

Why Aren't There More Women in Engineering: Can We Really Do Anything?

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Abstract

Engineering has always included women; however, engineering has never included very many women. Some basic reasons are explored on why women do or do not choose engineering, why they leave engineering, and why the number of women in engineering is not increasing as rapidly as the numbers of women in medicine and law. These topics include: the lack of engineering curriculum in K-12, the lack of a positive public image of engineers, the lack of a vision on what an engineer really is, and the lack of support for women to succeed in engineering.

Efforts at Arizona State University to increase the recruitment and retention of women in engineering, computer science, and construction are introduced. Recruitment efforts include summer programs for middle school and high school girls, campus events during the academic year, a Bridge Program for entering freshmen women, Saturday Academies for middle school and high school women, and a program with middle school and high school teachers and counselors to acquaint them with engineering. These participants are helped to develop modules on engineering that will be attractive to young women and that will be incorporated in their science and math classes. Retention programs for college women in the College of Engineering and Applied Sciences are also presented.

The paper describes lessons learned while developing these programs. How to start and build a program to recruit and to retain women in engineering is examined. Outcomes and results of these efforts are also discussed.

I. Introduction

Engineering has always included some women; however, engineering has never included very many women. Only 9% of the engineering workforce is comprised of women, up from about 4% some twenty years ago. Significant increases in the enrollment of women in engineering took place during the 1980s. However, during the 1990s, although the enrollment of undergraduate women in engineering grew from 61,816 in 1990 to 76,027 in 2000, the percentage of undergraduate women in engineering only grew from 16.3% to 19.7%. In addition, women comprised only 20.8% of the engineering Master's degree enrollment and 19.3% of the PhD degree enrollment in engineering in Fall 2000.^{1,2} Of the engineering degrees earned during 2000, women earned only 20.6% of the BS degrees, 21.1% of the MS degrees, and 15.8% of the

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PhDs.³ Interest in engineering is near a 30-year low. In the Fall of 2001, only 2.5% of college freshmen women identified engineering as their probable career, while 13.2% of the freshmen men did. In addition, while 8.3% of the freshmen men selected computer programmer or analyst as a probable career, this career was selected by only 1.4% of the freshmen women.⁴ At this rate, the percentage of women in engineering will continue to increase, but very slowly.

Why don't more women choose engineering? Why do they choose some areas of engineering over others? Why are they not retained in engineering as well as the men? Why aren't the numbers of women in engineering increasing as they are in medicine and law, where approximately half of the students in these majors are female? Is there anything that can be done?

II. The Low Interest in Engineering by Women

In most cases, it is not a matter of women saying "No" to engineering. Most women do not ever consider engineering as a career choice because the average woman knows little about engineering. A 1998 Harris Poll, commissioned by the American Association of Engineering Societies (AAES), showed that about 75% of women are not well informed about engineers and don't seem to know what engineers do or how engineers contribute to society. This means that when the time comes to choose a career and a college to attend, engineering is not even an option from which many young women choose.

Engineering is not a subject normally taught at the elementary, middle, or high school levels. Although the students are taught mathematics and science, usually the connection of applied mathematics and applied science to engineering is not made. This should not be surprising when we consider that few Colleges of Education have a curriculum that includes engineering as a topic to be taken by their pre-service teachers, even for mathematics and science specialists. This issue is further complicated by the mathematics and science standards at district, state, and national levels to which teachers must comply. Even if the teacher did know something about engineering and wanted to introduce the subject in the classroom, it is not clear from the standards how this can easily be done. The issue of an engineering curriculum in K-12 has become a national issue. The state of Massachusetts has mandated that engineering will be incorporated in their K-12 system. Although not yet implemented, this is a good first step as other states are now considering the issue. Another encouraging note is that Deans of Colleges of Engineering and of Education are now working together in national forums, as well as local forums, to introduce engineering in the K-12. This is a win-win situation as Colleges of Engineering are trying to recruit more engineering students to meet the demands of industry and Colleges of Education are working to enhance the preparation of pre-service teachers and to give exciting new material for the classroom to their in-service teachers.⁵

In a review of literature on the possible causes for the underrepresentation of women in science and engineering, two major themes emerged.⁶ The first theme was that the idea of a person-environment fit appears to strongly influence the range of careers that a young woman is willing to consider. For example, a young woman may view a nontraditional career as not compatible with who she is and with raising children.⁶ It is not generally considered "cool" for a young

woman to be good in mathematics or to aspire to be an engineer. Another example of a person-environment fit is that many young women want to do something to help people. Therefore, nurse, veterinarian, now doctor, and other such professions that help people are generally popular career choices among young women. Engineering is not generally viewed as a helping profession, however the bioengineering, civil engineering, and industrial engineering majors often have a higher percentage of women students than other engineering majors because these majors are more closely related to working with or helping people. Most young women do not understand that engineers solve problems to help people. Young women often consider bioengineering because this major is advertised as a good step to medical school and bioengineering majors often work with the medical profession to help people with prostheses, for example.

Most young women do not have a vision of what an engineer really is, even those that may initially choose engineering as a major in college. Most young women do not understand that engineering is profoundly creative.⁷ Engineers solve problems under constraints and in solving those problems they use research and design to find a “best” solution, because usually there is not only one answer. In any creative profession, what comes out is a function of the life experiences of those who do it. Without diversity, the set of life experiences that are applied to a problem is limited. Without diversity, an opportunity cost is paid – a cost in products not built, in design not considered, in constraints not understood, in processes not invented.⁷ The word “engineering” is not normally associated with “creativity.”⁷ There is a lack of diversity in engineering (few women and underrepresented minorities) due to a wrong opinion of what engineering really is.⁷

A second major theme in the review of literature on the reasons for the lack of women in engineering is that women’s self-efficacy for pursuing science and engineering careers tends to be low as a result of lack of information to build self-efficacy.⁶ Self-efficacy is one’s belief about how well she or he can perform a given task or behavior.⁸ Self-efficacy is built through four sources of information: past performance accomplishments (in math and science), vicarious learning (through female role models), encouragement and support (particularly by parents, teachers, and guidance counselors), and lowered anxiety (especially in math performance).^{6,9} The significant difference between male and female science students is not ability, but self-confidence. The loss of self-confidence is most dramatic in fields dominated by men.¹⁰ As an example, consider a 2000 study that reported that women had closed the gender gap in computer use, but lagged behind in computing confidence. A new survey item in the annual American Freshman: National Norms found that women were half as likely as men to rate their computer skills as “above average” or “top 10%” relative to people their age (23.2 percent among women, versus 46.4 percent among men). This gap in self-confidence most probably contributes to the fact that men are five times more likely than women are to pursue careers in computer programming (9.3 percent of men versus 1.8 percent of women). The computer confidence gap among 2000 freshmen is the largest in the history of the survey (taken since 1966).¹¹ A major factor in why there are so few women in computer science is that the female students in high school and college not only lack confidence in math and science, but when they compare themselves to males, many of whom have been consumed with tinkering with computers from a very young age, they immediately conclude that they cannot compete.¹⁰

Past studies have shown that if a girl does not do well on a mathematics test, she will conclude that math is not for her. On the other hand, if a boy does not do well on a mathematics exam, he will say that the teacher wasn't good, the test wasn't fair, or he just didn't study for the exam, since it is generally accepted that boys are "naturally" good in mathematics. The encouragement of teachers and their place as a role model is important here. Many female teachers, because they did not have much mathematics in their training, may feel uncomfortable teaching mathematics. This feeling is transferred to the young women in the class, and they have yet another data point that women and mathematics do not go well together.

The lack of role models and a positive public image of engineers support continued low interest in engineering by young women. The numbers of women enrolling in medical and law schools is now around 50%. Young women see many attractive, well-groomed, young women in very nice offices with good-looking friends in the role of a lawyer on television. The lawyers in most cases are portrayed as helping people. Television also shows many competent women doctors helping and saving people. The role models for young girls of doctors and lawyers include many young women. There is no LA Engineer to attract them to becoming a woman engineer. In fact, recent experiments of asking girls to draw a picture of a scientist or engineer show that most of them draw a man in a lab coat with frizzled hair. This character is not their role model.

The support of parents, teachers, and guidance counselors is very important for young women to pursue a career in engineering. Some mothers do not want their daughters to enter a male-dominated field, concluding that they will then be less desired as a wife and might well not be able to marry. Recalling the Harris poll, many mothers do not have any knowledge of engineering and so might find it difficult to encourage their daughter to pursue this career. Some engineering fathers do not want their daughters to be an engineer.¹² Numerous studies have shown that counselors are often discouraging to young women wishing to pursue a career in engineering. Some of this advice is well intentioned, since they as a man have difficulty with mathematics, then surely they must protect this young woman from difficulty and failure in mathematics and engineering. Recently, an African American mother told about her daughter who is an excellent student. Her male high school counselor discouraged her after learning that she intended to become an engineer. He told her that she would never make it for two reasons: she was a female and she was a minority. The student believed that her counselor knew what he was talking about, so she chose another major in college.

The choice of a career is influenced by many factors. In view of these factors, as discussed above, why do we have as many engineering women as we do and what can be done to interest more young women in engineering?

III. How To Interest Young Women in Engineering

With the interest in engineering so low, why do we have as many female engineering students and engineers as we do? A Cooper Union Study in 1989 (and other more recent students have confirmed this trend) showed that many women who choose engineering had a family member who was an engineer.¹³ For example, a mother who majored in the Letters, expressed surprise

that her third daughter was not interested in English or Foreign Languages as she and her two older sisters were. The mother had no idea how this daughter had concluded that engineering was for her. When asked, the young woman said her father was an engineer and also her uncle and grandfather had been engineers. However, young women do not have the choice of the careers of their parents and family.

What can be done? We need to make young women aware of engineering in a positive way. We need to have teachers and counselors in K-12 aware of engineering and able to see engineering as the application of mathematics and science. We need to work to get new technological standards to go with mathematics and science standards so that engineering will be introduced in K-12. We need to inform parents of the opportunities, rewards, and challenges in engineering as a career.

Colleges of Engineering and Colleges of Education need to work together to introduce engineering concepts into the curriculum for all pre-service teachers and to provide classes about engineering concepts to in-service teachers, who regularly take graduate classes for upgrades in pay and who are actively seeking meaningful classes. Middle school math and science teachers are usually less restricted by state and national standards on what they can teach. Research has shown that middle school is a crucial time for intervention for young women relative to further study in mathematics and science.¹⁴ Therefore, it is logical that we must provide programs for middle school girls to interest them in mathematics, science, and engineering. At the same time, we need to educate the parents so that they can be supportive of their daughters and encourage them to pursue a career in engineering. We also have to prepare a supportive environment for their study of engineering once they have enrolled and then continue to support them so they will graduate and be prepared for the workplace.

The College of Engineering and Applied Sciences (CEAS) at Arizona State University (ASU) is concerned with the lack of women engineers in the United States. To that end, an Associate Dean of Student Affairs is dedicated to the recruitment, retention, and placement of engineering students. The largest untapped resource for increasing the enrollment in engineering is women. Therefore, as part of the Office of Student Affairs, a Women In applied Sciences and Engineering (WISE) Office was established in 1993 to recruit, to retain, and to graduate women engineers. We have developed a comprehensive approach to recruitment and retention in the CEAS.^{15, 16}

Recruitment and outreach programs for underrepresented minority students are another avenue for recruiting more women to engineering. It is interesting to note that in the Fall 2000 enrollment of engineering students nation-wide, while only 19.7% of all engineering students enrolled were women, the percentages of women were higher among the underrepresented minority groups. Among African American engineering students, 33.3% were women, 23.3% of Hispanic engineering students were women, and 24.9% of American Indian engineering students are women.² Therefore, the renewal of an Office of Minority Engineering Programs (OMEP) in 1993 has also helped to recruit, to retain, and to graduate more women engineers.

Following is a description of the major activities of the WISE Office and the OMEP and how they are helping to increase the number of women engineers in this nation, based on the research that has been reviewed.

IV. Recruitment Efforts in the CEAS

The Dean of the CEAS and the Dean of the College of Education are working together in national meetings and locally to try to solve the education gap between teachers and engineering. Engineering faculty are working with education faculty to enrich the pre-service and the in-service teacher's curriculum with an integration of mathematics, science, and engineering.⁵ This collaboration is a bold and new positive step to help get engineering into the K-12.

In the meantime, the WISE Investments program, sponsored by the National Science Foundation, is in its fourth year of introducing engineering into the middle school and high school classroom.¹⁷ This program is built on a two-week summer workshop on the ASU campus for mathematics and science teachers and counselors to learn about engineering. Engineering faculty and graduate students work with the participants in hands-on labs covering eight engineering disciplines and also act as coaches as the teachers prepare material for their classroom. A team of a math teacher, a science teacher, and a counselor from each school is encouraged to work together in the workshop and in their school after the workshop. Gender equity training is also a part of the workshop. The teachers and counselors also participate in an optional one-week internship shadowing engineers in industry to have a more complete understanding of what engineers are and what they do. During the following academic year, eight Saturday Academies are held for middle school and high school young women.¹⁸ At each Academy, a teacher/counselor team presents an engineering discipline in a way encouraging to young women. The teachers are also observed in their classrooms during the year and encouraged to present engineering to their students in a way that is exciting to all students, including women. Parents are included in an introductory program for the Saturday Academies, encouraged to attend the academies, and are also invited to the year-end program for the Saturday Academies. The two programs are well attended by parents and the parents learn more about engineering and encouraging their daughters.

The Office of Student Affairs now delivers 11 summer programs for students ranging from entering sixth graders through entering freshmen serving over 300 students each year. Four of the programs are targeted for women. Two of these targeted programs are three-day commuter programs (TEAMS) for grades 6-7 and 8-9. WISE-UP is a five-day residential program for girls entering grades 10-12.¹⁹ A four-day Summer Bridge residential program just before the fall semester is held for freshmen women entering the CEAS. Five of the summer programs are targeted for minority students (with good female representation) and two of the programs, one at the junior high level and one at the high school level are open enrollment programs. One of the targeted minority programs is a two-week residential Bridge Program for entering freshmen that greatly improves college retention for its participants.^{20, 21, 22}

WISE participates in additional outreach activities such as presentations to high schools and "Bring Your Daughter to Work Day" at the university and in industry. Recently WISE had a

booth at a Sally Ride Science Club event and spoke with 75-90 middle school girls and their parents about the opportunities in engineering and in participating in a summer program on engineering.

The OMEP has an academic outreach program in 31 schools with a high minority enrollment, with five more soon to be added, through the Mathematics, Engineering, Science Achievement (MESA) program. The ASU MESA program is a part of Arizona MESA that is in a coalition of eight states that form MESA USA. The ASU MESA is now in grades 3 through 12. Each school has a MESA advisor and MESA is either an elective class taken by the students or an after school club. The ASU MESA is a college preparatory program with the goal of making its students competitive for college admission and encouraging the students to enroll in engineering. A Regional and Statewide competition on engineering-related projects and subjects is held each year. The MESA program includes training for the MESA advisors and information sessions for the parents to help them encourage their students to pursue engineering and science. Over 700 students are currently being served through ASU MESA. Approximately half of these students are young women.

Our college students make additional recruitment efforts. For example, the ASU student chapter of the National Society of Black Engineers (NSBE) holds a recruitment day each year inviting young black children to the campus who have never seen it before. Through the activities, the NSBE students serve as engineering student role models and encourage the young participants to study more mathematics and science and to consider engineering as a career. As another example, the Biomedical student organization holds a poster day each year showcasing research projects done by Bioengineering students. High school students and their parents are invited to the event.

In addition, to the targeted program by WISE and OMEP, our Office of Student Affairs has a Recruitment Office that holds events for high school students (many of them women) on our campus to introduce them to engineering. We also hold the JETS' TEAMS national competition on our campus. The Recruitment Coordinator attends high school career fairs. Representatives of our Office of Student Affairs also specifically recruit both women and men at the national conventions of the American Indian Science and Engineering Society (AISES), the Society of Hispanic Engineers (SHPE), NSBE, and the Society of Women Engineers (SWE).

V. Retention of Women in Engineering

Engineering is a difficult major. Nationally, less than half of all students who begin in engineering actually graduate in engineering. In addition, nationally, women and underrepresented minority students are not retained in engineering as well as Caucasian males. There are several recognized reasons for this. First, since women and minority students are so underrepresented in engineering, there is the lack of a critical mass to provide proper encouragement and support. In addition, male students and faculty often discourage women engineering students because they feel that women really do not belong in engineering. There is also discouragement from some international students where women are not valued in their own culture. In addition, a study by the Goodman Research Group, Inc. showed that women who

were retained in engineering were more likely to participate in all types of support activities than were women who dropped out of engineering.²³

The critical mass problem and the need for support activities for women and minority students is best solved by providing space and activities where women and minority students can study and interact with the support of other students like them. To this end, our WISE Program provides 30-40 retention programs per semester over a wide range of activities in their WISE Room dedicated to supporting CEAS women. These programs include mentoring. The WISE Office also works closely with the SWE chapter to support women. The WISE Student Success Program is designed as a comprehensive approach to increase the retention of female undergraduate students.²⁴ This WISE room is conveniently located across the hall from the WISE Office so that additional support and help is close by. A similar room is dedicated to the Coalition of Engineering Minority Societies (CEMS) that includes AISES, NSBE, and SHPE. In addition, our SWE society is in a coalition with CEMS, called CEMSWE, so the underrepresented students all support each other.²⁵ CEMSWE holds two leadership retreats each year, as well as two major events of a fall career fair and a spring awards banquet. The OMEP provides additional retention programs targeted for minority students. Minority women tend to associate with the OMEP, but many of them also participate in the WISE activities.

The number one factor contributing to women undergraduates' decision to switch from science, mathematics, and engineering (SME) majors was identified by Seymour and Hewitt as "Reasons for choice of SME major prove inappropriate."²⁶ The second ranked reason was "Poor teaching by SME faculty." Men who left SME ranked the poor teaching number one and the inappropriate reason second. Both women and men gave "Inadequate advising or help with academic problems" as the third most important factor.²⁶ The "inappropriate reason" for choosing engineering may well have been because the young woman did not really understand what engineering is. She did not know that it was a creative discipline and a helping discipline. In the freshman year as an engineering student, it is difficult to keep sight of the vision of becoming an engineer. Much of the first two years of an engineering discipline is spent in learning the tools with which an engineer will solve problems: mathematics, chemistry, physics, English, and other general studies required for a general education. Many young women have chosen engineering as a major upon the advice of a high school teacher who complimented her on her math skills and suggested that she would make a good engineer. The young woman begins engineering with little idea of where this career is headed. By educating young women through summer programs and other activities about engineering, the young women will better be able to have a vision of engineering and to understand the reasons she chose engineering before she begins her college work. Our Office of Student Affairs believes that our recruitment programs are retention programs as well. We have seen more than one student who has taken three or more summers to become convinced that engineering is for them and then doggedly stick with their engineering program as a college student because they know that engineering is for them. An additional retention problem of women in engineering is that fewer of them continue for the Master's and PhD degrees, as previously noted in the enrollment and graduation statistics.

A study on the retention of minority and non-minority students was conducted by the National Action Council for Minorities in Engineering, Inc. (NACME).²⁷ The retention in engineering institutions was examined relative to five characteristics: (1) institutional control (public versus private); (2) college cost; (3) selectivity; (4) number of accredited engineering programs; and (5) number of student support programs. Selectivity was found to be the most important predictor of degree attainment for both minority and non-minority engineering students. Selectivity ratings are self assessments made by each college based on three criteria: percentage of applicants accepted, high school class rank, and standardized test scores of freshmen who actually enrolled in the institution. The more selective the institution, the higher the graduation rate is for both minority and non-minority students.²⁸ For example, ASU accepts 80% of its applicants. Schools with lower acceptance rates and larger percentages of top high school students than ASU, have better retention rates, in general.

The NACME researchers interviewed the administrators at the most successful institutions to suggest other factors that impact retention. Six key actions were identified: (1) strong institutional commitment as measured by attitudes of faculty and staff, integral minority engineering programs, and allocation of resources; (2) focus on removing barriers to student success; (3) involvement of the corporate community; (4) precollege development of potential engineering students; (5) summer bridge programs; and (6) special attention to early success of freshmen.²⁷ Our Office of Student Affairs embraces the above six key actions. The strong commitment of the College to the Office of Student Affairs and to WISE and OMEP has been mentioned. Examples of removing barriers include a mandatory placement exam for Calculus I and an introductory course on computer basics that was initiated last fall targeted for underrepresented minority freshmen. The Office of Student Affairs has a Student Affairs Advisory Council composed of industry representatives and ASU representatives. Industry supports nine of the 11 summer programs. Pre-college and summer bridge programs have been described. Fall orientation and Academic Mentoring for mathematics classes are helping with early success of freshmen. A Residential Hall program is also focused on the early success of CEAS freshmen.

Early retention efforts in the college include a fall orientation of three days designed for entering engineering students. This orientation is run as a special stream within the university orientation program. The Office of Student Affairs and University Residential Life provide a Residence Hall program for engineering freshmen.^{29, 30} The CEAS students are placed on the floor of a conveniently located Residence Hall according to a Roommate Preference Form.³⁰ Other college retention programs include an Inclusive Learning Communities Program with Academic Mentoring and Career Mentoring, strong student council and student organization support (over 30 student organizations), an integrated curriculum program for freshmen, and cohorts of freshmen engineering students who take three classes together. Student organizations can receive money from the Associate Dean of Student Affairs to support trips to national conferences (a retention event) and other events. In repayment of this money, the students are credited with \$8/hour of volunteer work they do to assist the college in recruitment events with middle school or high school students.³¹ As students work with the college to recruit others, usually their own attachment to the college and their chosen career is strengthened. In addition, since lack of success in the first mathematics class was found to be a strong indicator of

retention, a required placement exam for Calculus I has been put in place. An optional placement exam is provided for the Pre-Calculus class.

A Scholars program and now a scholarship program emphasizing research and graduate school have been run in our college to encourage more of our students to attend graduate school. The Scholars program targeted women students and the current scholarship program targets women and minority students. ASU is also a charter member of the GEM Consortium, dedicated to increasing the number of underrepresented minority students who receive Master's and PhDs in engineering, and of the EMERGE Consortium, also dedicated to increasing the number of minority engineering students in graduate school.

VI. Lessons Learned

The support of the Dean's Office in a College of Engineering is usually necessary for successful recruitment and retention programs for women in engineering. A program can start very small, with just a half-time graduate student, for example. Our WISE Office began its first outreach program with a two-day commuter program for middle school girls. As demand and support from industry grew, more programs were added. It is important to conduct focus groups or surveys with the engineering women periodically to determine their needs. In early WISE programs, the engineering women said that they did not need additional tutoring help, but they did want to see more role models. At the same time, the minority students said that they wanted additional tutoring help. In recent years there have been requests from the women for additional academic tutoring help. We have found that the CEAS programs for women and for minority students have much to gain if they collaborate. CEMSWE has been a very important and successful means of developing student leaders, fostering diversity and understanding, and giving students additional experience working in teams. A difficult lesson to learn is that if a project is not funded with the first ask, one should not be discouraged, but should write the proposal again, using the information learned from the first submission. As in any program, the passion, dedication, and administrative skills of the staff are fundamental to successful recruitment and retention programs for women.

VII. Results

What have been the results of the efforts of the WISE Program to increase the enrollment and retention of women to the CEAS? The enrollment of women in the Schools of Engineering and Construction has grown from 544 (17.0%) in Fall 1992 to 940 (20.2%) in Fall 2001. In Fall 2001, 21.1% of the engineering students were women, above the national average. The one-year retention for first-time, full-time freshmen women was 72.3% at ASU and only 53.2% in the CEAS on average during 1993-95. For the last five cohorts of first-time, full-time freshmen women, on average their retention has been over 81% at ASU and over 65% in the CEAS. This past fall, the retention programming by WISE was greatly expanded. As a result, over 400 female students were actively involved with WISE, an increase of over 254% of the involvement for Fall 2000. These results are encouraging, but there is always much more that can be done.

VIII. Conclusion

There are too few women in engineering. Major factors for the low interest of women in engineering include the high number of women who are not well informed about engineers and engineering, too few young women identifying engineering as a person-environment fit, and women's low self-efficacy for pursuing science and engineering careers. Solutions include the inclusion of engineering in K-12 and recruitment and outreach programs to introduce young women to the challenges and rewards of engineering.

The retention of women in engineering is compounded by the lack of a critical mass and discouragement from some male students and some international students. The number one reason for women leaving engineering and science is "inappropriate reasons to stay." Through outreach and recruitment programs we try to instill a vision in young women of what engineering is all about and how the first couple of years are tool-building years. The WISE Office provides and promotes retention programs to the women in the CEAS to support them in the academic, social, and personal arenas of their lives.

Although there are too few women in engineering and the problem is not easy to solve, there are solutions. If we all work together, we can make a difference.

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Biography

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