

2006-1221: ATTRACTING WOMEN TO ENGINEERING THAT SERVES DEVELOPING COMMUNITIES

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Attracting Women to Engineering that Serves Developing Communities

Abstract

The University of Colorado at Boulder has created a program in Engineering for Developing Communities (EDC). It is currently formalized as a graduate program within the Environmental sub-discipline of Civil Engineering. Longer term plans are to create a certificate option for undergraduate students in the College of Engineering. In the meantime, a variety of courses have included EDC-related content and projects. Service-learning and active-learning opportunities to serve developing communities are available at the University of Colorado. To date, anecdotal evidence exists that the EDC program is particularly attractive to women. In the Engineers Without Borders (EWB) student chapter at the University of Colorado, the leadership board has been composed of 40-62% women over the years fall 2002 to spring 2005, compared to 25% and 15% on the American Society of Civil Engineering (ASCE-CU) and American Society of Mechanical Engineering (ASME-CU) boards in the 2004-2005 academic year, respectively. A nationwide survey of 35 to 45 different student chapters of these same organizations (EWB, ASCE, ASME) show more similar percentages of women on the leadership boards. At 22 universities where the ASCE student chapter has an "Outreach" or "Community Service" officer, 66% of these positions are filled by women. An on-going research project on a simple and low cost drinking water treatment device, the Filtrón, has attracted eight undergraduate researchers including 50% women and 50% minorities. In a college-wide undergraduate research internship program, the topics serving developing communities have attracted more women and minority student applicants than the average project topic. Although it appears that EDC is particularly attractive to women, larger sample sizes and broader evaluation of control populations are needed to confirm this hypothesis. Efforts are on-going to gather more definitive evidence. However, if a greater awareness of the opportunities to serve society were made known more women might enter engineering as a major in college and eventually as a profession.

Background

After gains in the representation of women graduating with engineering degrees from around 1990 to 2000, more recently these numbers have been declining in the US and Canada¹ (http://www.ccpe.ca/e/prog_women_1.cfm). Based on U.S. data from a variety of sources, the percentage of bachelor's degrees in engineering that were awarded to women has been fairly constant at about 20-21% from 1999 through 2004 (see Figure 1)^{2,3,4,5}. The representation of women in engineering varies significantly by major, with 40.6, 36.5, 23.1, and 13.7% of environmental, chemical, civil, and mechanical engineering bachelor's degrees awarded to women in 2004³.

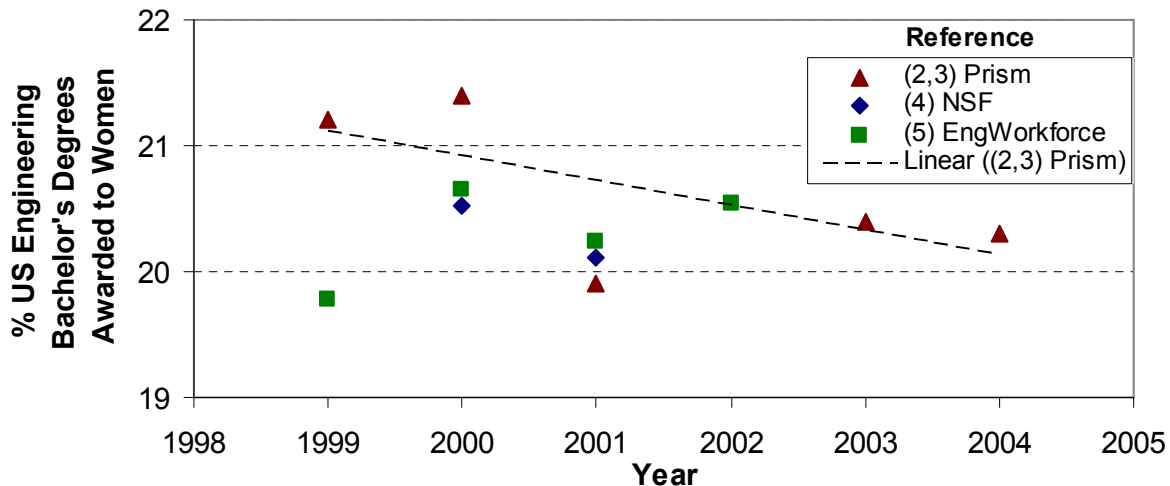


Figure 1. Percentage of US engineering bachelor's degrees awarded to women from 1999 through 2004; values varied in different references^{2,3,4,5}

From 1990 to 1993, Seymour⁶ conducted interviews and focus groups with 335 current and former science, mathematics and engineering (SME) majors or intended majors on seven campuses in order to discover the relative importance of factors contributing to the loss of undergraduates from these majors; 51.9% of all the study participants were women. Seymour notes: "In the process of developing and clarifying their career goals, however, women expressed more altruism than men and were more likely to switch to career paths that reflected humanitarian goals or offered more satisfying work."⁶ Based on this research finding, it was of interest to look for trends among gender participation in a new Engineering for Developing Communities (EDC) program at the University of Colorado at Boulder.

Engineering for Developing Communities

Developing communities around the globe are desperately in need of basic services and infrastructure including clean water, sanitation, energy, and shelter⁷. All of these needs will require engineers to provide effective and affordable long-term solutions. In response to these needs, the University of Colorado at Boulder (CU) has created a program in Engineering for Developing Communities (EDC) (<http://www.edc-cu.org/>). The goal of the program is to "educate globally responsible engineering students who can offer sustainable and appropriate solutions to the endemic problems faced by developing communities worldwide." EDC is currently formalized as a graduate program within the Environmental sub-discipline of Civil Engineering. Beyond the required core courses that all environmental engineers take, this emphasis requires additional coursework in Environmental Health and Appropriate Treatment Technologies, and a project or research experience relevant to a developing community. Longer term plans are to create a certificate option for undergraduate students in the College of Engineering. It is hypothesized that EDC might be particularly attractive to women, and could serve to attract and retain more women in engineering. A variety of undergraduate courses and extracurricular activities at the University of Colorado have included EDC-related content and projects. These activities are described below with data that has been collected on demographics and student perceptions.

Freshman Courses with EDC Components

EDC has been incorporated into a variety of activities in the 1-credit *Introduction to Civil Engineering* course (<http://www.colorado.edu/engineering/civil/CVEN1317/syllabus.html>). For example, students are required to attend a meeting of an engineering professional society, such as the American Society of Civil Engineers (ASCE). Of the 94 students in the 2003-2004 classes, 33% attended the University of Colorado's student chapter of Engineers Without Borders (EWB-CU). EWB is an organization dedicated to partnering with disadvantaged communities to improve their quality of life. In essays on this experience, 16% of the men and 27% of the women stated interest in joining a professional organization due to a desire to contribute to society. One female student stated: "I want to join a group to help me get involved in community service." Another woman noted: "[The EWB group] really excites me with all the opportunities that engineers have to change and help different parts of the world." One part of the course includes a project on the technical, social, and environmental aspects of the Three Gorges Dam in China. In the ethics module, students can read about moral exemplars, including a civil engineer that worked in refugee camps in areas hit with natural disasters and civil conflicts. At the end of the semester, students write reflective essays on civil engineering and why they may want to become civil engineers. In these essays, 50% of the 8 women and 21% of the 84 men stated an interest in serving society. One female student wrote: "I was surprised and interested to read [about] the international and service aspects.... I would like to find out more about this form of 'emergency civil engineering'." Another female student commented: "I like that I would be doing something that makes a difference in the community."

The three-credit First-Year Engineering Projects course (GEEN 1400) has had a few sections focused on "Appropriate Technology" over the past 4 years. The course is a hands-on, team oriented class (<http://itll.colorado.edu/GEEN1400/>). At the end of the semester all of the students participate in a design expo that is open to the public. Examples of projects in the Appropriate Technology sections are: production of biogas from rotting bananas, power from water turbines and hand cranks, cooling systems for preserving vaccines, improving cook stoves, sanitation and disposal of human wastes without water. All of these projects would serve to improve life in developing communities. In other sections of GEEN 1400 students may build Lego robots, Rube Goldberg contraptions, Children's Museum exhibits, and assistive technology. The course as a whole has had significant benefits to retaining student in engineering, particularly women and minorities. Results show a seventh-semester retention rate of 63% for students who enrolled in the projects course during their first year, compared to a college-wide rate of 58%. In addition, 67% of women who took the projects course in their first year were retained into their seventh semester, versus less than 58% for females that did not take the projects course⁸. The specific benefits of the Appropriate Technology sections relative to the other course topics have not yet been evaluated, and is a topic for future study.

Senior Design Course with EDC Projects

In the three-credit Environmental Engineering senior capstone design course, teams of students work on projects for a single client or community for the entire semester (<http://www.colorado.edu/engineering/civil/CVEN4434/projects.html>). Students select the

project they work on from three to five projects developed by the instructor before the start of the semester. From 2001-2004, women comprised 46% of the 68 total students. During this same time period, women represented 50% of the 32 students who chose to work on a service-learning project for a developing community. An example of a service-learning project was to determine a low-cost and sustainable way to treat drinking water for a community of Mayans in Belize; they currently used untreated water that could cause a variety of diseases. Other projects available were for industries, local municipalities, etc; for example, up-grading the wastewater treatment facility for a nearby city. This is initial evidence that women may be more attracted to projects that have a more direct impact on people's quality of life.

Student Chapters of Professional Societies

In EWB-CU from 2002 through 2005, the leadership board has been composed of 40 to 62% female students. This compares with 25% and 15% women on the American Society of Civil Engineering (ASCE-CU) and American Society of Mechanical Engineering (ASME-CU) boards, respectively, in the 2004-2005 academic year (see Figure 2). For the civil and mechanical societies, these percentages are similar to nationwide averages of Bachelor's degrees awarded of 23% and 14%, respectively³. Students from a wide range of majors participate in EWB. From 2003-2005 the leadership board included civil, environmental, mechanical, architectural, chemical, aerospace and non-engineering majors. Based on the majors represented by EWB students at the University of Colorado and the fraction of women in these majors^{2,3}, it would be expected that the board would be 29% women. Thus, women appear to be over-represented in leadership roles in EWB-CU. Furthermore, women comprised 41% of the 61 active participants on seven different EWB-CU projects, much higher than the 26% women expected based on the engineering majors that the students represented.

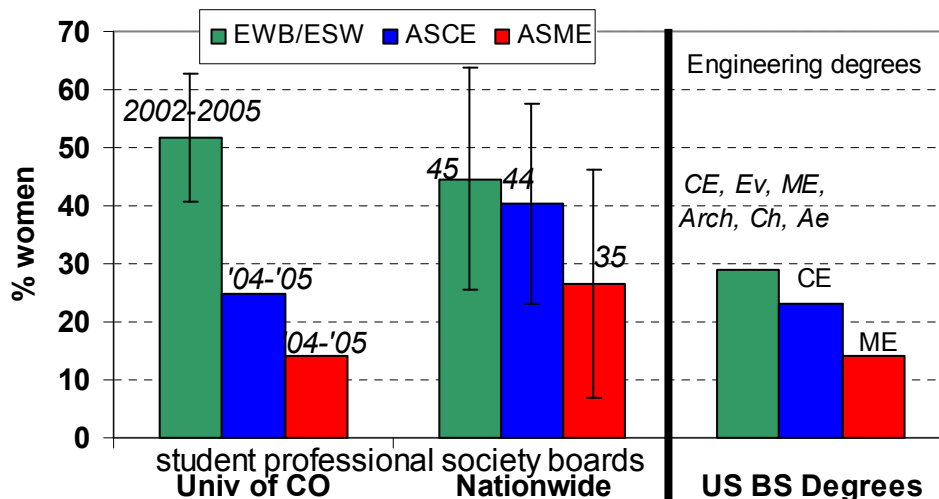


Figure 2. Percentage of student engineering professional society boards composed of women, and US engineering bachelor's degrees awarded to women in various majors³.

A nationwide survey of 35 to 45 different student chapters of EWB, ASCE, ASME (based on websites in summer 2005) found more similar percentages of women on the leadership boards, at 45%, 40%, and 27%, respectively (see Figure 2). This also indicates over-representation of

women on the leadership boards of ASCE and ASME relative to the percentage of Bachelor's degrees awarded to women. During the nationwide survey, it was noted that at 22 universities where the ASCE student chapter had an "outreach" or "community service" officer, 66% of these positions were filled by women (note that 32 universities did not list these positions on the website with their officer boards). This serves as further evidence that many women are interested in the humanistic aspects of engineering.

Independent Study Opportunities on Engineers Without Borders Projects

From 2003 through 2005, three students have earned 3 credits of independent study with Professor Bielefeldt for learning conducted in association with Engineers Without Borders (EWB) projects. (More than ten other engineering students at the University of Colorado have earned independent study credits for their EWB-associated work under the mentorship of Professor Amadei and others.) The students were actively involved in an EWB-CU project, recognized that there was an aspect that they wished to investigate in more depth, and then approached a mentor to establish an Independent Study project. All of the student projects included a literature survey to understand the political, social, and geographical aspects of the country and community that they were working with; and then a technical "design" evaluation to solve a water or sanitation issue associated with the community. One student wrote a more in-depth research proposal and was awarded funding from the University of Colorado's Undergraduate Research Opportunities Program (UROP). This money was primarily used to pay for international travel to the community being served by the EWB project. The same student also wrote a proposal to the Engineering Excellence Fund (EEF) and received funding to purchase portable water quality analysis equipment. This student completed a laboratory research component to learn and evaluate the robustness of a microbial water quality indicator test. All three students worked with a team of other students and a professional mentor on the EWB project, and traveled internationally to their community over the course of the project experience. Of the two women and one male student mentored by Prof. Bielefeldt, one is now pursuing a Master's degree and the other two are working in the engineering profession. Two are still involved with EWB projects.

In December 2005 a written survey of 110 questions on the learning outcomes from working on these EWB/Independent Study projects was e-mailed to the three students who worked with Prof. Bielefeldt. This survey was developed based on the student-reported learning outcomes of undergraduate participation in research, as described by Seymour et al.⁹. The small number of students available to survey clearly limits the usefulness of the results, but further students will be queried in future years as the EWB program continues. Although the complete survey results are too long to be presented here and there is too small a sample to yield conclusive data, a few points are noteworthy. Most of the survey elicited student responses to various statements on a 5-point Likert scale (1 = strongly agree, 3 = neutral, 5 = strongly disagree). All three students stated that "wanted to benefit society through the results" and "learn about an interesting topic" as two of their top three motivating factors for participating in the experience. Two also placed "clarify career interests" as a primary motivator. The student who linked the proposals and laboratory research to her project listed "wanted to create new knowledge" as a significant motivator. The students reported spending about 280 to 360 hours on these projects. That is higher than most students spend on a three-credit technical course of perhaps 150 to 200 hours.

The learning outcomes of the project included many of the ABET A to K program outcomes criteria¹⁰. For example, all three students strongly agreed that the experience improved their: ability to function on multi-disciplinary teams (criteria d), understanding of the impact of engineering solutions in a global and societal context (criteria h), and understanding of professional and ethical responsibility (criteria f). It is interesting to note that the two women reported strong agreement with the statements “the experience increased my self-esteem”, “the experience increased my confidence”, and “the experience increase the probability that I will go on to graduate school”; while the male student gave a neutral response to these statements.

The students also responded to 8 open-ended questions. In response to the question “how was the experience more beneficial than taking a normal course for the same amount of credits”, one of the female students responded:

I actually cared about what I was doing. It mattered to me and to the people whose health I was trying to guarantee. This experience cannot be compared to a “normal course.” This sounds like a cliché, but it changed my life.

Although the current data set is very small, it appears that there are numerous beneficial learning outcomes from participating in the Engineers Without Borders projects. Women may achieve additional beneficial outcomes, possibly due to the motivation provided by directly benefiting the health and welfare of people. Alternatively, the added benefits may derive from the one-on-one mentoring environment of the Independent Study project. Further student surveys will be needed with a larger pool of participants to fully elucidate these benefits.

Research on Appropriate and Sustainable Technology

An on-going research project on an appropriate and sustainable technology for drinking water treatment, the Filtrón, has attracted eight undergraduate researchers to commit at least a semester to the project, including 50% women and 50% minorities. Six of these students were paid as part of an intern program, including the Research Experience for Undergraduates (REU), Summer Multicultural Access to Research and Training (SMART), Discovery Learning (DL) internship, or Multicultural Engineering Program (MEP) grant. The other two students earned Independent Study credit for their research projects. The students were mentored by Professor Bielefeldt and/or R. Scott Summers of the Department of Civil, Environmental, and Architectural Engineering. The students were earning degrees in civil (2 students), chemical (1 student), environmental (4 students), or mechanical (1 student) engineering.

Undergraduate students from across the University of Colorado’s College of Engineering could apply to become Discovery Learning (DL) interns (<http://ecadw.colorado.edu/engineering/activelearning/discovery.htm>). The program pays students an hourly wage (\$10/hr, for a maximum of \$1500/semester). Thus the typical time invested is about 10 hours per week. At the end of the semester, a Discovery Learning Symposium is held where all students present the results of their work orally and with posters. Descriptions of the specific research projects available were provided to the students, who indicated up to four project preferences when they applied to the program. The first three semesters of the program, students generally applied for a single semester, while in 2005/2006 the program moved to a full academic year model. Filtrón projects co-mentored by Professors Bielefeldt and Summers were available in the first three

single semester cycles. There were other projects available directly tied to helping people in developing communities available in Spring 2005 and 2005/2006. One was “Software Tools to Support Global Hunger Reduction Project” with Professor Ken Strzepek. The project description noted the project goal was “to assist policy makers in developing policies to reduce hunger by 50% by 2025.” A project on “Membrane-Assisted Solar Desalination” sponsored by John Pellegrino noted that “for small, rural communities, especially in developing regions, solar distillation for water purification can possibly be inserted as a low maintenance, quality-of-life improvement.” The other DL projects available spanned traditional and high tech engineering topics including satellite systems, computing, fuel cells, etc. A summary of data on the undergraduate student applicants is included in Table 1.

Table 1. Summary of Applicant Data for DL Intern Projects over Four Cycles

Project Topic	# projects available	# applicants	average applicants per project	% female applicants	% underrepresented minority applicants
All	122	151*	3.4	17	7.9
Filtrón	3	20	6.7	25	10.0
Other EDC	4	18	4.5	39	22.2

* 420 projects were selected by the 151 separate individuals

Based on the number of applicants per project, the Filtrón and other EDC projects were more popular than the average project available. The Filtrón project attracted applicants majoring in aerospace, chemical, civil, environmental, and mechanical engineering and applied math. The other EDC projects additionally attracted applicants majoring in architectural, electrical and computer engineering. The Filtrón and EDC projects were more popular with women and underrepresented minorities (Hispanics, Native Americans, and Blacks) than the average engineering projects available.

Written surveys (almost identical to the 110-question survey sent to the EWB students as described on page 4) were emailed to twelve undergraduates that Prof. Bielefeldt mentored in research activities from 2000 to 2005, including all eight students who worked on the Filtrón projects. Professor R. Scott Summers co-mentored most of the students who studied the Filtrón. The survey was similar to the EWB Independent Study survey discussed above. Responses were received from seven Filtrón researchers (four women, three men; although one survey was only partially filled out, with all of the outcome statements left blank) and three women who researched other environmental engineering topics. Of eight potential motivating factors for participation in research that were listed on the survey, 6 of the 7 women and 2 of the 3 men included “wanted to benefit society through the research results” among motivators. Among other interesting results, five women strongly agreed (rated as “1”) and 1 agreed (rated as “2”) with the statement “the research experience increased the probability that you will go on to graduate school” (the 7th female did not respond to this statement or any other “outcomes”, as noted above); two men agreed and one strongly agreed with this statement. No definitive statements contrasting the results for men and women can be made given the small data set; efforts to expand the pool of students surveyed and improve survey return rates are on-going.

Summary and Conclusions

Through courses, extracurricular professional societies, and undergraduate research opportunities available to engineering students at the University of Colorado, there is preliminary anecdotal evidence that EDC is particularly attractive to women. Due to the newness of the program and small sample sizes, there is currently insufficient data on which to base conclusive statements. However, those mentoring students in the EDC program all agree that women generally appear attracted to the humanistic and service-related aspects of engineering geared to assisting global development. If a greater awareness of the opportunities to serve society were made known, more women might enter engineering as a major and a profession. Opportunities within their coursework to learn about the direct benefits that engineering can have on the survival and quality of life of people on the planet may help retain women in engineering who might otherwise lose motivation and transfer out of engineering degrees. This can be readily accomplished with minimal effort in many different courses, through the selection of examples and case studies that highlight humanitarian aid linked to a wide variety of engineering disciplines. The Engineers Without Borders – USA website (www.ewb-usa.org) contains information on many of these types of projects. As the EDC program continues to evolve at the University of Colorado at Boulder, further efforts will be made to gather data support or refute the benefits of EDC in attracting and retaining women in engineering.

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