20 percent of engineering degree recipients, although they accounted for nearly 57 percent of degrees awarded in all fields (NSF 2015; AAUW 2015).1 Disparities are even more striking for some ethnic groups: Black and Hispanic women account for fewer than 2 percent of engineers and women from underrepresented minority groups (URMs) account for only 3 percent of undergraduate degrees, although they comprise 18 percent of the general population (AAUW 2015).

This lack of diversity in engineering education and the profession is a national problem, as it may hamper the creativity and synergies in teamwork that lead to the innovations needed to increase productivity and foster new discoveries. It also signals a missed opportunity—the opportunity for women to contribute to a workforce that is projected to suffer from severe shortages (unless these shortages are addressed through immigration or global outsourcing) (PCAST 2013). From an equity standpoint, observed disparities also signal lack of opportunities for women to benefit from high paying engineering jobs.

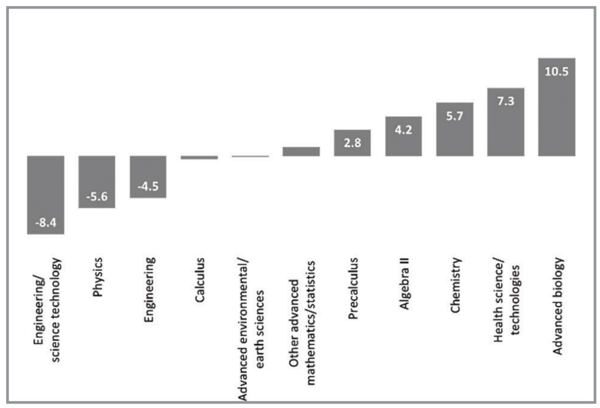
In this paper, we rely on the existing literature and our own analysis (described at the end) to present an overview of (1) women's preparation for, and interest in entering engineering studies, and their representation (2) in engineering education programs, (3) among engineering degree holders, and (4) in the engineering workforce.

1. Female high school graduates are prepared to study engineering, but are neither well exposed to the field nor likely to enter college interested in engineering

Girls are likely to complete high school having taken advanced mathematics, but not engineering courses.

Despite not being as likely as boys to enjoy math and science2, girls are as likely or more likely than boys to earn high school credits in advanced mathematics courses (such as precalculus and calculus) needed to pursue studies in engineering (Cunningham et al. 2015). However, girls are less likely to have taken courses in engineering or engineering/science technologies in high school; the same is true of physics and computer and information science. In contrast, they are more likely than boys to have earned credits in other advanced science and health-related courses, namely, biology, chemistry, and health science (Figure D.1).

Figure D.1. Difference in the percentage of female versus male high school graduates who earned credits in science, technology, engineering, and mathematics (STEM) courses



Source: Cunningham et al. 2015. Analysis based on the 2009 National Assessment of Educational Progress (NAEP) High School Transcript.

Women are less likely than men to enter college intending to major in engineering.

Among first-year college students, women are less likely than men to indicate that they intend to study engineering. A recent analysis by the American Association of University Women (AAUW) suggests that the gender gap in field of intended studies is largest in engineering compared to other STEM fields. Men are three times more likely than women to report intending to major in engineering (6 percent of women versus 19 percent of men) (AAUW 2015). In other words, 1 out of 5 men versus 1 out of 17 women enter college intending to pursue their studies in engineering. This holds by ethnicity as well, although the size of the gender gap within ethnic groups differs.

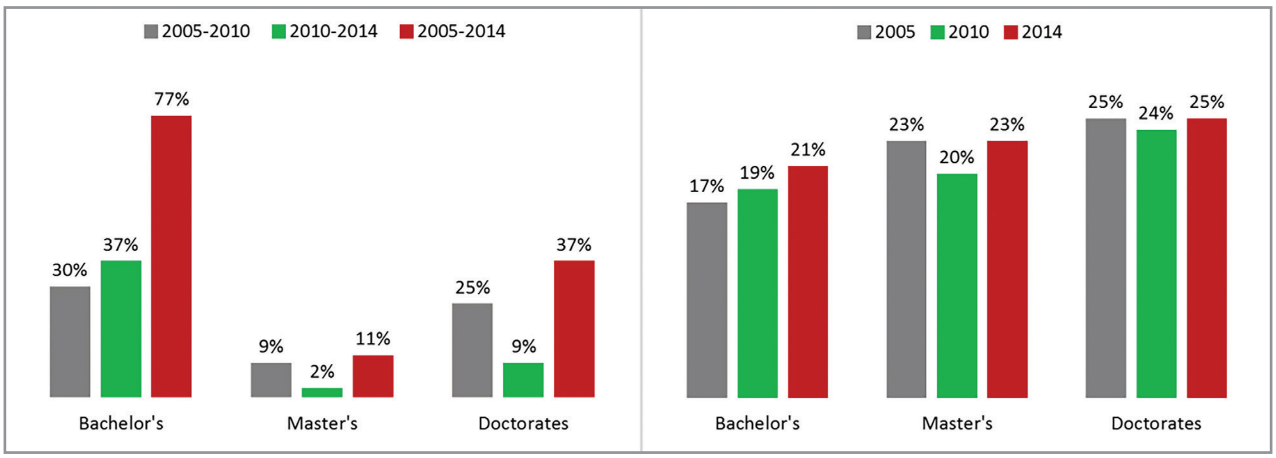
2. Women's enrollment in engineering education is growing

The number and share of women enrolling in engineering programs of study has increased over time.

Overall, the number of women enrolling in engineering bachelor's degrees grew by 77 percent over the past decade (2005 to 2014), while increasing by 11 percent in master's degrees and 37 percent in doctoral degrees over the same time period (Figure D.2.a). However, due to increasing enrollment among men, the share of women in engineering bachelor's degree programs grew modestly by 4 percentage points between 2005 and 2014, and remained unchanged in master's and doctoral programs (Figure D.2.b). Consequently, as of 2014, women constitute about 21 percent of bachelor's, 23 percent of master's, and 25 percent of doctoral students in engineering.

Figure D.2.a. Growth in enrollment among full-time female students

Figure D.2.b. Women as a share of full-enrollment



Source: Authors' analysis of ASEE profile surveys of universities.

Women's enrollment grew in nearly all engineering-related bachelor's degree disciplines.

In engineering bachelor's degree programs, the largest growth in women's enrollment is observed in disciplines where women are well represented in the baseline year of 2005 (defined as having a share of women that is above the national average for the given program). These fields include environmental, biomedical, chemical, biological/agricultural, and metallurgical/materials engineering. Computer science and mechanical engineering, two disciplines that had low representation of women in 2005, also experienced significant growth over time; in these cases, the small baseline numbers likely resulted in large percentage increases. With some notable exceptions, these findings hold for master's and doctoral degrees, although growth in women's enrollment in these degrees was not as marked as with bachelor's degrees. Indeed, in some fields—such as electrical and industrial/manufacturing—women's enrollment in graduate programs declined between 2005 and 2014.

Some disciplines enjoy growth in women's enrollment across bachelor's, master's, and/ordoctoral degrees.

Between 2005 and 2014, women's enrollment grew across bachelor's, master's, and doctoral degrees in two disciplines—mechanical and mining engineering. Women's enrollment also grew in bachelor's and master's degrees (in biomedical and petroleum engineering) and in bachelor's and doctoral degrees (in environmental and biological and agricultural engineering). Many other disciplines experienced growth in the representation of women only in bachelor's degrees.

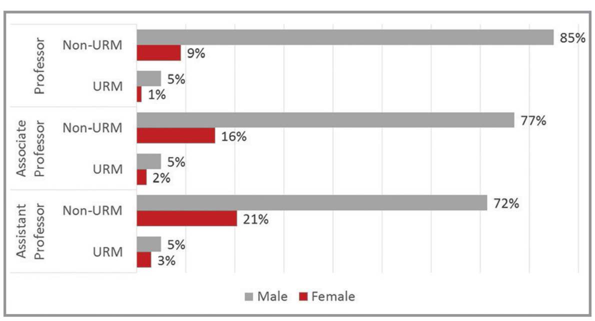
3. Once they enroll, women are as likely as men to graduate

Overall, women who enroll in engineering are as likely to graduate in engineering as their male counterparts, but continue to be underrepresented among engineering degree holders due to low participation of women in engineering studies (Cosentino and Deterding 2009).

As of 2014, women are as likely as men to graduate in most undergraduate engineering disciplines.

The parity index of female to male graduation in engineering improved over time across most disciplines at the undergraduate level (Figure D.4). In 2010, the parity index was below 1 in ten disciplines, indicating that women were less likely to complete their degrees than men. By 2014, this was true only in seven disciplines. In fact, some of these disciplines experienced significant improvements in the parity index (engineering (general), electrical/computer, and architectural engineering), while two experienced significant drops (engineering management and engineering science and physics).

Figure D.4. Percentage of engineering disciplines with a parity index of 1 or greater

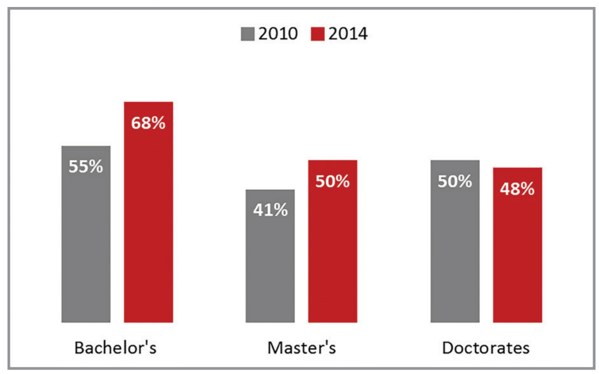


Source: Authors' analysis of ASEE profile surveys of universities.

4. Women are less likely than men to enter academia or remain in the engineering workforce over time.

Very few women engineers—and particularly URM women—join academia.
As of 2013, women make up only 23 percent of assistant professors, 17 percent of associate professors, and 9 percent of full professors in engineering. With time, and assuming women are promoted as fast as men, the share of women will likely grow among associate and full professors. But even if this is the case, it is unlikely to increase by much given the low numbers of women engineers in academia. Even more striking is the share of URM women in academia—3 percent of assistant professors, 2 percent of associate professors, and one percent of full professors in engineering (Figure D.5).

Figure D.5. Percentage of engineering faculty by gender, ethnicity, and academic rank



Source: AAUW 2015. Note: Estimates for 2013.

Most engineering graduates enter the engineering workforce, but women are less likely to be retained than men.

Based on 2010 data, about 65 percent of women (and men) holding engineering degrees obtain jobs in engineering after graduation, but with time women are more likely to drop out of the profession than men. Consequently, 30 to 35 years after first getting a job in engineering (in their 50s), women are half as likely to be working as engineers as men (19 versus 39 percent among men; AAUW 2015).

Inspire, educate, and mentor in a nurturing environment

To summarize, this paper shows that important progress has been made in preparing women to study engineering and in increasing their representation in engineering programs of study. Women are likely to complete the mathematics and science courses needed to pursue a degree in engineering, and the number of women enrolling in engineering has grown drastically. In addition, those women who pursue engineering studies are as likely as men to complete them. However, women are still unlikely to enter college intending to pursue a degree in engineering and continue to be severely underrepresented in engineering education programs, academia, and the profession.

The recent AAUW study—Solving the Equation (2015)—reviews the literature to provide a detailed analysis of potential explanations for the underrepresentation of women in engineering (and computer science). The authors conclude that the solution to this problem lies in "create[ing] environments that are truly welcoming for women." This is true. But findings from this analysis suggest that this solution needs to be complemented with an active approach to engaging girls early to expose them to a wide range of engineering fields and work opportunities and to inspire them to pursue a career in engineering. Reaching down to K-12 education to provide this exposure will be just as important as ensuring that the right environment is fostered in K-12 and awaits them both in higher education and in the workforce.

Data

This analysis is based on the ASEE profile surveys of universities. The ASEE profile survey is a voluntary, web-based survey administered in the Fall of every year to all (530) colleges and universities in the United States offering at least one full-time graduate engineering program or ABET accredited undergraduate engineering program. The data needed for this analysis are available since the 2004-2005 academic year. We report the 2004-2005 year as the baseline year and approximately five-year intervals thereafter (2009-2010 and 2013-2014 as the most recent year available). For the years used in this analysis, an average of about 65 percent of institutions responded to the survey. With a response rate of 90 percent, findings are representative of doctoral degree granting institutions in the U.S., but may not generalize to smaller master's degree granting institutions (nearly 50 percent responded) or baccalaureate institutions (40 percent responded). All results reported are statistically significant at the .05 level.

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

By Lecia Barker

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. 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 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."*

- 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.

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 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.

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 Engineer-Girl, 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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Appendix G: The University Experience: Retention to Degree

By Rachelle Reisberg

Lack of Progress for Women in Engineering (WIE)

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

Questions… and more Questions

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

Numbers

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

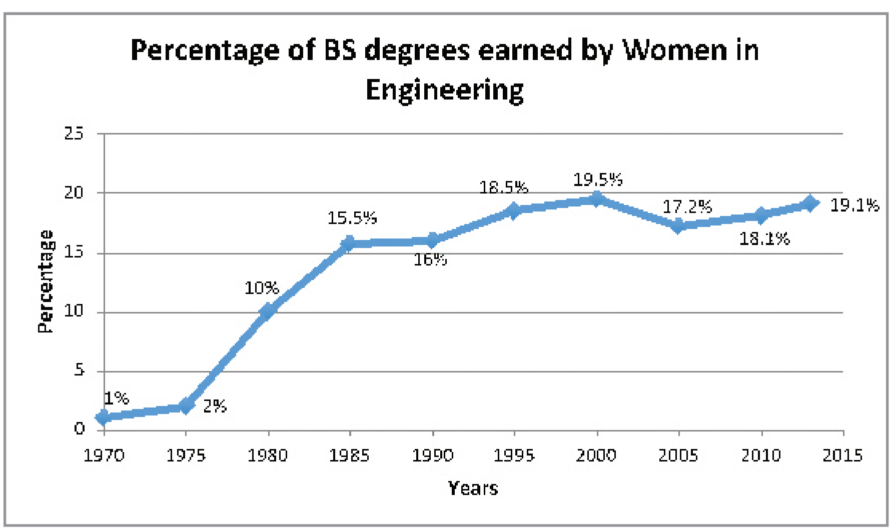

Figure 1 shows the percentage of bachelor's degree earned by WIE over the past four decades.

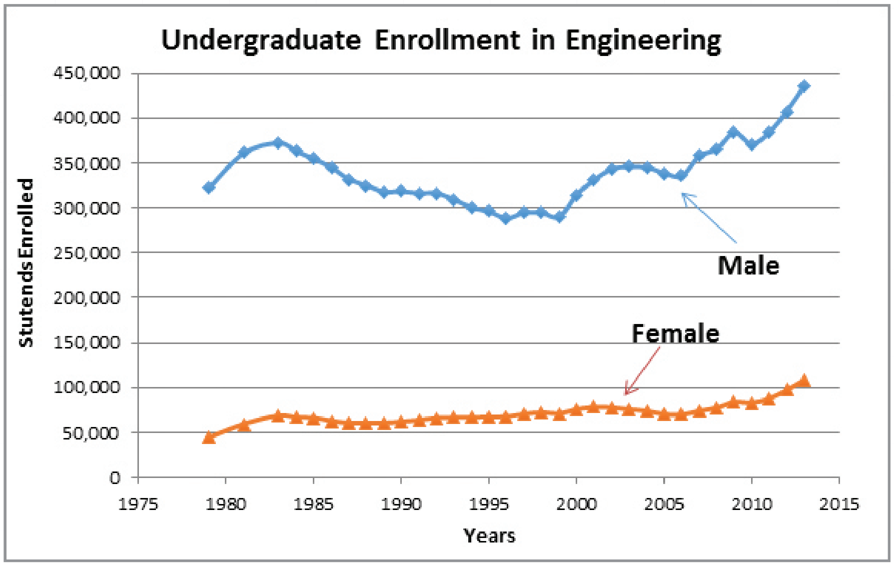

Figure 2 shows enrollment trends in undergraduate engineering from 1979 till 2014

Key Factors

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

Welcoming Environment

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

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

The personal adjustment can be due to students entering a new community, living away from home, being given more freedom and responsibilities. In the freshman year, living learning communities are proven to support women and provide a welcoming environment. Stassen (2003) explored the effect of living learning community models on a variety of students with different experiences and academic performances. They strengthen connections between the learning environment in the classroom and the living environment in the residence hall. Learning communities have received considerable attention by higher education scholars and practitioners since they encourage student engagement in educationally purposeful activities inside and outside of the classroom. They both challenge and support students. Tinto's study (2003) showed the impact of learning communities on student success, and discovered that learning communities not only help enroll a cohort of students in classes together, but they also help to involve students both socially and intellectually in ways that promote cognitive development and shared responsibility.

Are we putting enough funding into sustaining and expanding these successful programs? Do we do enough to promote student involvement in these as students make enrollment decisions?

Social Relevance

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

In a recent article in the NY Times (2015), author Lina Nilsson suggests that one solution to greater female enrollment into engineering could lie in universities introducing societally meaningful content. Several universities that offer these types of programs and courses report significant increases in the number of women participating. Student organizations and clubs such as Engineers Without Borders see similar patterns. This indicates that another key factor to increasing the number of female engineers may be reframing the goals of engineering research and curriculums to be more relevant to societal needs.

A recently released report by the American Association of University Women, AAUW (Solving the Equation) draws on a large body of research that explores the factors underlying the underrepresentation of women in engineering and computing, including stereotypes and biases. This report also points out that a factor "that may contribute to girls and women choosing to pursue fields other than engineering and computing is the small but well-documented gender difference in desire to work with and help other people."

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

Classroom and Curriculum

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

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

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

Contextual Support

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

Lent et al (2003) in their research on Social Cognitive Career Theory (SCCT) looked at the contextual supports and barriers related to the pursuit of engineering majors and found that environmental factors like family support and financial constraints were linked to choice of goals and actions (i.e., persistence in engineering) indirectly through their self-efficacy.
Raelin et al (2014) in a pathways model described that academic achievement, academic self-efficacy, as well as contextual support (e.g. from mentors, advisers, financial aid, family, friends, teachers, professional clubs, campus life, and living-learning communities) were critical to retention, especially to women. This support was found to be particularly important to women in engineering and appeared to serve as an inducement to stay at the university and in the major. It was found that women took significantly more advantage of support in all forms indicating that women utilize resources if provided.

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

Opportunities Outside of the Classroom

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

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

Could programs be provided that provide comparable, alternative experiences?

Leadership Opportunities

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

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

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

Role Models

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

Author Joan Williams (2015) discusses gender bias against women of color in science in her latest article "Double Jeopardy" featured in SWE Advance. The study from the Center for WorkLife Law at UC Hastings by Professor Williams et al (2015) combined in-depth interviews of women of color in STEM with survey results from both women of color and white women. The study found that there is pervasive gender bias with African American women reporting that they are more likely to have to prove themselves over and over again; and Latinas reporting of being pressured to do administrative work for their male colleagues (such as organizing meetings).

How does this affect undergraduate WIE? Do they see role models in the work place facing this gender bias and stereotyping and get discouraged? Are they worried that they will face similar bias and stereotyping? Can we do more during their university experience to prepare them (e.g. career management classes, career services offices, career mentoring programs)?

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

Can we influence the practices of the companies that recruit our female students?

Parallels with Underrepresented Minority (URM) Students

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

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

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

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

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

Summary

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

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

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

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Appendix H: Promising Practices in Engineering Education (as Viewed through Four Frames)

By Daryl E. Chubin

"Change" as a Problem

Changing organizational culture is a popular mantra among STEM researchers and reformers. Increasing participation of women in engineering is only one of many challenges that organizations face. In this paper, a framework adapted from the management literature (Kolb et al., 1998) for decomposing approaches to organizational change is presented. As a lens for viewing practices that reflect healthy, welcoming, supportive, and evolving environments for women in engineering, the "four frames" help to categorize what has been tried—and worked—in changing the engineering education experience.

The emphasis here is on transforming *organizations* to be a continuing source of production both of skilled professionals and new knowledge—the hallmarks of any discipline. As economist Scott Page's *The Difference* (2008) has shown, a focus on diversity of all kinds demonstrates the power of diverse teams to perform, innovate, and succeed. The adaptation of the four frames to engineering (Holloway, 2014) likewise serves to clarify the difference between individual and organizational behavior, particularly the creation of inclusive learning environments.

The value of the four frames is their clear delineation of practice—how, in the present application, the problem of underrepresentation of a category of participant in engineering, women, has been conceptualized and studied in different ways. Each frame has a distinctive focus that constrains measurement and illuminates the problem, but only one frame combines foci and harbors the potential for transformation of organizational behavior. As has been observed, "In engineering, a field in which the educational and professional environments are closely linked, professional role confidence starts to develop as women and men begin their engineering education" (AAUW, 2015: 86).

This paper therefore is presented with the intent of *starting* a discussion. It is not comprehensive and does not present data on gender underrepresentation. It uses the four frames as a classification tool. The literature selected and described conforms to the focus of a frame and illustrates a promising practice for engineering. The inclusion of citations below therefore is heuristic and provocative—each is context-specific and may not satisfy some readers' standards of proof. Determining what is "promising," though anchored empirically, is still inescapably an art.

Four Frames for Understanding Organizational Change

As AAUW (2015) reminds us, "we all hold gender biases shaped by cultural stereotypes in the wider culture, that affect how we evaluate and treat one another. Explicit gender bias may be declining, but "implicit or unconscious bias remains widespread." The challenge, then, takes many forms: to identify, measure, deter, rehabilitate, etc. Changing culture demands a collective response to a pervasive problem.

Each of the four frames identifies problems to be studied and acted upon. All advance our knowledge of barriers to the participation of women in engineering. But each attacks the problem differently. The accretion of what is learned represents a partial or whole strategy of what can be done to mitigate the problem. By assembling these empirical nuggets, we gain a fuller sense of what is possible, transferable, and adaptable to new settings.

The four frames are outlined below, distilling Kolb et al. (1998) in the *italicized* paragraphs below, followed by the context for the problems each frame addresses and what later will be explored through examples derived from the literature (primarily, but not solely, on engineering education). No single example produces a "promising practice." By accumulating new insights through these examples, we recognize how combining them in creative ways helps to promote gender equity and reduce the underrepresentation of women all along educational pathways to a career in engineering.

A. Equip the Women/Prepare Women for Success

The most traditional and popular approach to achieving gender equity is equipping participants with the resources to compete as equals. In practice, this means remediating women through training programs and *skills development. It recognizes that organizations are flawed, but offers opportunities for individual women to acquire the skills to compete without changing the policies and structures in place.*

A majority of empirical studies have historically adopted this frame—some variation on "fix-the-student-and-women's-representation-will-increase." Brainard and Carlin (1998) found no such impact a generation ago. Yet the ability to control a small set of variables through data-collection via survey or observation using pre-post designs or control-group comparisons yields changes in individual behavior, e.g., retention or persistence, that can be associated with a purposeful manipulation of treatment. Sometimes, these observed differences can be explained, especially with longitudinal data. For example, Fox, Sonnert, and Nikiforova (2011) have catalogued "individual obstacles" addressed by 49 undergraduate WEPAN programs. While various department-based activities can be influential, they tend not to disturb the learning environment in an enduring way. Retention and graduation rates may be affected by such factors as admission policies, school missions, and geographic area that are beyond a program's control (Staying Power 2015). Frame 1 studies show that women can compete, excel, adapt, and succeed like any other student in engineering, but that broader organizational strategies are needed to translate important findings into structural change.

B. Heed Policy and Law

The second frame focuses on structural barriers, with the "deficiencies" of individual women no longer viewed as the source of the problem. Rather, structures of opportunity create an uneven playing field, with interventions introduced from outside the institution that are both legalistic and policy-based. Implementation of organizational accommodations reduce structural disadvantages to promote recruitment, retention, and graduation of women. But such actions are directed to the formal organization, not the informal rules and practices that govern behavior. Therefore, they are insufficient for achieving lasting gains because they do not change campus culture.

Gender- and race-conscious policies, contrary to much commentary, are legal remedies under federal statutes, to past discrimination. The key to their use, however, requires carefully crafted justification tied to institutional mission statements (Burgoyne et al. 2010: 23-24). Virtually all such statements in higher education explicitly cite access, diversity, and/or inclusion as essential to the achievement of educational objectives. The burden is on implementation and documentation by public and private institutions that receive federal funding.

Title IX of the Education Amendments of 1972 is a law prohibiting discrimination based on sex in educational programs that receive federal funds (Sevo ND). Historically, its application outside of athletics, i.e., equal opportunity for women to participate in collegiate competitions, has been limited. Its extension to participation in STEM dates to the mid-oughts (Sturm 2006), but few compliance reviews have been conducted. This all changed in 2011 when, after 40+ years of Title IX, the U.S. Department of Education announced that any college or university receiving federal aid will be held accountable for failing to deter and punish campus sexual assaults. Like all policies, however, enforcement tends to lag the offending behavior. Not surprisingly, institutions of higher education have struggled with enforcement, and today more than 100 are under investigation for alleged mishandling of cases (Wallace 2015).

The problem is even more complex. University policies vary on how to report and evaluate cases of student assault. And many institutions lack Title IX coordinators (Fabris 2015; Moody-Adams 2015). How to ensure a fair hearing of those accused of assault, as well as establishing a causal link more generally between drinking and violence, is a challenge (New 2015). The larger issue is this: such ambiguity contributes to a climate of discomfort, if not fear, among undergraduate women. It interferes with learning, adding yet another barrier to those confronting women in STEM disciplines such as engineering.

C. Value Differences/Value Diversity

The third frame places gender equity within the context of broader diversity. It is thus more systemic about valuing differences of all kinds and focuses on practices anchored in evaluation criteria. But it fails to break down gender stereotypes and challenge the hierarchical valuing of what is "masculine"—assertiveness, decisiveness, competitive—over what is "feminine"—people skills—in *producing desired organizational results. In short, valuing differences, even celebrating them, does not penetrate the culture or change the behavior of those who dominate it.*

Valuing difference continues to shift the focus of analysis to the environment. Researchers must search for evidence of change in climate beyond single classrooms or category of student. Measures of faculty behavior, from notions of skilldifferences between male and female students to novel pedagogies that support all learners, are valued in this frame.

AAUW (2015) reports that "women are more likely than men to prioritize helping and working with other people over other career goals. . . . By emphasizing the wide varietyof expertise necessary to be a successful engineer or computing professional including less stereotypically masculine skills such as writing, communicating, and organizing—college engineering . . . can help young women see engineering . . . as [where] they belong." Others refer to a redesigned engineering curriculum as integrating the liberal arts and encouraging team-teaching, supplying the "missing basics" of engineering education, in the words of the president of Olin College of Engineering, "which include design and creativity, teamwork and interdisciplinary thinking, and understanding the social, political, historical, and economic context of a project" (Bordoloi and Winebrake 2015: A25). The challenge, of course, is buy-in from faculty, which a handful ofdepartments of Engineering Education nationally have achieved. The result is a greaterarray of classroom pedagogies, more faculty engagement with students, and a more explicit social relevance. At the very least, it is one promising model (Benson, Becker, Cooper, Griffin, and Smith 2010). The student composition shows the result: more diversity of all kinds.

D. Re-envision Work Culture

The fourth frame integrates the first three frames and sees the organization as inherently gendered. In other words, the organization is unconsciously biased by privileging traits socially and culturally ascribed to men while devaluing or ignoring those ascribed to women. This frame is difficult for many to acknowledge because what has always appeared neutral and inconsequential is now re-conceived as an unearned advantage that differentially impacts men and women inhabiting the organization. To operate on the organization at its most fundamental level of practices requires an ongoing and iterative process of examining, experimenting, and learning. This takes time, demands commitment, and may sacrifice short-time organizational strife for enduring gender equity. It ties policies to their use in practice, entertains alternative strategies for success, and lays bare conceptions of ideal workers, exemplary managers, and strong leaders. Most organizations are not ready for such a cultural transformation, but the fourth frame imagines the possibilities that will benefit women, men, and the organization as a whole.

The transforming culture is both a recognition of accumulated lessons from the three prior frames plus a self-conscious inventory of practices that expose the gender biases inherent in the organization and its people. Only then can the reconstruction proceed—or not. Knowledge is not implementation. Campus communities feature a churn in membership—administrators, faculty, and students come and go. It is unclear whether shedding organizational history is easier for newcomers or those who lived through previous phases. Again, measuring the evolution of such big changes requires a commitment to learn and replace habits and customs, rewards and punishments, with new ones. This cannot be legislated, yet must be scaled to affect more than one person or campus unit at a time (Fox, Sonnert, and Nikiforova 2009).

Seen through any of the four frames, programs develop, justify, and implement practices. These can be considered component behaviors hypothesized to positively impact categories of students that experience them. Today's categories have proliferated—at-risk, first-generation, low-income, LGBT—have joined the historically underrepresented—minorities, women, etc. With the passage of time, our criterion of positive change should become even more rigorous, with indications that the intervention dissolves any measurable difference in performance between the majority and named category of student. Such an intervention, upon replication in other settings, is a candidate for adaptation as a *promising practice.*

Applying the Four Frames to Undergraduate Engineering Education

The four frames outline a typology of action that can be applied to any broad discipline like engineering. They also form a continuum of actions that extend from episodic, ad hoc interventions affecting individuals at a particular time and place such as a classroom, to a breadth of behaviors that reflect the force of influences outside both the discipline and the institution. With the passage of time, the culture of the institution may be measured as "changing" or in the throes of a transformation process. Any "transformation" requires a "maintenance plan." It is not simply "reached" as a state of grace for all time.

In the spirit of the four frames, the following shorthand is offered as guides to the literature:

- **equip the student**
- **enforce policy and law**
- **embrace difference**
- **evolve the organizational culture.**

Each of these frames not only implicates different actors working independently or in concert, but also demarcates research that illustrates the most promising of practices to effect change as defined within the frame. The question to be asked is "how?"

The answer to how is a "promising practice." This notion is drawn from the term "promising programs" popularized more than a decade ago by a public-private initiative known as BEST—Building Engineering and Science Talent. In the report, *A Bridge for All* (BEST 2004), 124 university-based, undergraduate-centered STEM programs operating in the United States were reviewed, using the National Science Foundation (NSF) model of employing a face-to-face panel of experts drawn from a range of relevant disciplines.

BEST did not focus solely on women, but rather on the conditions for broadening participation for all in undergraduate STEM. Among the eight "design principles" BEST (2004: 5) identified, six are essential—leadership, engaged faculty, peer support, enriched research experience, and bridging to the next level. Each subsequently gained empirical support (summarized in Chubin and Ward 2009), demonstrating the benefits of organizational changes, especially in orientation to those underserved by disciplinary and campus-wide practices. The application of the design principles is tantamount to evolving the culture of engineering to serve all. This is Frame 4 (see below). But such change takes time, at least a decade, as BEST found.

Under the four frames, learning outcomes may reach parity by gender, but what about the conditions under which the learning occurs? AAUW (2015) calls this "a gendered sense of fit: [a] narrow math and science emphasis disproportionately disadvantages women because it emphasizes male-stereotyped skills while devaluing skills that are gender neutral or female-stereotyped, such as writing, communication, and managerial skills." This relates more to environmental factors captured subjectively by climate surveys, illuminating the difference between individual characteristics such as "grit" (persistence or resilience, Hoerr 2013), and more contextual factors such as the aforementioned critical mass that can change the classroom dynamic.

In the following, each frame is illustrated by literature that captures successful interventions that go only so far. The more comprehensive they get with the addition of other frames, the closer a different organizational culture becomes visible. While the purpose is not to cite an array of sources that offer strategies and solutions for underrepresentation of women in engineering, tracing earlier signal works informing current thinking is needed.

The method for selecting these sources varied from suggestions by WIE Planning Committee members, retrieval of recent literature via keyword searches (gender, intervention, engineering, STEM) from compiler sites such as Web of Science, and my search of the empirical literature contained in online sites such as Assessing Women and Men in Engineering (AWE). Of particular utility was an examination of columns appearing in the 2014 and 2015 issues of ASEE Prism. Highlights that explicitly included a gender dimension are noted here as a leading edge of practices. They hold promise as interventions empirically assessed and generalizable to a variety of higher education settings. By appearing in Prism they also reflect the latest forward thinking of practicing engineering educators. They are presented as a series of vignettes—a capsule of findings and commentary suggesting they be considered for further action.

Equip the Student

Riley (2015) has argued that "We must make the engineering bachelor's flexible, family-friendly, and resource-rich. We must shift the balance of power between two- and four-year schools: those who know low- income, first-generation students best must be the ones to lead four-year institutions in designing learning experiences, curricula, degree plans, and support structures to see them through to a career in engineering.

The two- to four-year college transition has been a staple of the problems besetting engineering (which admittedly is more successful effecting transfer than other STEM disciplines). With a growing cadre of diverse, first-generation students today beginning their higher education in more affordable, closer-to-home two-year colleges, four-year institutions must redouble their efforts to accept, support, and help transfer students succeed. This is done not merely with articulation agreements, but through student-centered collegial exchanges negotiated by faculty and their departments (Coleman, Lipper, Keith, Chubin, and Taylor 2012).

AAUW (2015) finds that "trying to recruit girls and women into existing engineering and computing educational programs and workplaces has had limited success. Changing the environment . . . appears to be a prerequisite for fully integrating women into these fields." Practices operate in micro climates that vary among faculty and student classroom composition. The culture of the classroom is within the purview of the professor. Drawing on resources from the outside, or adjusting pedagogy based on one's own experience, makes the potential for change real albeit piecemeal. For the student, gaining benefit is luck of the draw, i.e., innovative teaching and learning may be practiced in only a few classrooms (typical of Frame 1).

1. *Classroom Pedagogies.* Peer-led team learning, the flipped classroom, just-in-time teaching, and interactive learning strategies are examples of NSF-funded instructional innovations to improve STEM student outcomes (Chubin 2013). Of particular note for the retention of women in engineering is the classroom-based ENGAGE project (*www.engageengineering.org*) begun in 2012 and now operating in 72 engineering schools. Of the three primary ENGAGE strategies—everyday examples, faculty-student interaction, and spatial visualization skills—the latter has a decided gender dimension. As Metz, Donohue, and Moore (2012) explain, "significant gender disparities exist on spatial-skills test performance and . . . can directly affect perceptions of self-efficacy, especially in women and individuals from lower socioeconomic groups." Recent research shows that "spatial skills, like other cognitive skills, can be learned, and respond well to training."

A recent study of 120 undergraduate engineering students led the author to conclude that: "Overriding gender stereotypes sometimes requires creating 'microenvironments' that have more than gender parity. This may involve the occasional experience of working in small teams with a high concentration of female peers that encourage women to jump in, speak up and help their team solve technical problems" (Dasgupta in *EurekaAlert* 2015).

Yet others (Chachra 2015) suggest that demographic differences, such as gender, among engineering students don't necessarily mean that we need to design different experiences for each group. "Observed differences between genders reveal an axis along which the student experience varies; what we need to do, then, is design educational experiences that work for students along the entire axis," an example of the "universal design" principle—providing accommodations for people with mobility or other differences (as mandated by the 1990 Americans with Disabilities Act in the U.S.) makes things better for everyone. Dropped curbs are probably the best-known example.

The lesson here is the implementation of practices that help underserved students of all kinds surmount barriers that deter some from pursuing engineering as a career. It reminds us too that policy and law are can inform classroom practices, but are fruitless unless enforced. It is preferable to employ the practices we control in our educational context than tempt the punitive impositions of organizations on the outside. Better to be proactive, both professionally and pedagogically.

2. *Research Experiences.* A corollary of these cooperative learning tools is the exposure of undergraduate students to research (as detected by the BEST review of intervention programs). Nothing seems to "induct" undergrads into the prospect of a research career better than the hands-on experience of doing research as part of a team with graduate students, postdocs, and faculty. It promotes a key ingredient, self-efficacy, or the belief that one is capable and competent in one's skills to succeed in a STEM discipline. It is a significant predictor of both motivation and task performance, especially among minority and women students (Bandura 1986; Rittmaier and Beier 2009).

Undergraduate research experiences "can be life changing for a young person," Duke University NSF REU Director Martha Absher says, because they provide opportunities to work with professionals and solve real-world problems. Such challenges often spark "the confidence and drive to go on into higher engineering education and research" More than a decade of research has found that those with research experience—especially in the first or second year of college and across STEM disciplines, gender, ethnicity, and various institutional settings—are more likely to pursue graduate degrees. They also were more apt to report that a faculty member played an important role in their career choice (Daniel 2014). Thus, research is simultaneously an instructional tool, a recruitment device, and a gateway to the laboratory as a possible future workplace.

Enforce Policy and Law

To bring legal and policy considerations to bear on institutional behavior—not just faculty and not just women—changes the narrative from one of practice alone (Frame 1) to one of sanctions (Frame 2). It also puts empirical studies to the test of application, and in so doing, raises the stakes from "discovery" (as in new knowledge) to "advocacy" (acting to mitigate discrimination).

A prominent example was documented in Patricia Gurin's (2004) defense of affirmative action. Diversity was sustained as a compelling interest in the Grutter and Gratz Supreme Court admissions rulings. A key element of that interest is "critical mass," a concept derived from social science research suggesting that individuals from minority groups are easily marginalized when they are "only a small presence in a larger population, and as a result, may not contribute as fully to their learning environment. The same phenomenon is observed when women are a small presence" (Burgoyne et al. 2010: 27).

Critical mass demonstrates the power of numbers—a measurable, yet relative situation where there is more than one student with a visible difference, e.g., gender or color. In any context, being a minority can inhibit, even stigmatize, by creating a unwelcome climate for those who are perceived as different. Like diversity itself, critical mass is a context-specific construct. It is socially relevant because it points to a condition—the presence or absence of difference. Thus, increasing the number who are different—in a classroom, discipline, or workplace—recalibrates expectations of capability and a sense of belonging by faculty and students alike.

Classroom, and especially campus climate, of course, does not impact just engineering majors, but all women. It can infect the classroom and interactions outside. One response is to resist assimilating into an unwelcoming culture. That is to say, women may leave engineering for reasons unrelated to their ability, interest, or performance. That disengagement is the hallmark of stereotype threat (Steele 1997), a far cry from what law and policy are implemented to protect, but at the very core of affirmative action.

Affirmative action policies—not just Title IX, but Titles VI and VII of the Civil Rights Act of 1964 and the Equal Protection Clause of the 14th Amendment (Malcom et al. 2004)—are a tool to be used to counteract gender biases, unwitting or not, that keep women and persons of color out of engineering. In short, federal funding defines the public interest. Viewed through Frame 2, the burden in an academic context shifts from the enrolled student to the host educating institution.

Embrace Difference

There are pockets of diversity on every campus. But demographic scorekeeping by the institution only describes the composition of its student body, and perhaps where there are critical masses of minorities and women. It says nothing about the inclusiveness of the the campus and the organization's respect and comfort for difference. Some institutions cultivate inclusiveness through constituent units (colleges, centers, institutes, living-learning facilities), which can vary student experiences by diversifying or (in contrast to the norm) homogenizing the composition of participants. Three opportunities to embrace difference institutionally are curriculum re-design, modifying admissions criteria, and rethinking faculty hiring.

1. *Curriculum Re-design.* Besides reconfiguring the engineering classroom to account for student diversity and learning styles, the engineering curriculum can widen the circle of professionals to whom the student is exposed and offer different work contexts. Out-of-class experiences preview the kinds of work cultures one may encounter. Therefore, the teamwork, problem-solving, and on-the-job training that engineering is known for becomes a real-time test that may be a wild departure from classroom projects featuring skewed sex ratios and unsupportive peers. Cooperative education, either mandatory or optional, extends the internship experience to more than a single semester-long experience. Female co-op students in particular were found to have higher retention from year 2 to 4, enhanced academic achievement and self-efficacy, and overall sense of contextual support (Raelin et al. 2014). Co-op represents a curriculum that provides options—organizationally endorsed and faculty practiced—that value off-campus work. Co-op also succeeds in illustrating that what occurs in the work environment is possible in the educational environment. In the process, it inoculates against stereotype threat.

2. *Modifying Admissions Criteria.* Undergraduate admissions is typically centralized in a single office on campus. Faculty are detached from this process (unlike their involvement in graduate admissions decisions). Holloway et al. (2014) hypothesized that "If admissions policies have a significant role in the opportunity to become an engineer, changing such policies may play a role in increasing the representation of groups such as women and minorities in engineering." Using Institutional data from a public university for the years 2006-10, when the cutoff score for standardized math tests was removed as an admissions factor, the number of "women admitted to the College of Engineering increased and mitigation of gender bias was statistically confirmed." The research impact was a change in the admissions policy at this university.

A single data point, of course, does not suggest that this could be done at other engineering degree-granting institutions. It does signal, however, that control over undergraduate admissions might be better administered by the School of Engineering instead of a central university office. Put another way, even in this era of "holistic review" (Burgoyne et al. 2010: 28-35, 51-52), if the university resists amending its admissions policy in the face of evidence of gender bias, then should Engineering (or any other School on campus) argue for more decentralized admissions decision making authority?

3. *Rethinking Faculty Hiring.* ASEE (2014) has explored the relationship between gender diversity in the university faculty pool and the rate of female students graduating from bachelor's degree programs. Extracting faculty and graduation data between 2005 and 2013, ASEE found a correlation between the proportions of women faculty members and women's graduation rates in disciplines that traditionally have low proportions of female faculty. However, they did not find a similar correlation in disciplines that traditionally attract a high number of female faculty members, such as engineering management and environmental, chemical, and biomedical engineering.

Perhaps a key, both symbolic and substantive, is the presence of a female dean of engineering—a growing phenomenon. About two dozen engineering colleges are now led by a female dean. The perception of a woman as the locus of authority may be more powerful as a role model and guarantor of fairness than the dean's actual impact on the student's classroom experience. Extending this hypothesis further, one looks to woman presidents and chancellors who infuse this can-do attitude into their entire institutions, notably Maria Klawe at Harvey Mudd and Linda Katehi at UC-Davis, with an eye on inspiring women in STEM.

Another variation on faculty hiring is the "cluster hire" approach, which can increase interdisciplinary collaboration and improve diversity, campus climate, and faculty success (Urban Universities for Health 2015). While legally defensible, such hiring is akin to "target of opportunity" models that cannot be gender- or race-conscious, i.e., they must grow out of a publicly-advertised recruitment (Keith and Chubin 2011: 17-18).

Evolve the Organizational Culture

We know that Implicit bias and stereotype threat are environmental conditions that affect individual behavior. They infect the culture and typically cannot be traced to any one cause. That is why they are so difficult to root out even when identified. The scholarship of Valian (1998), Rosser (1990), and others can be seen as resources, if not precursors, of efforts to transform organizational culture. The epitome of a successful STEM-based effort is NSF-ADVANCE, the first women-centered professional development program aimed at transforming campus culture. The shift in emphasis is significant, from what women need to do to succeed to how the institution needs to change to encourage and support all. Especially in international comparisons, the first cohort of ADVANCE institutions (e.g., Michigan and Wisconsin, which date to the mid-1990s) are on a trajectory of thorough-going cross-campus structural change, far from complete but undeniably more than promising (Chubin, Didion, and Boku-Betts 2015).

Specifically, the collection of "best practices," either under the aegis of a campus program or its evolution as the behavioral norm, requires an embrace from top administrators to in-the-trenches personnel. Indeed, the BEST (2004: 6) analysis concluded that: (1) the components of effective programs should not be viewed as an a la carte menu but as a package; (2) outstanding programs have the capacity to acknowledge and learn from their mistakes; (3) what often sets best-in-class apart is not a difference in kind but in degree—the quality of teaching, mentoring, research opportunity, etc., that separates top producers of technical talent from other institutions; and (4) the next generation of scientists and engineers is being developed in an educational setting far different from the baby boomers that they will replace. New learning technologies, eroding boundaries between campus, home and work, and demographic shifts demand a keen understanding of the role that context plays in changing culture. According to the BEST criteria, the only institution to experience whole campus culture change was the University of Maryland-Baltimore County with the Meyerhoff Fellows Program as the catalyst.

Taken together, a regime of experimental interventions must demonstrate the support and success of all students, the reward of participating faculty, and a transformation in how the institution capitalizes on difference to achieve educational goals. Such integration, with diversity at the core, is transformative of the culture (Frame 4).

Catalyst has found that a vital ingredient for organizational culture change is breaking barriers to men's engagement. The three barriers are apathy, fear, and ignorance. But organizations limit men's awareness of gender bias by touting "the idea that they are wholly meritocratic and that their human resource policies and practices are invulnerable to bias. By perpetuating the myth of meritocracy and failing to institute checks and balances to limit bias, organizations can inadvertently decrease men's sensitivity to gender inequalities" (Prime and Moss-Racusin 2009).

A hallmark of ADVANCE and much corporate scorekeeping on cultural change within organizations is the use of diversity and inclusion benchmarks. Such metrics utilize institutional data augmented by periodic climate surveys to characterize movements beyond measures by human resource offices, individual academic units, or categories of personnel (Worthington, Stanley, and Lewis 2014). Monitoring change keeps organizational culture uppermost in everyone's mind and provides feedback on the effectiveness of promising practices.

Options for Action

Gleaning from recent (AAUW's Solving the Equation) and seasoned (BEST's A Bridge for All) reports, as well as the literature discussed above, here are a set of actions that different actors, all represented in this workshop, can take to move organizations toward Frame 4. This is an unvarnished act of advocacy focused on the "what" if not the "how." The options are presented in no particular order by category of organizational change agent.

Universities

- Identify "champions of diversity" on campus. These are visible scholars, especially men, with impeccable research records who are also known to mentor and coach women students toward careers in engineering, if not STEM more generally.

- Raise awareness about the costs of gender inequality, discourage zero-sum thinking, help men recognize their gender biases, and provide opportunities for dialogue both within and across gender groups.

- Institute gender-inclusive policies that defines sexual harassment, reduces work-family conflicts, and uses gender-neutral language in public documents—mission statement, job postings, internal communications—and as part of classroom decorum.

- Require the Implicit Association Test (*www.implicit.harvard.edu*) as a university-wide tool of self-awareness that helps to establish a "bias" baseline. Link administration of this tool to stereotype threat training.

Schools of Engineering/Departments of Engineering

- Conduct curriculum reviews that may result in reconnecting engineering with the rest of the campus through team-taught courses and dual-degree programs.

- Explore decentralized admissions by granting more discretion in applying supplementary criteria to those used in university admissions decisions (much like the practice in graduate program admissions).

- Consult with ABET on accreditation criteria to include diversity metrics for department faculty as well as student enrollment and degree completion.

- Revisit gender bias through climate surveys disaggregated by engineering department to allow for comparisons with School of Engineering norms.

- Commit to hiring and promoting women through the ranks of engineering faculty, chair, dean, and upper administration.

- Adjust recruitment and hiring procedures to ensure diverse searches, i.e., a pool with a diversity of candidates, and accountability for selections through the department chair and dean.

- Pair faculty mentors with new hires to provide a roadmap and guidance to career development.

- Ensure undergraduate contact early and often with non-faculty engineering professionals, especially female role models

- Encourage consultation of sources presenting ENGAGE-like everyday examples that brings engineering to life in the classroom. Similarly, Schools of Engineering could regularly bring novel research on classroom practices to the faculty. Linking adaptation of pedagogical innovations should become a consideration in promotion and tenure evaluation.

Federal Agencies

- Link Title IX compliance reviews on pending investigations to pre-award review after competitive proposal review has recommended new funding.

- Use evidence of sluggish hiring, retention, and advancement of hiring to trigger on-campus training by federal officials, even in the absence of Title IX or other discrimination suits. Recognize the top annual producers of women baccalaureates awarded in engineering (as a proportion of total degrees awarded and by institutional type). A Presidential Award modeled on Presidential Awards for Excellence in Science, Mathematics, and Engineering Mentoring (PAESMEM—for higher education faculty) or Presidential Awards for Excellence in Mathematics and Science Teaching (PAEMST—for precollege educators) could be created and administered by one of the R&D agencies.

Conclusions

Engineering writ large is a successful discipline as measured by enrollments, degrees granted, and market demand (entry-level positions and starting salaries). Other metrics, however, tell a different, more nuanced story highlighted above—gender disparities in admissions, retention unrelated to academic performance (lack of critical mass in particular fields, harassment, impediments to access and social relevance), and workplace biases. The reality is that success breeds inertia, not action. Why change—especially if such exhortations flow primarily from those wronged? AAUW (2015) reports that diversity-championing efforts are valued and approved when performed by white men, but disapproved when women and other underrepresented groups dominate. That is why it is vital that white males advocate (Ashcraft et al. 2013) for the action agenda proposed here. Any so-called special pleading must more accurately be seen on behalf of a socially-conscious engineering as a discipline and profession.

Organizationally, the overarching purpose of culture change is not merely to increase the success of certain members, but to reconstitute what they know and can do. To change an organization is to alter the character of the discipline it inhabits and the profession it renews. The Four Frames is thus a blueprint for action enabling progress toward leveling the playing-field in engineering education. But to do so, engineering education must continue to equip, enforce, embrace, and evolve.

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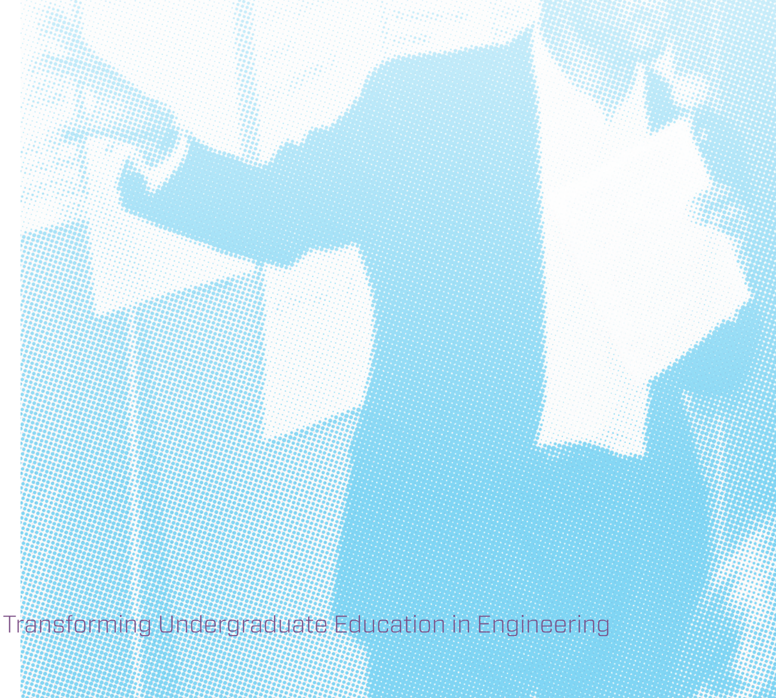

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