Gender Participation in Humanitarian vs. Traditional Multidisciplinary Senior Design Projects

Catherine Skokan, Joan Gosink

Division of Engineering, Colorado School of Mines

Abstract

In 2003, the Colorado School of Mines received a grant from the William and Flora Hewlett Foundation to establish a minor in Humanitarian Engineering. One of the goals of the Hewlett Foundation's Engineering Schools of the West Initiative was to increase the number and diversity of engineering students in the United States. We have investigated the gender mix of students in traditional multidisciplinary senior design projects for the Engineering Division at the Colorado School of Mines versus the gender mix of students choosing humanitarian-designated multidisciplinary projects. A humanitarian-based senior design project is a requirement for the Humanitarian Engineering Minor. Humanitarian projects included a broad range of topics such as a water quality project in an economically disadvantaged area of rural Colorado and construction of an onion storage facility in Senegal. Four semesters of senior design classes were investigated with about 500 students participating. Women comprised about 23% of the total class population for these senior design course offerings. In the Humanitarian projects, women comprised over 50%. This significant difference supports the concept that women will be drawn more to engineering as a career if the application of engineering to humanitarian problems is emphasized.

CSM and a History of Women on Campus

Colorado School of Mines, founded in 1874, is a public research university devoted to engineering and applied science with a student body of 3500. It has the highest admissions standards of any university in Colorado and among the highest of any public university in the U.S. CSM has distinguished itself by developing a curriculum and research program that is geared towards responsible stewardship of the earth and its resources. In addition to strong education and research programs in traditional fields of science and engineering, CSM is one of a very few institutions in the world having broad expertise in resource exploration, extraction, production and utilization. As such, CSM occupies a unique position among the world's institutions of higher education[1].

Women have participated in much of the history of CSM[2]. The first woman to graduate, Florence Caldwell, received a degree in Civil Engineering in 1898. By 1959, three more women had graduated. In the 1960's, the number of women at CSM increased and an additional 10

women received degrees. The first PhD awarded to a woman (Catherine Skokan, one author of this paper), occurred in 1974. Today, both the undergraduate and graduate student populations are composed of 25% women. This is greater than the national average of 20.4% [3]. However, we continue to strive to increase diversity in our student body.

The Hewlett Foundation Grant

In Fall 2002 the William and Flora Hewlett Foundation issued a request for proposals to a limited number of universities and colleges in western states. The general objectives of the Hewlett-sponsored program were to improve the quality of engineering education in terms of recruitment and retention of under-represented groups, innovative teaching and learning strategies, advancement of student professionalism, development of academic and industrial partnerships, and extended impact. CSM responded with a proposal for the development of a minor program in Humanitarian Engineering. The Hewlett Foundation funded our proposal. In addition, eight other universities: Boise State University, Idaho State University, Montana State University, Northern Arizona University, Oregon State University, University of Nevada/Reno, University of Utah, and the University of Wyoming received funding. The collective group is known as the Engineering Schools of the West Initiative (ESWI).

The overall goal of the Humanitarian Engineering program at CSM is the creation of new cadre of engineers, sensitive to social contexts, committed and qualified to serve humanity by contributing to the solution of complex problems at regional, national, and international levels and locations around the world in need of "smart" technical assistance. We are achieving this goal through the development of a comprehensive humanitarian engineering curriculum that teaches engineering students how to bring technical knowledge and skill to bear on the real-world problems of the less materially advantaged in order to promote development of the common good. We focus on our existing strengths -- in energy systems, geotechnical and geoenvironmental engineering, remote sensing, signal processing, and image processing, and new technologies for "Sustainable Engineering," and in emerging engineering disciplines including, bioengineering, information systems, and micro-nano systems. These capabilities are applied to the solution of problems for areas and people who can benefit from engineering expertise. This objective is particularly relevant to the CSM, a school with a long tradition of leadership in resource and minerals fields, but with a strong commitment to stewardship of global resources.

Incorporation and implementation of humanitarian projects into Senior Design is but one component of the new curriculum, which extends to the development of new courses, modification of existing courses, and outreach activities. The focus of this article is on the humanitarian projects in Senior Design, but more information on the overall program can be found at the CSM website (http://humanitarian.mines.edu/home.htm).

Four specific goals of the Humanitarian Engineering program were defined in the original proposal:

(1) *Create a culture of acceptance and value of community and international service activities at CSM.* The goal is to create an enhanced appreciation of the value and importance of the participation of engineers in community and international service.

(2) *Increase the number of CSM engineering graduates that enter occupations that have a community or international service emphasis.* Although this is a long time goal, we anticipate measurable changes in employment patterns by the conclusion of the grant.
(3) *Increase the recruitment of women and minority students to the engineering program at CSM.* As a result of new recruitment activities that emphasize service and our K-12 outreach activities, we anticipate an increase in applications from women and minority students.
(4) *Increase the number of engineering students that enter internships in community or international service.*

Assessment measures for each of these specific goals were established, and some results are presented in a concurrent ASEE paper[4]. Goal number 3 is particularly relevant to the current paper. The challenge is to attract larger numbers of female and minority students into the pool of applicants to CSM through the program in Humanitarian Engineering. As we discuss below, the newly inaugurated Senior Design projects with humanitarian themes are attractive to current female upper-class students. The next step is to publicize these activities to K-12 students and teachers to improve their understanding of the contributions that engineering makes to society. Through these efforts, both the K-12 teachers and students will learn that engineering is a profession dedicated to the benefit of the community. We believe that this awareness will encourage more students to seriously consider careers in engineering.

Senior Design Program

The CSM Engineering Division Capstone Design Course is a creative multidisciplinary design experience emerging from combined efforts in civil, electrical, mechanical, and environmental specialties in engineering. Within the engineering community it is widely believed that many of the challenges which are facing practicing engineers in the 21st century can best be met by exploiting multidisciplinary approaches. This Program in Senior Capstone Engineering Design has been established to demonstrate the value and ingenuity which can be derived from cooperative design efforts among traditional engineering disciplines.

Project for the senior design program are suggested by industrial, academic, and governmental clients, and from professional society through engineering contests. The requirements are that the project be open-ended, multidisciplinary, and have non-engineering constraints (e.g., economic, environmental, aesthetic). There must be a client external to the senior design faculty and usually outside of the school. The students are given a choice of 20 to 50 projects (depending upon class enrollment) and write a memo stating their top three choices. The senior design faculty team assigns three to five students to each project by taking into account the student choice and student capabilities as indicated on a resume, and assigning a multidisciplinary mix for the final team. Gender is not a consideration in team or project assignment.

Since the spring semester of 2003, the project choices have included humanitarian projects. These projects have incorporated community water projects, curriculum help for rural and inner-city schools, building design and construction, and engineering solutions for economic expansion. Both domestic and international projects have been undertaken.

One example of an assignment was a water project in rural Conejos County, Colorado. Conejos County is located in South Central Colorado and has a population of 8400. Twenty-three percent of the population lives below the poverty line. The external clients included the county officials who were concerned with arsenic in well water. A senior design team of five women students (3 environmental engineers and 2 civil engineers) first tested well water throughout the county and mapped the arsenic level. They also investigated heavy metals and bacteria in the water. The few wells that were contaminated were clustered in a set at the northeastern edge of the county. Next the team worked on locating the source of elevated levels of arsenic and other contaminants. Their conclusion was that the shallower aquifer contained more contaminants than deeper aquifers. A recommendation for further study of the stratigraphy and groundwater was made. Finally, the students designed a mitigation plan for homeowners and distributed a pamphlet on health concerns and well water. Many of the residents who had thought that their groundwater was contaminated and were purchasing bottled water were relieved to learn that their water was safe.

An international example involved the design and construction of an onion storage facility in Senegal. The population of 1200 in the rural community of Rao, about 19 km south of St. Louis in Northern Senegal, is sustained by agricultural activities mostly in growing purple onions. The selling price of this vegetable, which is widely used in Senegalese kitchens, is very low at the time of harvest as the supply is greater than the demand. Thus the farmers must sell their onions at below-cost rates and frequently cannot sell their entire crop. Because of this, the village is suffering financially. The needs of the village are great but the first priority set by the village was for an onion storage facility so that some of the crop might be sold a few months after harvest for a higher price. A student team of three women and one man designed and helped to construct an onion storehouse for the village. This multidisciplinary team included two civil engineers, one mechanical engineer, and one electrical engineer. The village of Rao supplied a mason and construction workers, as well as room and board for the Colorado visitors. Travel and supplies were supported through the Hewlett Foundation Grant. This 10m x 20m structure, when completed, contained solar-powered fans to provide ventilation. This brick structure with a brick roof will remain cool enough to store onions for up to three months.

Gender Participation in Senior Design Projects

We investigated the project choices made by students over four semesters, since the beginning of the Hewlett Grant. Seniors may choose to begin the year-long senior design course sequence in either the fall or spring semesters. Typically, the enrollment in the sequence beginning in the fall semester is three to four times greater than the enrollment in the sequence beginning in the spring. The first humanitarian-designated project was introduced to the Senior Design Program in the spring of 2003. Students on this team designed and constructed a pumping and distribution system for water in a village in Mauritania. Five humanitarian projects were offered in the Fall semester of 2003. These humanitarian projects have been suggested by non-profit charitable organizations such as Engineers Without Borders, Namlo Foundation and ICAST, as well as local school districts or CSM faculty. It is not our intent to replace all senior design projects with humanitarian projects. We anticipate that 10 – 20 % of future projects will have a humanitarian theme. Table 1 below summarizes the total number of senior design projects assigned to student teams and the number of humanitarian projects over the last two years. The

table also lists the percentages of women participating in each senior design offering. These numbers reflect the percentage of women undergraduate students in the entire school. The number of students on Humanitarian Project teams and the percentage of women on these teams illustrate a significant difference in gender participation. The team composition of humanitarian designated projects is around 50% women, a doubling of the percentage of women in traditional projects.

Semester	Total Projects	Humanitarian Projects	Total Students	% Women	Humanitarian Students	% Women
Spring '03	14	1	61	20	5	40
Fall '03	44	5	222	22	23	56
Spring '04	12	3	57	32	15	47
Fall'04	36	5	169	24	26	50

Table 1: Data on senior design project team gender composition

In writing memos to indicate project choice, students who listed Humanitarian Projects among their three choices gave reasons for their interest:

- "I love Africa and its people and would enjoy another opportunity to help one of its countries" (This student had completed an internship in Uganda.)
- "the possibility for me to help out …really appeals to me"
- "I would love to have the opportunity to help others. I know I would take this project very seriously due to the fact that it will help to improve the lives of others."
- "The reason this project stood out to me is because it involves working with children and will allow me to help motivate them to learn…Currently I am a volunteer for Big Brothers/Big Sisters.."
- "To this day, it was one of the most fulfilling experiences in my life." (referring to previous experience in helping needy children)

In order to investigate whether or not the area of engineering skewed the gender data of Table 1, these data were separated out and listed for civil, electrical, environmental and mechanical specialties. Because of the multidisciplinary nature of our division, students often participate in more than one specialty. However, when choosing a project, students are asked to provide an area of expertise for team selection. Table 2 summarizes the separated data for the Senior Design offering for Fall, 2004. In each area of engineering, there was a significant increase in the percentage of women participating in humanitarian-designated projects compared to the percentage of women enrolled in the class. Although the percentages for environmental engineering appear to be high, the total number of environmental engineering students enrolled in senior design is low.

Specialty	# Students Registered	% women registered	% women humanitarian projects
Civil	43	26	47
Electrical	38	29	62
Environmental	9	67	78
Mechanical	70	17	24
Unlisted	9	n/a	n/a

Table 2: Separation of student by area of specialty and percentages of women for the Fall, 2004 senior design class.

As was stated earlier, gender is not a consideration in the team selection process. To verify this, the percentage of women indicating a preference for humanitarian projects prior to team assignment was observed. Table 3 shows the total number of students selecting humanitarian-designated projects for their first, second or third choices at the start of the Fall Semester, 2004. In assigning projects, preference is given to the students' first choice. Generally, 95+% students are assigned to one of their three preferences and often the first choice.

Choice	# students requesting humanitarian projects	% women requesting humanitarian projects
First	32	53
Second	21	33
Third	23	44

Table 3: Number of students selecting humanitarian projects for the Fall Semester, 2004.

The students who chose humanitarian senior design projects were aware that their engineering careers could be used to help others. The gender data indicate that humanitarian-designated senior design projects have also helped to meet Goal 3 (*Increase the recruitment of women and minority students to the engineering program at CSM)* of the Hewlett Grant.

Gender Issues in Engineering

Data from the National Science Foundation[5] display persistently low percentages of doctoral degrees awarded to women in engineering. The following table, taken from the NSF Division of Science Resource Statistics, reveals that engineering programs awarded the smallest percentage of doctoral degrees to women among all fields of science and engineering.

Field of study	% Doctorates Awarded to Women 2002
Science and engineering, total	37.3
Biological/agricultural sciences	42.9
Earth, atmospheric and ocean sciences	30.9
Engineering	17.5
Mathematical/computer sciences	25.0
Physical sciences	26.8
Psychology	66.7
Social sciences	44.5

Table 4: NSF data on percentage of doctorates awarded to women

The reasons for this disparity can be found in recent research. For example, a number of research studies demonstrate the existence of significant gender differences in the relative value ascribed to altruistic and humanitarian activities by students. Marini et al.[6] report that in a study of gender differences in the job values of U.S. high school seniors from 1976 to 1991, females regarded altruistic and social rewards much more highly than did their male counterparts. In contrast, male and female students weighed other factors, such as extrinsic rewards and personal influence or control, more evenly. This difference in value systems is reflected in students' career choices[7] with females avoiding occupations that appeared to lack social commitment. Williams[8] notes that, for selecting a career, high school girls are more influenced than boys by the following five concepts and perceptions: their own marks and self-evaluation of their abilities; the advice of parents and teachers; job opportunities in the field; desire for career flexibility with a balance of career and family responsibilities; and the desire to make the world a better place. The last item is consistent with the objectives of the humanitarian engineering program at CSM.

A report from the Whitaker Foundation[9] lends credibility to this observation. The relatively new field of biomedical engineering is drawing large numbers of women students. Indeed biomedical engineering leads all engineering disciplines in the percentage of degrees awarded to women at all levels: bachelor's (36%), master's (34%) and doctoral (32%). Female students enrolled in these programs reveal a strong interest in socially altruistic or humanitarian objectives. For example, Sara Koehler, a graduate student at Northwestern University's Department of Biomedical Engineering, stated, "I liked engineering and still wanted to something that was actually going to affect people." Janice Turlington, a graduate student in biomedical engineering at Pennsylvania State University, claimed, "I really want to help someone. It has nothing to do with the money. It has nothing to do with how far up the ladder I can go. For me, it has everything to do with how much I can help people." David Nelson, chair of Michigan Tech's Biomedical Engineering Department concurs: "The difference I see with biomedical engineering students is they are much more focused on what's going to be the social utility of what they do."

Similarly, a study by University of Michigan psychologist Jacqueline Eccles and research scientist Mina Vida[10] found that young women chose careers in the biological sciences and medicine over the physical sciences and engineering, because "they perceived the latter to be less people-oriented and to have less value to society." This study, funded by the National Institute of Child Health and Human Development and the National Science Foundation, collected data for over 17 years and involved more than 1700 Michigan students from sixth grade through young adulthood. To quote Dr. Eccles, "Although these girls might be interested in physics and are confident of their mathematical abilities, they choose to go into the biological sciences or medicine because they want a job that more directly helps people."

Awareness of these interests has led to the development of a series of outreach projects designed specifically to attract and retain women in undergraduate engineering programs by engineering educators in Canada[11]. These initiatives include an emphasis on the societal role of engineering, the important contributions that engineering makes to society, and the value of interactions with others in engineering design and analysis. The Canadian intervention projects appear to be bearing fruit, since female enrollment in engineering programs doubled, to about 21%, during the

decade of the 1990's. Interestingly female enrollment in engineering programs at the University of Guelph in Ontario reached 43%. Perhaps not surprisingly, this university offers programs in biomedical, environmental and chemical engineering rather than the traditional fields on civil, computer and mechanical engineering.

According to a study done by Williams[8], female students also appear to be slightly more drawn to applications-oriented learning. This author describes gender differences in cognitive learning patterns in terms of "relational" versus "hierarchical" styles. Although the great majority of students appear to feel most comfortable with the relational, rather than the hierarchical style, there is a small gender-based difference that suggests that women prefer learning through observation and experience rather than through argument and proof. Specifically, 93% of women students[12] and 77% of men follow a relational style. Relational learners, placed in a hierarchical environment, will question legitimacy, motivation and relevance. For relational learners, contextual relationships are primary, and these are validated through observation and experience[8]. Arguably, this suggests that women students will do well in senior design projects in general, but even more so in highly motivating endeavors such as the humanitarian projects.

Conclusion and Challenges

As part of the Hewlett Foundation's Engineering Schools of the West Initiative, the Colorado School of Mines received a grant to develop a minor in Humanitarian Engineering. Among the objectives in the grant was Goal 3: *Increase the recruitment of women and minority students to the engineering program at CSM.* One of the requirements for the Humanitarian Minor is to complete a humanitarian-designated multidisciplinary senior design project. We investigated the gender composition of traditional versus humanitarian senior design projects and found that the percentage of women on humanitarian project teams was more than 50%. This is twice the percentage of women participating in the class. This significant increase is encouraging to achieve our goal for seniors already at CSM. However, the challenge is to inform students applying for college about this opportunity in engineering. Part of this process could begin as early as elementary or middle school to educate students as early as possible about the application of engineering to humanitarian needs. Additionally, data should be collected to investigate the participation of minority students in humanitarian-designated senior design projects to further support our goal.

References

1. About CSM, www.mines.edu/, 12/31/04
2. Florence Caldwell Centennial Celebration Committee and WISEM., 1998, A Century of Women at Mines , Colorado School of Mines, Golden, CO.
3. Michael T. Gibbons…A New Look at Engineering in Profiles of Engineering and Engineering Technology Colleges, 2003, http://www.asee.org/about/publications/profiles/upload/2003engprofile.pdf
4. E. Heidi Bauer, B. Moskal, J. Gosink, J. Lucena, and D. Muñoz, Understanding Student and Faculty Attitudes with Respect to Service Learning: Lessons from the Humanitarian Engineering Project, submitted to the 2005 ASEE Annual Conference and Exposition, June 12-15, 2005, Portland, Oregon.

5. NSF Statistics, http://www.nsf.gov/sbe/srs/databrf/nsf01312/start.htm, 12/31/04

6. Marini, MM., P-L Fan, E. Finley, and A. Beutel, Gender and Job Values, Sociology of Education, Jan96, Vol. 69 Issue 1, p49-65.

7. Shu, X. and M.M. Marini, Gender-Related Change in Occupational Aspirations, Sociology of Education, Jan98, Vol.62 Issue 4, p43-67.

8. Williams, F. Mary, Access and Merit: A Debate on Encouraging Women in Science & Engineering, www.ccwest.org/Library/Conf2000Papers/WilliamsMary.pdfwww.ccwest.org/Library/Conf2000Papers/WilliamsMary.pdf, 1/02/05

9. Whitaker Foundation, Women Choose Biomedical Engineering, http://www.scienceblog.com/community/older/2001/F/200115977.html

10. J. Chamberlin, Study Offers Clues on Why Women Choose Medicine over Engineering, http://www.apa.org/monitor/sep03/clues.html

11. Malgorzata S. Zywno, Kimberley A. Gilbride, and Nadine Gudz, Innovative Outreach Programmes to Attract and Retain Women in Undergraduate Engineering Programmes, Global J. of Engng. Educ., Vol.4, No. 3, p. 293-302.

12. Brooks, C., Instructor's Handbook: Working with Female Relational Learners in Technology and Trades Training, 1986, Fanashawe College and Ontario Ministry of Skills Development.

Biographical Information

CATHERINE SKOKAN
Catherine K. Skokan (cskokan@mines.edu) received her Ph.D. in Geophysical Engineering from the Colorado School of Mines. She is presently an Associate Professor of Electrical Engineering at Colorado School of Mines. Her research interests include engineering applications of geophysics, curriculum development, and K-12 outreach.

JOAN GOSINK
Joan Gosink is an Emerita Professor and former Director of the Engineering Division at CSM, the largest department or division in the School. Under her direction, the Division received various accolades, including designation as a Program of Excellence from the Colorado Commission on Higher Education. The program also expanded to include Masters and Doctorate degrees and an undergraduate specialty in environmental engineering. Dr. Gosink twice served as a Program Director at NSF, and is an experienced ABET evaluator.