Effective Partnerships to Increase Female Attainment of Engineering Bachelor's Degrees

Elizabeth T. Cady, Norman L. Fortenberry, and Catherine J. Didion
National Academy of Engineering
Washington, DC

Abstract

The Engineering Equity Extension Service (EEES) aims to increase the number of women receiving bachelor's degrees, specifically in mechanical and electrical engineering, two of the largest disciplines with the lowest percentages of women. To further that goal, we recently collaborated with 19 university departments of mechanical and electrical/computer engineering. Departments received small grants to support their efforts as well as advice from our experts in gender equity and engineering education research. Each department developed and evaluated its own set of project activities. Departments conducted projects related to middle or high school outreach, undergraduate retention, faculty development, and/or academic and outreach material development, review and revision. Fourteen departments participated during the 2008-2009 school year and six departments are currently participating.

Introduction

Between 1970 and 2000, the percentage of engineering graduates who were women increased from 0.7% to 20%. However, considering that women received 57% of all bachelor's degrees in 2001, they remain severely underrepresented in engineering compared to other fields. Women are also underrepresented among recipients of advanced engineering degrees. Women received just over a fifth of master's degrees in 2001, and only 17% of doctorates in engineering that year (Freeman 2004).

Part of the problem is the lack of both introduction to and preparation for engineering courses in high school. Both males and females in high school are far less likely to take an engineering course than math or science courses. Although 6.7% of students (7.1% of males and 6.5% of females) in public schools took high school engineering courses in 1998, in 2000 those percentages had dipped to 4.3% of males and 3.5% of females (Freeman 2004). Although we lack data on the number of high schools that offer engineering courses, it is clear that relatively few high school students either have or avail themselves of the opportunity to learn and practice engineering skills compared to other school subjects. However, engineering courses are increasingly becoming part of secondary school courses, which exposes students to engineering and could lead to increased interest enrollment in engineering majors by those students (Katehi, Pearson, and Feder 2009).

Widespread engagement of high school science and math teachers to introduce engineering to their students could convey the message that all are equally welcome in engineering. A necessary first step may be the need to change the perceptions of engineering among the teachers themselves. For example, working with male and female high school physics teachers, Hoh and Toh (2007) employed a relatively simple activity that resulted in changed perceptions of engineers among the teachers. Workshop participants worked for one week in groups to research and present a report on a highly successful female electrical or computer engineer. Prior to the activity, all male and over 90% of female physics teachers drew a man when asked to draw an engineer at work. However, after researching, presenting, and watching other groups present information about female engineers, only 60% of males and 31% of females drew a male engineer. (Hoh and Toh 2007). Correcting misperceptions of engineering among teachers is crucial to enlisting their aid in encouraging women and underrepresented minority students to consider the field.

Camps and workshops for pre-college students can increase knowledge of engineering and encourage attendees to consider a major and career in engineering (Anderson and Gilbride 2007). Ryerson Polytechnic University instituted a week-long summer camp for girls in their final years of high school. The girls completed hands-on projects in several engineering disciplines and were able to interact with female role models in engineering and science. A cross-sectional survey was given to campers immediately following the camp as well as to women who had attended several years prior to the study. Many of the respondents to the immediate survey indicated their plans to major in engineering or science, and among those surveyed who had attended the camp one-, two- or three-years earlier (who were not given an immediate post survey), almost half the women were studying engineering. Almost three-quarters of the later group indicated the camp had influenced their choice of major (Gilbride et al 1999).

However, interest alone will not sustain persistence in an engineering major. When the immediate survey respondents in the previously cited study were asked how they overcame difficulties such as nervousness or frustration in classes, the majority indicated that their own hard work and determination got them past those barriers (Gilbride, Kennedy, Waalen, and Zywno 1999). This suggests the importance of building skills such as self-efficacy and metacognition in female students.

Role models for girls and women can also affect enrollment. Although positive images of female engineers provide some information for teenaged girls contemplating a career in engineering, role models are most effective when girls are allowed to interact repeatedly with and develop personal connections to the adults. Because images may give an impression of perfection and thus an unattainable goal, a woman scientist or engineer who cares about the girls and connects on a personal level will be a more effective role model than a media image or someone who visits only once (Buck, Clark, Leslie-Pelecky, Lu, and Cerda-Lizarraga 2008).

Finally, the environment or even perceived environment can affect how comfortable women feel in engineering courses or activities, and that feeling can translate into attraction to or avoidance of engineering. Murphy, Steele, and Gross (2007) showed upper level science, mathematics, and engineering majors individually a video showing either a 1:1 gender ratio or a 3 males:1 female ratio at a conference and then asked their opinions about the meeting as well as their memories of both the video and the room where they watched it. Women accurately recalled more details about both the room and the video when they watched the unbalanced video compared to women who watched the gender balanced video. This suggests that women in an underrepresented situation become more vigilant and less comfortable. Men’s recall did not differ across conditions, indicating no increased vigilance or decreased comfort level. In addition, women recalled more than men when watching the gender imbalanced video, but no differences were observed between women and men in the gender balanced condition (Murphy et al 2007). This suggests that women currently enrolled in engineering and related STEM majors might not feel as if they truly belong, and thus would be more susceptible to changing majors.

In addition, women watching the imbalanced video had more pronounced physiological responses than those watching the balanced video, while men's responses did not differ. This corroborates the indication of increased vigilance and sense of threat in women who watched the video showing the 3:1 ratio. Women in the unbalanced condition also felt a lower sense of belonging when asked to imagine attending the conference than all other groups, and both men and women wanted to attend the balanced conference more than the unbalanced (Murphy et al 2007). This suggests that increasing the number of women in engineering will encourage both men and women in the field.

Even the suggestion of a masculine environment without any men or women in it can discourage women. Cheryan, Plaut, Davies, and Steele (2009) presented men and women who were not computer science majors with two computer science environments, one very stereotypical with science fiction posters, junk food, and video games and one not stereotypical with nature posters, healthy food, and general interest books. The stereotypical environment was viewed as masculine by both men and women, but only women experienced a lower sense of belonging compared to the other environment. The greater feeling of belonging in the less stereotypical environment led to more interest in the field of computer science compared to the other environment (Cheryan et al 2009). This suggests that simple steps towards making engineering look more inclusive of all students could help recruiting and retention efforts.

Many efforts to increase the number of women engineering graduates focus on reducing the attrition rate of women students, although given low numbers of women matriculating into engineering recruiting should also be a focus (Cosentino de Cohen and Deterding 2009). The current project addresses both issues. Specifically, the Engineering Equity Extension Service (EEES) focuses in part on the recruitment and retention of female students in mechanical and electrical engineering, which are two of the largest engineering disciplines with the lowest percentages of women. EEES works through various collaborating organizations (e.g. American Society of Mechanical Engineers, Institute of Electrical and Electronics Engineers, and Project Lead The Way), that have chosen a targeted population for training, such as mechanical engineering faculty, K-12 outreach volunteers, and high school teachers., EEES recently partnered with 19 university departments of mechanical and electrical/computer engineering to support departmental projects related to middle or high school outreach, undergraduate retention, faculty development, and/or academic and outreach material development, review, and revision.

Current Project

The project and many results from the 2008-2009 cohort have been described previously (Cady, Fortenberry, Didion, and Peterman 2009) and are summarized here. Fourteen departments participated and conducted a range of activities involving faculty, precollege teachers, undergraduate students, and precollege students. The approximate number, ages, and gender of students reached as well as faculty or other facilitators who have participated so far in the first and second round of projects are presented in Table 1. Due to the large attendance at some events, some numbers are approximate.

Table 1. Demographic Information of Participants from Both Cohorts as of January 2010.

Activity	Age of Students	# of Students	% Female	# of Faculty	# of Parents
K-12 Outreach	Elementary School	25	> 50%	< 5	
K-12 Outreach	Middle School	300	> 60%	3	26
K-12 Outreach	High School	600	> 80%	12	10
Undergraduate Retention	Undergraduate	140	> 50%	14	
Faculty Workshop	--	--	--	50	
Materials Revision	All Ages	Unknown	Unknown	> 4	Unknown

In the first cohort, 8 of the institutions organized outreach activities for pre-college students. Although aimed primarily at girls, both male and female pre-college students were invited to a majority of the activities. Approximately 320 students in grades K-12 participated in activities ranging from one-day workshops or events to longer camps. Over 80% of those students were female, and many indicated an interest in becoming an engineer following their participation.

Nine of these institutions held activities that targeted undergraduate retention through engaging students in social activities, peer mentoring and serving as role models and mentors for pre-college students, and faculty role modeling. These women also took leadership positions for several of these activities and in many cases became more involved in departmental activities as a result. Approximately 140 students, about half of them women, participated in these activities.

Three departments held faculty workshops, and faculty members also served as mentors for other activities. In all, approximately 70 faculty members participated in the project. Parents and high school teachers were involved or observed several of the outreach projects.

In addition, 3 institutions revised recruiting or course materials. As these materials are disseminated to students, parents, and faculty, it is unknown how many individuals will see the revised material. Most of these revisions involved including more gender-neutral descriptions and pictures as well as describing student projects that appeal to a wide range of students.

In the 2009-2010 school year there are six institutions, with one participating for the second year. Three institutions will be completing academic and outreach material revisions that will affect undergraduate students and faculty, and three institutions will be completing outreach activities for K-12 students. Thus far, two institutions have reported on their K-12 outreach activities. Institution A held a luncheon with a female engineer speaker for 150 junior high and high school girls. This institution held a similarly successful luncheon in the first cohort. Institution B participated in both a career and education fair in a small, rural town on a reservation as well as a larger science and engineering fun night at the museum associated with that institution. Although the number of students attending the fair in the small town was not given, the entire school district contains fewer than 1000 students. On the other hand, 460 middle and high school students attended the museum night. In addition, Institution B has created a list of students who will travel to their hometown high schools to speak about electrical and computer engineering. These student ambassadors will receive mentor training about effective ways of encouraging all students to think about electrical engineering. As the projects are ongoing, summative evaluative data from these institutions has not been collected yet.

Discussion

As reported previously (Cady et al 2009), the participants in the various activities in Cohort 1 showed positive results from their activities. In general, younger students who experienced engineering either in a workshop or from a speaker were more interested in engineering after participating. Undergraduate women took the lead on several projects and became involved in K-12 outreach as well as on-campus projects. The use of undergraduate students (both women and men) who can serve as role models to younger students could maintain interest in the field. Specifically, the alumnae/i who will travel to their own high schools will provide a role model with whom the students can identify, which will strengthen the relationship (Buck et al 2008). Revising both recruiting and curricular materials to be more gender-equitable will increase women students' sense of belonging (Murphy et al 2007; Cheryan et al 2009) and might encourage them to enter engineering. In addition, the participation of high school teachers in activities focused on women engineers may have changed any misperceptions of engineering as a male-only field (Hoh and Toh 2007). Overall, this project shows that partnering with individual departments and providing small monetary motivation as well as expert advice can lead to advancements in gender equity across institutions, which in turn may increase the number of women earning undergraduate mechanical and electrical engineering degrees.

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