Undergraduate Engineering: Some Problems Faced by Women Students

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Today our nation faces global challenges in scientific research, technological development, and the renewal of science, mathematics, and engineering faculties. It is both fair and practical that populations whose engineering talent has heretofore been under-utilized be tapped. One of the obvious populations is women.

The percent women among those obtaining engineering degrees during the past 40 years in the U.S. is shown in Figure 1. There has been a sizeable increase over the past 20 years, but parity between men and women has not been reached and the increase has leveled off disturbingly. Brush (1991) described possible explanations for this leveling off. Moreover, differential attrition of women compared to men occurs in obtaining advanced engineering degrees. As shown in Table 1, women obtain 14.5% of bachelor of science degrees in engineering, but they obtain only 6.8% of the doctorates. This differential attrition occurs to a smaller or larger extent in all major specialties. Differential attrition is reduced slightly but is still significant when only domestic graduate students are considered. The low percentage of women in undergraduate programs and the differential attrition that occurs in pursuing advanced degrees has several important ramifications. More women must obtain advanced degrees in engineering if more women are to hold high level engineering positions. More women in key positions likely will have a resounding effect on both recruitment and retention of still more women. On average, it is simply harder for a person surrounded by persons of a different gender, and seeing only that different gender in positions of leadership, to imagine themselves in those key positions.

To provide some perspective on the percentages of women in engineering, the corresponding percentages in the sciences are also presented in Table 1. There is significantly less differential attrition and much greater representation of women in the sciences than in engineering. Professionals in the water resources field are likely to be drawn from both engineering and sciences. It is interesting to note that at many universities, graduate departments of environmental and water resources engineering have close to 50% women students, but many of those women have an undergraduate degree in science rather than engineering. In most cases, these students are required to take a core set of fundamental engineering courses to provide them with the essentials of an undergraduate engineering education and the background to pass professional registration examinations. Such courses allow them to obtain an accredited masters degree in engineering without having to return to school for a second undergraduate degree, which in many universities is not permitted anyway. This alternative route into the field of water resources engineering is key for opening the professional door to women who are more likely than men to have not considered engineering as an option until later in life. Unfortunately, some engineering firms do not recognize this alternative entry way and continue to maintain that a traditional undergraduate engineering degree is required to obtain the title of engineer (and with it the title, salary scale, and professional credit).

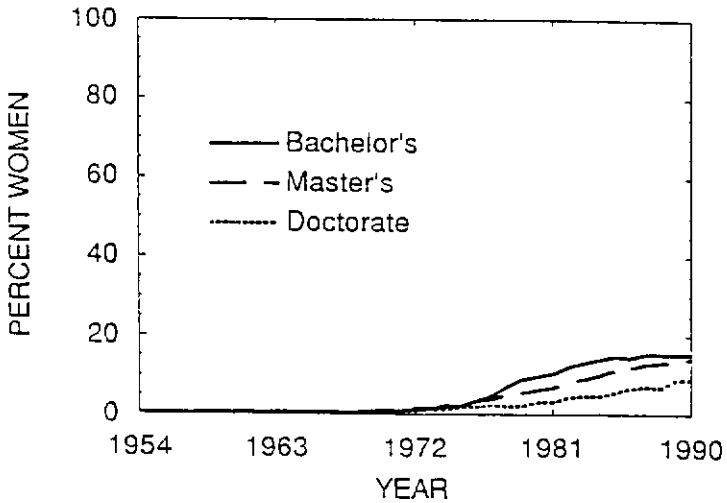

Figure 1. Engineering Graduates (1954-1990)
(data from Engineering Manpower Bulletin, American Association of Engineering Societies, No. 109, May 1991)

Table 1. Engineering and science degrees: percent women[a]

Field	B.S.	M.S.	Ph.D
Engineering	14.5	11.6	6.8
Aeronautical	8.5	6.9	6.0
Chemical	24.7	15.7	9.6
Civil	13.1	10.2	5.1
Electrical	12.0	10.0	4.3
Industrial	30.1	16.9	15.0
Mechanical	10.3	7.7	4.3
Other	16.8	13.7	8.4
Sciences	45.3	40.5	31.7

[a]Percentages reflect B.S. and Ph.D. degrees earned in 1988 and M.S. degrees in 1986. Data from NSF (1990), Women and Minorities in Science and Engineering. Table adapted from Betz, 1990.

Engineering is not a homogeneous profession with regard to women's participation. One difference among the various specialties is illustrated in Figure 2. The percent women within a specialty is plotted on the ordinate. The percent of all male engineers in each specialty is plotted on the abscissa. If all specialties were equally popular among women, one would expect to see a horizontal line at approximately 15% (the national composite average). Although electrical and mechanical engineering are by far the two largest/most popular specialties for both men and women, the percent of women within those fields (12.2 and 11.6%, respectively) is below the average for the profession. Civil engineering, which is the engineering specialty most closely associated with water resources, is the third most popular branch for both men and women, and women are represented on par with the engineering profession as a whole (14.5%). Specialties that have a significantly smaller percentages of women include aerospace (10.6%), petroleum (7.0%), and marine (5.7%) engineering. These are relatively small fields that currently are considered low growth and have been hit hard by economic conditions.

Relatively small specialties that have participation by women well above the national average include environmental (40.9%), biomedical (29.8%), chemical (29.1%), industrial (28.0%), and material science (25.0%) engineering. These fields either are newer specialties or are traditional specialties with a changed focus. Although small compared to the three dominant specialties, they are in high growth phases. Interesting questions arise because economics alone is unlikely to be the sole explanation of these data. Certainly fewer people (regardless of gender) will enter a field that is undergoing difficult times, and more will enter fields that are doing well. However, the statistics indicate that women and men are not responding equally. Do women engineering students respond to economic forces more readily than men? When the outlook is poor, do they voluntarily avoid a specialty at a greater rate than men, and when the outlook is good do they enter at a greater rate than men? Or perhaps, for the specialties undergoing stress, are women less welcome than traditional engineers? For the specialties undergoing growth, are newcomers more welcome? Finally, is it the nature of the work itself within the specialties that causes the differences in representation? Probably all of these factors play a role, some to more extent than others, depending on the specialty.

To understand why women are not well represented in the engineering practicing profession, it is useful to look at entering and graduation rates on a university level. A summary of percent women entering the engineering programs in the College of Engineering at the University of California, Davis (UCD) is shown in Table 2. In the College of Engineering at UCD, a faculty of 140 teach a student body of 2240 undergraduates and 664 graduate students. Women currently constitute 19% of undergraduates (as compared with 16% nationally), 15% of domestic graduate students, and 7% of tenure track faculty.

The number of women undergraduates entering engineering at UCD began to grow in the 1970s, as it did elsewhere, and peaked at 31.6% in 1980, with a overall decline thereafter. One ramification of these statistics is that even if all the women who entered engineering programs in the past 20 years had persisted in engineering, there still would be a significant disparity in the numbers of men and women graduating engineers. To get more women into engineering, action must be taken at the pre-college level.

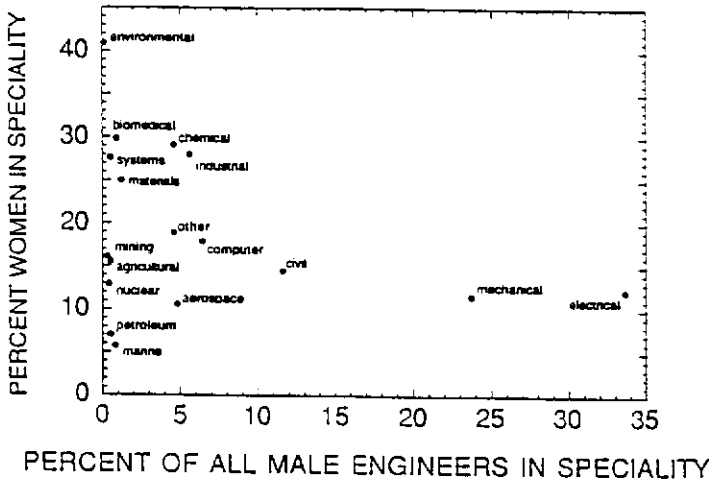

Figure 2. Specialities of Engineering Graduates with B.S. Degree (data from Engineering Manpower Bulletin, American Association of Engineering Societies, No. 109, May 1991)

Table 2. Entering and graduation percentages: engineering undergraduates[a]

Entry Year	% Women Entering (1st Year)	% Women Entering (Transfers)	% Ultimately Graduating (1st Year) Men	% Ultimately Graduating (1st Year) Women	% Ultimately Graduating (Transfers) Men	% Ultimately Graduating (Transfers) Women
1976	17.4	13.6	71.8	50.0	72.4	50.0
1977	17.9	13.4	72.6	80.0	83.5	87.5
1978	17.8	10.9	75.6	71.4	88.5	76.5
1979	21.8	12.3	71.2	72.1	86.0	84.6
1980	31.6	16.4	74.6	58.1	73.8	91.7
1981	31.5	15.6	63.8	57.1	87.7	83.3
1982	27.6	20.0	62.9	48.5	83.8	80.0
1983	26.8	16.1	67.8	52.2	92.3	86.7
1984	21.4	12.1	61.2	44.7	87.9	82.4
1985	18.2	23.3	67.4	44.2	81.2	85.7
1986	19.4	12.4	55.4	53.3	86.9	92.9
1987	21.2	17.1			81.6	67.9
1988	26.7	21.9			75.2	70.6
1989	20.5	10.1				
1990	19.7	14.8				
1991	21.1					

[a]UCD College of Engineering, data from Student Affairs Research and Information

Women must be prepared, both academically and psychologically, prior to college, to consider engineering as a feasible profession.

Results from *Project Talent* (Betz, 1990; Lubinski and Humphreys, 1990), a longitudinal study of a cohort of children who had math achievement scores at or above the 99th percentile in high school, indicate that mathematical talent alone is not enough to ensure that a woman (or a man) will attempt and persist in a technical profession. According to this study, 20% of the gifted females and 9% of the gifted males did not even get a college degree. Only 29% of the females (compared to 61% of the males) obtained advanced degrees (of any type). More universities are recognizing this linkage and have begun secondary and elementary school outreach programs. For instance, the Center for Women in Engineering at UCD, through the Fund for Improvement of Post Secondary Education (sponsored by the U.S. Department of Education), is developing an outreach program in a nearby large public K-12 school district. Workshops, speakers, tours, internships, and curriculum materials are provided to educate teachers and students about engineering, largely to counter stereotypical and negative pictures of engineering.

The persistence of students in undergraduate engineering programs is also a critical factor. The ultimate graduation percentages of both entering first year and transfer men and women at UCD also are shown in Table 2. Graduation for first year women entering in 1977 was a remarkable 80% but rates declined thereafter and have been considerably lower for women than for men. Annual fluctuations make predictions for the future difficult, but the downward trend for both genders is disturbing, as is the mean difference between the genders. The percent ultimate graduation for transfer students is higher for both men and women; it is well known that most attrition occurs at the lower division. On average from 1976 to 1984, 19% of entering engineering women at UCD had left engineering by the end of 2 years, and another 11% had left engineering by the end of three years for a total of 30%. This profile contrasts with the average rates for men: 16% for the first two years and 7% for the third year for a total of 23%. For the fourth and fifth years the average attrition rate for women and men is comparable with 5% each year for women and 4% each year for men. Even then, women do not go on to graduate school in the same proportion at which they graduate. The graduating classes of 1984 through 1988 averaged 22% women but only 15% of the domestic graduate students are women.

The statistics presented here indicate that compared to men, women on average are less likely to enter and to persist in undergraduate engineering programs and less likely to complete a graduate degree; ultimately they are poorly represented among the practicing profession. Few studies have been directed at explaining these statistics. In 1992, 419 engineering students at UCD were surveyed. Closed-form questions were used to provide valid data for statistical analysis, and open-form questions were used to provide deeper insights.

Students were asked to respond to six statements. The statements and the responses are presented in Table 3. For three statements (*all faculty members treat me with fairness and respect; I feel that I am an equal participant in group work; and I am comfortable approaching professors for help outside of class*) the majority of the students were quite positive in their response, 3.7 to 3.9 on a scale of 1 to 5, with 5 being "strongly agree". Moreover, there was no statistically significant difference between the responses of the women and the men. However, for three other statements the responses of the women were significantly different than those of the men. The women were much more likely to report being discouraged about obtaining an engineering degree, being uncomfortable asking questions in the classroom, and being less confident about their future excellence as an engineer. It could be argued that the male students are overconfident rather than that the female students are not confident enough; but when these responses are viewed in light of attrition statistics, the focus on lack of confidence seems justified.

The mean graduating GPA for women at UCD is 3.039 as compared to 3.023 for men. This strong grade

Table 3. Academic environment in engineering: student attitudes

		Mean	Strongly Agree (5 - 4) %	(3) %	Strongly Disagree (2 - 1) %
All faculty members treat me with fairness and respect.					
	Women	3.84	73	22	4
not significant	Men	3.83	71	23	5
I feel that I am an equal participant in group work.					
	Women	3.78	66	27	7
not significant	Men	3.92	73	22	4
I am comfortable approaching professors for help outside of class.					
	Women	3.70	65	23	12
not significant	Men	3.67	63	23	14
I have not felt discouraged about pursuing an engineering degree.					
	Women	3.23	47	23	30
p = 0.02	Men	3.60	58	27	15
I am comfortable asking questions in the classroom					
	Women	3.13	37	33	30
p = 0.028	Men	3.48	49	33	18
I will be an excellent engineer.					
	Women	3.80	58	38	4
p = 0.025	Men	4.06	72	24	4

point average indicates that women do not leave engineering or lose confidence for academic reasons. The indications are that women are affected by the environment they encounter and tend to leave because of the negative effect of that environment on their self-image and self-esteem. Open-form survey questions and conversations with women engineering students, faculty in engineering, and professional engineers indicated five reasons why women leave or become discouraged with engineering: isolation; not seeing relevance of highly theoretical basic courses; negative experiences in laboratory courses; the 'cold classroom climate'; and lack of role models. Each of these reasons is explored further below.

Isolation. In K-12 grades, girls are isolated from the engineering profession. They do not know what an engineer does or the problems the engineering profession addresses. If they do know an engineer, it is not likely to be a woman. Unfortunately most stereotypes of engineering are isolating and discouraging. At the first and second year college level, engineering students are isolated from each other. They are scattered throughout university dormitories and throughout sections of the required basic mathematics, chemistry, and physics classes. Faced with a challenging course schedule, first year students often find it difficult to participate in engineering student organizations and do not readily form the academic/social network useful for survival in engineering. For women students, the isolation is compounded because of the small numbers of women. In the survey, 12% of the women but only 1% of the men indicated that isolation was a discouraging factor in engineering.

Not seeing relevance of highly theoretical basic courses. The basic mathematics, chemistry, and physics courses required of engineering students are highly theoretical. Although they form the foundation for the engineering courses that follow, students usually do not get a clear picture of engineering from these classes. While women, on average, perform well academically in these courses, some have difficulty relating this theoretical material to the applied problem-solving discipline of engineers. This difficulty is compounded because typical examples (e.g., the workings of an automobile or the trajectory of a football) used in attempts to make the material relevant are not drawn from women's prior experience. Because the material in these courses is not readily related to their prior knowledge or to their future goals, many women lose interest and turn to other majors, where the relevance is more clear. Men also suffer from this lack of clear relevancy in lower division courses, but they are more likely to have developed role models among faculty members, practicing engineers, or relatives who can help them make the connection.

Negative experiences in laboratory courses. Many women are intimidated because they have not had hands-on experience with mechanical and electrical devices and do not know the associated jargon. Many women find it intimidating to be the only woman in a laboratory group and seemingly the only one who has little hands-on experience. In fact, nowadays more and more men come into laboratory classes with as little hand-on experience as women but they are less likely to show that ignorance and less likely to see it as a weakness in themselves. Many women have not been socialized in how white male culture works; they do not know its norms and conventions and they may not embrace its values. Many women have not been socialized to compete for leadership roles. Yet, because white male culture dominates engineering, women are tacitly expected to conform to its norms. Sometimes both faculty and students confuse these cultural expectations with the nature of the science itself. Often in laboratory classes, women feel inadequate and marginally included, a reaction that leads them to question their ability to complete an engineering degree — and its desirability if they are to be continually marginalized. Women engineering students usually have their first such experience as first year students in a physics laboratory, and that experience is repeated throughout their undergraduate years; with each experience their confidence is further eroded. Some women leave what they perceive is a foreign environment. A striking 12% of women (compared with 2% of men in the survey indicated that laboratory experiences were a significant discouraging factor.

Classroom Climate. The learning environment in engineering is competitive. Grading usually is based on a curve, implying that if one person succeeds, another will fail. Approximately 7% of both men and women surveyed indicated that the competitive environment was a discouraging factor. However, women were significantly more reluctant than men to ask questions and participate in discussion, possibly because on average they are not socialized to be assertive, particularly in large groups and in the presence of males. This tendency is reinforced by the fear, often based on prior reactions of others, that their questions or comments are ignorant or trivial. The "chilly" environment for women in universities, and efforts to address it, have been described at length by Hall and Sandler (1982). However, few of the activities developed in response to that research have focused on the environment for women in math-based fields.

Lack of Role Models. There are few female role models on engineering faculties. Women students do not have access to a large number of faculty who have had similar experiences and whose very presence says "you can do it', as male students do. Yet there is some evidence that women, to a greater degree than men, consider supportive persons, including role models, as important. In the survey of engineering students at UCD, 34% of the women and only 15% of the men stated that people (teachers, family, and friends) were significant in reinforcing their desire to continue in engineering.

All of these factors take a toll on women's self-image as engineers and contribute not only to women's attrition from undergraduate programs but to their lack of motivation to pursue graduate study. Barriers that make it difficult for non-traditional engineers must be dismantled or circumvented, and support structures must be built wherever necessary to allow young people to enter and persist in engineering.

The statistics presented here provide some indication that pro-active policies for recruiting and retaining women in engineering are desirable, given the barriers present within engineering and the attraction of competing professions. For example, with support from the National Science Foundation, five programs are being developed and evaluated at UCD to address some of the more likely causes of attrition. These programs are:

(1) a new course called "How Things Work" offered to first and second year women engineering students and designed to provide exposure to hardware;
(2) faculty workshops on "Exploring the Academic Environment for Women in Engineering" designed to develop solutions to problems that have been articulated;
(3) brown bag lunches to bring women engineering students together with faculty in engineering;
(4) a job shadowing program linking women students and women engineering professionals; and
(5) an undergraduate research assistant/faculty mentor program in which fourth and fifth year women engineering students conduct research in faculty laboratories, whenever possible with female faculty.

References

Betz, N.E. 1990. What stops women and minorities from choosing and completing majors in science and engineering? Edited transcript of a Science and Public Policy Seminar presented by the Federation of Behavioral, Psychological, and Cognitive Sciences. Washington, D.C. June 5, 1990.

Brush, S.G. 1991. Women in science and engineering. *Amer. Scientist* 79: 404-419.

Hall, R.M. and Sandler, B.R. 1982. The classroom climate: a chilly one for women? Project on the Status and Education of Women. Association of American Colleges, Washington, D.C.

Lubinski, D. and Humphreys, L. 1990. A broadly based analysis of mathematical giftedness. *Intelligence*.