AC 2008-857: FROM OUR PERSPECTIVE: UNDERGRADUATE AND FACULTY WOMEN IN ELECTRICAL AND COMPUTER ENGINEERING PROGRAMS ON RECRUITMENT, RETENTION, AND WHAT REALLY WORKS

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Abstract

Women remain significantly under-represented in undergraduate electrical and computer engineering (ECE) degree programs in the U.S.; in recent years, their representation has eroded further. We are a group of women undergraduate students and faculty in ECE at a public university with one of the largest engineering programs in the U.S. In this paper, we present our perspective on why women are under-represented in undergraduate ECE programs: we examine some of the previously cited reasons for women's persistent under-representation and provide evidence for efforts that have been effective at recruiting and retaining women students in ECE. We elucidate the often-cited "lower self-confidence" issue that remains a significant threat by focusing on fallacies (there's something wrong with the women; they need to be fixed to have higher self-confidence) and distracting attention from the real problems that are grounded in the typical undergraduate engineering education experience. We describe results that indicate how four factors improved ***all*** students' learning, retention and satisfaction—and dramatically increased women students' enrollment—in our university's first-year ECE program.

Background

Women remain significantly under-represented in undergraduate electrical and computer engineering (ECE) degree programs; recently, they comprise an even smaller proportion of the overall shrinking enrollment. In the United States in 2006, women earned only 14.2% of the electrical engineering (EE) bachelor's degrees (down from 14.8% in 2002) and only 11.2% of the computer engineering (CE) bachelor's degrees (down from 12.8% in 2002)[1,2]. In 2006-2007 at our university (one of the larger engineering institutions in the U.S.), women earned only 8.8% of the EE and 2.0% of the CE bachelor's degrees[3].

Women's persistent under-representation in ECE is a combination of two factors: (i) not entering the field; and, (ii) leaving the field. The primary reasons cited in the literature include: unfriendly environments[4-9], dearth of role models[5-8], loss-of/lower self-confidence[7], gender-role socialization[4, 10-11], undesirable geek culture[4,10], and stereotypes[4,5, 12-20]. In this paper we focus on three previously published studies that we believe are most germane.

Margolis and Fisher describe a "nexus of confidence and interest" on women's declining enrollment and persistence in undergraduate computing degree programs (e.g. CE, computer science)[4]. The authors indicate that they do not attribute this to any weakness or shortcoming in the women students; instead, they state that the factors that require improvement are associated with institutional culture, curriculum, and faculty-student relations. However, the specific nature of these factors is not described because the scope of the study was limited. Their research is based on how the women are feeling about their choices and about their decision to stay or leave. Women students report negative feelings in response to poor performance (getting bad grades) and why they think that is ("everyone knows more than me" interpreted within the context of the common stereotype that it is a man's field). However, this is not connected to what actually led to the bad grades—for the women or the other students. The study reinforces the commonly understood difference that, on average, women suffer a loss of confidence in this environment, but men do not; moreover, it reinforces the previously reported similarity between women and men in terms of performance (as measured by GPA). Teaching and pedagogical practices have a big impact, but this has not been explored in Margolis and Fisher. Moreover, faculty perceptions and practices were not addressed in this study.

The Women's Experiences in College Engineering (WECE) study represents a comprehensive, in-depth evaluation of Women in Engineering (WIE) programs that, for the previous two decades, focused on improving the recruitment and retention of women in undergraduate engineering[6]. The WECE study showed that participation in professional activities (social events, guest speakers) was significantly associated with the women's persistence in engineering, but participation in the help activities (tutoring) was not. Moreover, the WECE study found that leavers cited dissatisfaction with the school's program (teaching, grades, workload, pace) and climate (competition, lack of support, discouraging faculty and peers). Despite the fact that 45% of leavers had A or B averages in their engineering course work, they were more discouraged with their grades than stayers. Even women who were performing well academically were discouraged by their grades—they were displeased with ***how*** they obtained their A and B grades. One unique aspect of the WECE study was its inclusion of engineering faculty. Unfortunately, the faculty interviews were focused on: evaluating the women students, their perceptions of the climate for women students, and their beliefs about WIE support programs. There was nothing about pedagogical practices on the faculty surveys.

Seymour and Hewitt's seminal work provides comprehensive, detailed insights into the many reasons why students enter and subsequently stay or leave undergraduate degree programs in science, math and engineering[7]. Their study is based on extensive data from undergraduate students. Seymour and Hewitt expertly describe how the common weed-out approach to introductory engineering education eliminates capable women and men students, but that women leave faster (despite their good GPAs). They show that women and men students exhibit: high dissatisfaction with faculty's teaching; and, a failure to develop interest in the discipline. Their work also reveals an important insight (that they describe as puzzling) that women students do ***not*** cite negative behaviors by faculty and male peers as reasons for leaving. Seymour and Hewitt conclude that the loss of capable women cannot be changed without changing traditional faculty norms and practices; unfortunately, their study did not include the faculty who—according to the primary findings of this work—are responsible for the most important factors in students' retention.

Who We Are

We are a group of five women undergraduate students and one woman faculty in ECE at Virginia Tech—the fourth largest undergraduate engineering program in the USA[21]. We students are all "persisters" who will earn our ECE degrees: 4 of us are juniors and 1 is a senior. Three of us self-identify as white/Caucasian, one self-identifies as African American and one self-identifies as Asian/Caucasian. Our average GPA is 3.4. The woman faculty in our group self-identifies as white/Caucasian; she has 10 years of experience as a professor, has tenure, and is actively engaged in teaching (3 teaching and advising awards) and research (NSF CAREER award, research funding from NSF, NIH, DoD, etc.).

We share many values and interests. We all report that we are: satisfied with ECE as our major choice; confident that we are/can-become successful ECE engineers; are capable of solving ECE engineering problems; and, it is important to us that we are good at ECE engineering. Furthermore, we value our individual interests and relationships that extend beyond our profession.

We developed this paper over a series of four group conversations. In our conversations, we explored our experiences, discussed the relevant literature, and ultimately drafted our ideas regarding women's recruitment and retention in undergraduate ECE programs. It is not our intent to provide a comprehensive retrospective on these issues. Instead, we address some important issues that have either been unexplored or not explained well in the literature.

In this paper, we do not distinguish "our view" into a student view and a faculty view. Instead, we recognize that we have a common view as engineers, but different views as students and faculty. We believe that our perspective is strengthened by our complementary knowledge and experiences: our student team members provide insight on student issues that our faculty team member struggles to remember and our faculty team member offers experience that our student team members are beginning to accumulate.

What is Wrong

We agree with the literature that women enter undergraduate degree programs at a high confidence level and that they lose confidence during the early engineering education experience. We have also observed that men, on average, do not suffer this drop in confidence—despite similar experiences in the same classes. The gender-role socialization argument concurs with our observation: men are more familiar with the weed-out culture and are quicker to externalize it and move forward[6]. However, the literature is inaccurate (primarily due to the myopic scope of many studies) in describing ***why*** women's confidence erodes; there are important factors that stem from the common approach to engineering education—and not from the women and their beliefs or upbringing. Here we elaborate the subtler dimensions of this issue—highlighting both the similarities and the differences between women and men students.

In our experience, average test scores in our ECE, introductory engineering, math and science courses range from 30% to 80%. There is no trend by academic year, but ECE and Physics courses have the lowest average test scores (~ 40%). At first, it was shocking to receive such low test scores—particularly since our high school experience included average test scores of 75%. Later, we learned about the "grade game": a low test score isn't a concern if the average test score is also low. What matters is to "beat the mean". Regardless of how low the average test score may be, a bias will be introduced at the end of the class that pegs it to about 75%. Once we discovered the grade game and how it worked, we were no longer so discouraged by low test scores. Instead, we learned to first ask "what was the mean." Unfortunately, women tend to learn this game later (or not at all if they leave quickly) than men since their social/professional networks are smaller. Unlike the men, we have concerns about the grade game that our male peers, on average, do not: (i) we question how worthwhile this approach is to quality engineering education; and, (ii) we are concerned about the implication of such low test scores on our preparation for future engineering work.

As persisters, we have experienced negative behaviors by faculty and our male peers. As the literature suggests, we have developed our own coping strategies for succeeding within this environment. We find ourselves increasingly unconcerned with these negative behaviors and the people who initiate them. Instead, we are preoccupied with a set of factors that are much more important to our learning, satisfaction and retention: these factors can be collectively described as poor teaching. Some examples include: faculty not knowing answers to our questions (and unwilling to find them); prohibited teamwork with other students; faculty with very few office hours; teaching assistants who do not understand the course material/assignments; lectures and assignments/exams that are riddled with errors; exams with average test scores below 60%; and, lack of feedback. For example, consider the poor teaching factor of a low average test score. We students can read one of the test questions and understand that it is based on the material we studied—but it seems so hard and unfamiliar. Our faculty member has a different perspective: I can read the same test question and notice how it is asking the students to perform at a much higher level of Bloom's taxonomy (e.g. synthesis), when the homework problems were comprised of problems at the lower analysis level. Our male peers' experience is similar; consequently, it is not surprising that they also indicate frustration with these poor teaching factors. However, they tend to be much less willing to express their concerns to the instructor. Indeed, the men are loathe even to ask the instructor a technical question in regard to a project assignment.

Finally, in addition to the aforementioned research findings, women students tend to be more interested in understanding the impact that their chosen work will have on the world. For example, Dr. Bernard Amadei, a founding member of the U.S. branch of Engineers Without Borders and Professor of Civil and Environmental Engineering at the University of Colorado at Boulder, stated that half of the students involved in EWB projects are women. Also, Virginia Tech engineering enrolls only 14.8% women, so it is compelling to note that 50% of the Virginia Tech engineering students who spent their 2006 spring break helping with Hurricane Katrina relief efforts were women. Unfortunately, the typical undergraduate engineering education experience does not illustrate how engineers impact society. For example, consider a fundamentally important insight from the American Association of University Women's 2000 *Tech-Savvy* report in which girls emphatically state "We can, but I don't want to" [22][22]. The 70 middle and high school girls in this study indicated that they feel confident and capable of solving problems in the computing world; however, they reject the violence and tedium of computer games, and the narrow, one-dimensional focus of computer programming classes. The current computing curriculum and culture do not appeal to their interests.

What Works

Again, we agree with the literature that coping strategies, forming support networks with our peers, and some key faculty role models play important roles in our persistence. However, there are subtle dimensions to these factors—as well as other, previously unmentioned factors—that are critical to our learning, enrollment, retention and satisfaction. We describe these in terms of the following four factors.

1. ***Design and implement an inspiring approach to early engineering education.*** From the very beginning, illustrate real ECE problems whose solutions benefit society. Engage the students through hands-on projects in which their team solves these problems. This approach—which eschews "toy" problems or "recipe" projects—mmakes ECE significantly more relevant and exciting to the students and provides them with opportunities to understand how their work might impact the world. The projects make connections to the real world by addressing contemporary problems and the students discover the importance of ECE problems and the excitement of designing creative solutions. This approach benefits all students, but with an even greater impact on women students. At our university we recently developed a new, first-year course that employs real-world, contemporary, hands-on projects that demonstrate what engineers do and how their work helps people. For example, in the first project students explore the signal processing area of ECE by implementing algorithms that exist in today's implantable cardioverter defibrillators; the students' algorithms work on real electrocardiogram signals to quickly and accurately detect the onset of a life threatening arrhythmia. After just one semester with this new course, we have realized improvements in student learning, enrollment, retention and satisfaction: for example, women's enrollment increased 60% (from 15 to 24).
2. ***Employ pedagogical practices based on how people learn:*** provide feedback that promotes student learning; encourage and guide effective teamwork; perform assessment based on learning objectives; use criterion-based grading and eschew grading on the curve; consider Bloom's taxonomy and the learning objectives when designing exam questions; and, promulgate an incremental theory view of intelligence. We have discovered how critical good study groups are to our performance and satisfaction. In particular, we have observed how teaching others in our group has dramatically improved our own understanding. At our university a first-year programming course had severe retention problems: only 38% of the women and 63% of the men who enrolled in the course completed it. We designed and implemented better pedagogy in the class (introducing teamwork and a more effective assessment plan were central to the new approach) and the results were amazing: now 86% of the women and 91% of the men completed the course.
3. ***Create supportive communities for students.*** It is important that these communities originate within a technical discipline (like ECE communities)—a broad, all-engineering-disciplines community has limited effectiveness. At our university, a WIE committee of the student IEEE group has created supportive communities for women and men. By not excluding anyone from this group, no one has felt left out or spotlighted. Instead, it has provided a way for each individual to find her or his own way with colleagues who have similar interests and needs. Indeed, a previous report attributes their first-year engineering students' retention-to-degree increases, in part, to creating a supportive learning community[23].
4. ***Interaction with enthusiastic, interested faculty.*** Students want to talk with faculty about their technical interests and career choices; moreover, they are motivated by being asked to provide their input and then have faculty respond it. In the new course we describe

above in (1), we have designed a sustainable model that allows first-year students to interact with 8 ECE faculty in diverse technical areas. We believe this was one of the primary reasons—along with guided teamwork and interesting, meaningful problems—that ***all*** students cited a 54% increase in feeling part of an ECE community from the beginning to the end of the course.

Discussion and Recommendations

The first woman doctor and the first woman electrical engineer earned their degrees in the same century. Yet women have long been earning about half of the medical degrees while women persistently earn fewer than 15% of the electrical engineering degrees. Undergraduate degrees in biomedical engineering have only been offered for about a decade—and yet women already earn almost half of these degrees. Medical school and biomedical engineering programs, like ECE, have reputations for being challenging and demanding; moreover, their departmental and classroom environments are as welcoming and friendly as ECE's. Historical trends indicate that women are highly motivated by performing interesting work that helps people.

Unfortunately, decades of explanations for women's under-representation in engineering have revealed no transformative solutions. Indeed, the literature suffers from an inadequate understanding of the problem and a focus on issues that are not paramount. Consider one example. For a long time, the conversation surrounding women's under-representation in engineering has had a strong flavor of "here's what's wrong with the women." Social scientists who study the issue from an outsider's perspective focus on how women lose or have lower self-confidence and describe how this dearth of confidence is related to women's leaving. Ironically, the academic engineering culture shares the same conclusion (something is wrong with the women), but for a different reason (the women aren't tough enough). The flawed notion that the women are deficient leads to two wrong-headed ideas: (i) the women need to be "fixed"; and, (ii) the women aren't destined to be good engineers. This conversation needs to be reversed from a focus on "what's wrong with the women students" to "what's lacking in our undergraduate engineering programs."

Almost no work describes the impact of the undergraduate engineering curriculum and teaching on women's recruitment and retention. Instead, the focus has been on K-12 education and how it: (i) inadequately prepares students for undergraduate engineering; and, (ii) insufficiently exposes students to the engineering field. It is true that engineering typically appears in the K-12 curriculum only indirectly through math and science classes. Moreover, it remains a challenge to get "content matter experts" into the K-12 math and science classrooms. Numerous outreach efforts—by individuals and organizations—to get K-12 kids exposed to engineering exist throughout the U.S. However, this conversation has also been focused in "one direction" (the deficiencies of K-12 education in preparation for engineering programs) and would benefit from a reversal. Whereas K-12 education suffers from a dearth of content matter experts, undergraduate engineering education suffers from a dearth of education experts. There needs to be more emphasis on this part of the equation—we need to develop better engineering teachers! This is not a recommendation to split engineering professors into two separate tracks: a teaching track and a research track. Clearly an engineering professor must retain her technical expertise by engaging in engineering work through research and consulting. However, she also needs acquire knowledge and skills about how students learn and design her course content and pedagogical practices accordingly.

Many analyses of women's under-representation in undergraduate engineering education have been conducted and published. Nearly all of these studies have been conducted either solely by non-engineers or with minimal input or involvement from engineering educators. Most WIE programs have been managed by non-engineers or with little involvement from engineering faculty. Unsurprisingly, these external evaluations and solutions have realized limited understanding and limited change. Industry, government and academic leaders have been loudly voicing their concerns about flagging interest and enrollment in undergraduate U.S. engineering programs. They believe our country's future depends on our ability to innovate—and engineers are our front-line innovators. We can no longer afford our antiquated approach to engineering education that drives away capable, interested students from any group. It is up to us—engineering faculty, department heads, and deans—to lead the way with innovative engineering education.

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