

**AC 2009-595: FACTORS THAT ENCOURAGE OR DISCOURAGE THE  
PERSISTENCE OF FEMALE STUDENTS IN UNDERGRADUATE EDUCATION**

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## **Factors that Impact Persistence of Female Students in Undergraduate Engineering**

The importance of engineering and technology to the economic and intellectual growth of the United States cannot be overstated. In today's knowledge-driven society, and despite the recent economic downturn, the number of U.S. citizens with education and training in engineering and technology has barely kept up with demand. Women, racial and ethnic minorities, and persons with disabilities are severely underrepresented in college engineering majors and in the engineering workforce<sup>1</sup>. The overarching goal of the present work is to increase our knowledge about U.S. colleges and departmental cultures that promote or discourage an equitable and inviting environment for women in engineering<sup>2,3</sup>.

Findings from several meta-analyses of studies documenting research into the underlying reasons for the disparities in participation by women in science, engineering, and technology (SET) high school courses, community college and university majors, and careers<sup>4,5</sup> have been published. These studies, as well as those about the efficacy of interventions at all educational levels, found that we must use a more integrative approach to build on past successes and to institutionalize those programs and activities that work. The majority of programs supported by outside funding that have shown success over a three to five year period were not then institutionalized or adopted by others<sup>5</sup>.

Organizational transformation is a difficult process that has been studied most extensively in the business world rather than in universities<sup>6,7,8,9</sup>. Fox<sup>10,11</sup> performed some of the earliest examinations of how SET curricula could be transformed from being male-centered and competition-driven to curricula that were more team-based and supportive. An inventory of 22 science and engineering departments at 16 universities revealed that those departments which had increased the numbers of female graduate students into their programs and retained a high percentage of them until graduation shared some characteristics. The successful departments had a history of strong leadership that encouraged gender diversity, there were written guidelines about performance and evaluation standards, and there was a clear understanding about what constituted a good mentoring environment for female students.

In light of this and other previous studies, the hypotheses that were developed to guide this work were: (1) There are subtle but significant differences in the cultures of engineering departments that graduate more or fewer females than the national average and that these differences are influenced by institutional leadership and history; and (2) Engineering colleges having high percentages of female graduates have intentionally supported and encouraged activities that improve the climate for women.

### **Methods**

Both qualitative and quantitative methods were used to allow a systematic and empirical comparison of engineering cultures in colleges of engineering. We targeted engineering colleges that had female undergraduate graduation rates well above (24% or higher) (high institutions) or below (16% or lower) (low institutions) the national average<sup>12</sup>. We sought to uncover subtle but

significant differences in the cultures of engineering departments that, if transformed, could result in an increase in the recruitment, retention, and graduation of female engineers.

We visited and collected data from the colleges of engineering at eight universities. These institutions were geographically diverse, public and private, religious and secular, and with both predominately white or racially and ethnically diverse student populations (Table 1). The institutions also had a range of Carnegie basic classifications. The percentage of female undergraduate engineering students at the high institutions ranged from 25% to 29%; at the low institutions it ranged from 13% to 15%. The percentage of bachelor's degrees in engineering awarded in 2007 at the high colleges was from 24% to 32% and for the low colleges, from 10% to 16% (Table 1).

Table 1. Institutional Characteristics

	Geographical Region	Carnegie classification*	Engineering Degrees (% B.S., Female)	Public/private
High 1	Northeast	RU/VH	24%	Private
High 2	Northeast	RU/VH	26%	Private
High 3	New England	RU/VH	32%	Private
Low 1	West	RU/H	10%	Religious
Low 2	Midwest	RU/VH	16%	Public
Low 3	West Coast	Master's L	16%	Public
Low 4	Northeast	Master's L	14%	Private
Low 5	Northwest	RU/VH	14%	Public

\* Carnegie Foundation basic classification scheme can be found at: <http://www.carnegiefoundation.org/classifications/index.asp?key=791>

In order to triangulate our findings and drill deeper into the values, perceptions, and quality of life at these engineering colleges, we used a mixed method design that collected quantitative as well as qualitative data. To collect qualitative data, we conducted individual interviews and focus groups with college deans, key administrators, department heads, faculty, and students at the undergraduate level. The interview protocols for administrators and faculty asked about characteristics of engineering undergraduates; skills and abilities required to complete an undergraduate engineering degree at the institution; essential educational experiences; strengths and weaknesses of the institution in supporting undergraduate education; and what those being interviewed perceived as efforts that could be made to promote the recruitment and retention of women in undergraduate engineering majors and into future engineering careers. During the focus group meetings with undergraduate women in engineering, we asked about their perception of the university and college environment for women in class and out-of-class, factors that had led them to decide to major in engineering, and the careers they planned for themselves. The interviews and focus group discussions were audiotaped with the participants' permission and transcribed. We received approval from the Institutional Review Boards at our home

university as well as from the universities we visited to conduct surveys, focus groups, and interviews.

We administered surveys (using a 4-point Likert scale) to undergraduate engineering students, faculty, and administrators at three high and five low colleges of engineering. A total of 1629 students (70% male; 30% female; 77% white) and 221 faculty (75% male; 25% female; 88% white) completed an online survey. Students were asked a series of questions about elements of the classroom and out-of-class experiences that promoted or discouraged their interest in engineering. These included quality of teaching, grades, study group members, group or team experiences, presence of student engineering organizations, and female only or male only engineering club activities. We compared the composite responses from the high colleges (424 students; 63 faculty) with the combined responses from the low colleges (1091 students; 124 faculty).

### Findings

One indication of persistence in a major is the willingness for a student to agree that they would still major in engineering if they had the opportunity to choose again. When the combined data from the low enrolling institutions was compared with the data from the high enrolling schools, we found no significant differences between the institutions (Table 2). Table 2 shows that there was no significant difference in the percentage of students from high and low institutions who would still major in engineering if they could revisit their decision. Of those female undergraduate students interviewed, most agreed that they were pleased with their university, college, and major. There were the usual complaints about one or two professors (overwhelmingly male) who were dismissive of female engineering students. For the most part, the support female students received from other faculty and students was enough to help them overcome these hindrances.

Table 2. Total number and percent of respondents who agreed that if they had to do it again, they would still major in engineering, by institution and gender

Institution		Overall		Male		Female	
		N	Percent	N	Percent	N	Percent
High	Total respondents/ average %	399	88.5%	226	88.1%	173	89.0%
Low	Total respondents/ average %	830	90.9%	605	91.1%	225	90.2%
Overall number of respondents / average %		1551	91.2%	1085	91.7%	466	89.9%

Interviews with students and administrators from the institution with the highest percentage of females and males indicating that they would select the same university if they had to do it over

again provided some context for understanding which environmental elements might facilitate retention of female students in particular. Undergraduate students at these institutions described themselves as self-starters and acknowledged some competition to get good grades, but they agreed that their institution has a culture where students are encouraged and respected for taking the initiative to seek out needed expertise. Interviews with administrators and faculty at the high institutions identified priorities for interdisciplinary and team-based projects. Placing these elements as priorities in the instructional experience may aid retention, communicating to the students that no one is expected to be able to solve complex problems alone.

Female students at this high institution identified faculty support as a major strength associated with their retention:

I like the resources available in regards to your professors having office hours, tutoring being available, advisors being available. I know I'm very much an office hour person. If I have a question, I'm probably going to be there. So, when I've been in there, there have been other students that have come in during the times. I was there as well and well over 75% of the time the other people who are coming in are females as well. So, I don't know if it's we're more comfortable for help, we hold ourselves to a higher standard, or the guys just get it more; I don't know, but I think that in my view females tend to use those type of resources more.

Another female student explained how support from the college helped motivate her:

...I like that the college of engineering provides a lot of assistance and events for you to do pretty much whatever it is you want to do or need to do, and I think that could be one of the biggest things that has helped me is the recourses available. I have talked to \_\_\_ she's a freshman advisor technically, but I'm a junior now and I still at least a couple of times a month stop by and ask her questions. She gives me advice about a lot of different things whether it's specifically with what class I'm going to take or whether it's what internships I might want to consider, and the program we have set up for you to get information about opportunities and how to go about things with your internships and co-ops because I feel like that's my goal eventually is to be able to work in this filed and being able to get a head start and kind of dip in to see what is going to be available, that is super helpful to me because it allows me to reassure myself that is what I really want to do.

The long term outlook for engineering majors staying in the major and making it a career appears to more positive for students at low institutions. Students at the low schools were significantly more likely than peers at high institutions to predict that they would be working in an engineering-related field in ten years (Table 3).

Table 3. Student respondents who strongly and somewhat agreed that they are likely to be working in an engineering-related field ten years from now, by gender and institution

Institution		Overall		Male		Female	
		N	Percent	N	Percent	N	Percent
High	Total	352	82.1% <sup>a</sup>	201	86.6% <sup>b,c</sup>	151	76.2% <sup>b,c</sup>
Low	Total	810	94.5% <sup>a</sup>	592	94.4% <sup>c</sup>	218	94.5% <sup>c</sup>
Overall		1476	90.2%	968	92.4% <sup>d</sup>	428	84.8% <sup>d</sup>

a, b, c, d : p<.001

There were significant differences in the predictions between high institution male and female student respondents when asked about long-term engineering careers. Males at high institutions were much more likely than females to see themselves staying in engineering. However, both males and females at high institutions were significantly less likely than their counterparts at low institutions to predict long-term engineering careers. Interestingly, there was no difference between male and female students at the low institutions. Interviews with students at both institutional types indicated that those at high institutions were aware of a wider range of career possibilities. Many spoke about career plans in medicine, law, or politics. Female undergraduates at low schools were much less likely to bring up life choices other than the possibility of leaving engineering to stay at home and raise a family.

Interviews with students who indicated they probably would be working in an engineering-related field in ten years mentioned that internships and related projects helped them understand what experiences and training they would need to have a successful engineering career.

I went to school to be an engineer, I intend to be an engineer, and if I would have gone to school for something else I would do something else...For my co-op, I was at XX and I'm planning on going back after graduation, and I plan to go on to grad school so in five years hopefully I'll still be in the aerospace industry.

Five years from now I would love to be standing at the completion of my first major project. I want to build big things. I figure it takes about five years to do one of those so hopefully I will be actually engineering and handling project management. My past experiences I always end up in some type of management away from the actual engineering. That's just -- that is apparently my strong suit in a situation. So, I will either end up in management or fight very, very hard to stay in engineering. As a female, they will want to promote me to management because it looks good and I guess I'm pretty good at it, the management thing, but I want to engineer. So, five years from now, ten years from now, fifteen years from now my career will always be a battle of staying in engineering when I have shown that I've got strengths all across the board and considering it is a male-dominated field, I'm going to have to fight to stay in engineering because I will look good so many other places.

Despite positive views among female and male students with regard to career aspirations, stereotypical views are still held among faculty and administrators. One administrator had a different perspective on gender-related career objectives:

I think, you know, in terms of their career objectives, the men have a better definition of what engineering is as a profession probably than the females do.

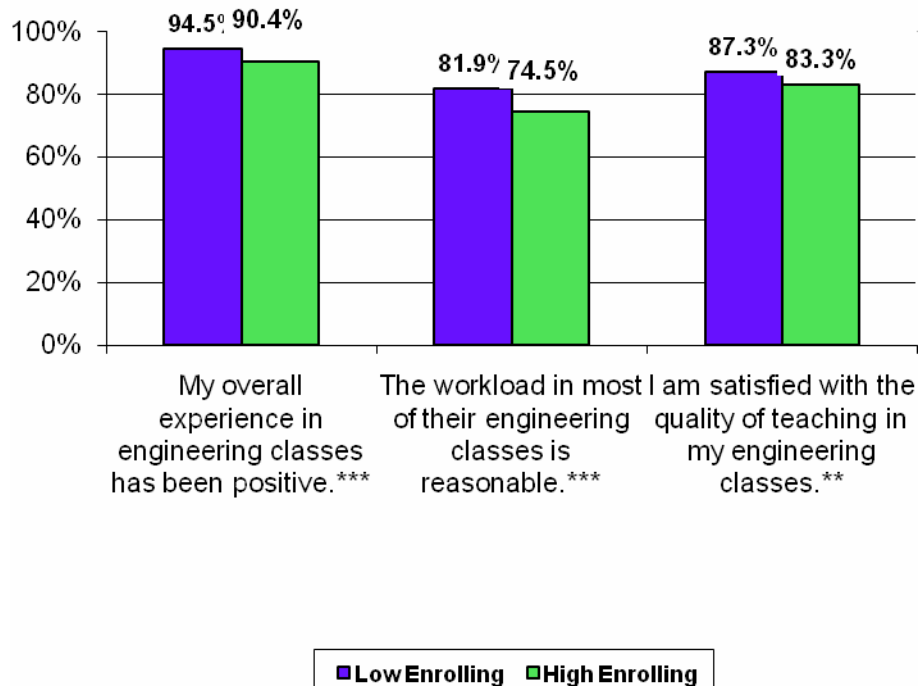
In interviews, students were candid about the reasons for pursuing a career in engineering:

I like the prestige that comes from being an engineer. I'm not going to lie. Going back to my high school friends and saying I'm an engineer and this is what I can do and this is what I've accomplished, but I like the possibilities. Your mind really opens as you start taking 600 graduate courses and beyond of what I can do. They tell you the sky is the limit, but you don't know what to think of the limit, right? And now it's like wow, can I do that? Let me think about it. And you start to realize all the things you can do, all the different directions you can take. It has been overwhelming, but it's definitely enticing.

Students were asked a series of questions about elements of the classroom and out-of-class experiences that promoted their interest in engineering. These included quality of teaching, grades, study group members, group or team experiences, engineering organizations, and female only or male only engineering club activities.

Students at low institutions were significantly more likely to indicate that without considering the difficulty level, their overall experience in engineering classes has been positive ( $p \leq .01$ ), they were significantly more satisfied with the quality of teaching in engineering classes ( $p \leq .01$ ), and more likely to agree that the workload in most of their engineering classes was reasonable ( $p \leq .001$ ). This satisfying educational experience may explain why students at low institutions have a more positive long-term outlook about staying in the engineering field. The students feel supported by faculty and feel as though expectations for work are reasonable.

Figure 1. Satisfaction with educational experience among students, by institutional type (%)



\*\* $p \leq .01$ ; \*\*\* $p \leq .001$

Students across institutions expressed how much they enjoyed working in a team-based setting on projects and how team work helped them manage challenging course work:

I guess at [low college] the quarter system makes it very high-paced so you do learn very quickly to work together and rely on people and being a female, a group of girls, we tend to have our own clique, group of people, I think normal at any institute. So, that's pretty much how I describe [low college] as a whole. It is fast paced and you do learn to work together with groups.

A female student at another low institution noted:

I have been hard pressed to find better faculty in the fact that I have gone to my advisor's office crying because I didn't understand a class and I didn't know what to do and this is not his area of expertise but he sat down, pulled out his old books and he stayed there for three and a half hours trying to help me understand the concept. The advisors and teachers really go out of their way to understand you and to help you.

Significant differences were seen between male and female students on several indicators relating to their engagement in the instructional experience, with females indicating less engagement than males. Students at high institutions were significantly less likely than peers at low institutions to participate in a group project both within their engineering classes and outside of engineering classes and serve as a leader on group projects; however, students at high institutions were significantly more likely to indicate faculty knew their name (Table 4).



Table 4. Indicators of student engagement: Differences by institutional type and gender (using a 4-point Likert scale from 4 strongly agree, 3 agree, 2 disagree, 1 strongly disagree)

	Overall Mean	Female	Male	High	Low
Raise your hand to ask a question in an engineering class?	3.19	2.94*	3.30	3.18	3.19
Visit an engineering professor during office hours?	2.84	2.92	2.81	2.75	2.87
Work on a group project in an engineering class?	2.92	2.88	2.94	2.76**	2.98
Work on a group project outside an engineering class?	2.46	2.35	2.50	2.25***	2.53
Serve as the leader of a group project in an engineering class?	1.89	1.89	1.89	1.82	1.92
Serve as the leader of a group project outside an engineering class?	1.78	1.75	1.80	1.65**	1.83
Were called on to answer a question in an engineering class?	2.66	2.48***	2.74	2.70	2.64
Knew your name?	2.58	2.71***	2.52	2.69**	2.54

\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$ .

Significant differences were seen between males and female students on several indicators relating to their involvement in out-of-class experiences. Female students were significantly more likely than their male peers to have participated in an engineering activity or event; been a member of an engineering organization; sought career information from a faculty or staff member; served as a mentor for a female student; or participated in outreach to K-12 students, engineering competitions, out-of-class engineering workshops, or engineering social events (data not shown).

In looking at other factors that encourage retention, student respondents at both high and low institutions cited salary potential, future employment opportunities, and interest in engineering subject matter as factors encouraging them to remain in engineering. Female students at high institutions were more likely to cite salary potential along with opportunities for engagement as encouraging factors.

Of the factors that discouraged students, female and male students at both high and low institutions cited the amount of time required for engineering homework, grades, and competition in engineering classes as discouraging factors. Most females at both high and low colleges agreed that competition in the classroom was the second most discouraging factor. Third on the list for most females were grades. Males, on the other hand, mentioned “predominately female or male activities” as one of their second or third highest ranked discouraging factors. This was true at both high and low institutions.

## Conclusions

While there were some significant differences between undergraduate male and female students and between groups of male and female faculty, we did not uncover the differences we hoped to find between colleges of engineering that graduated low percentages of females and those with very high percentages. An examination of elements such as history of gender- and diversity-related initiatives and other indications of a supportive environment, such as high levels of faculty engagement with students and an emphasis on undergraduate teaching, did not distinguish the high and low institutions in any consistent way. Our interviews with administrators at low institutions revealed a desire to increase the numbers of female students and, in some cases, programs had already been developed and produced to recruit (through summer engineering events and interactions with high school teachers and counselors) and retain (by supporting student chapters of the Society of Women Engineers, introducing all-female learning communities, and/or institutionalizing more hands on and team projects) more female students

Questionnaire items directly related to gender captured elements of the undergraduate environment that distinguished institutions with above and below average enrollments of undergraduate women in engineering. We found that female students at low institutions may be happier overall with their experience than students at high institutions. This may be due to the manner in which classes are structured and the degree of faculty support. In our interviews, hands-on research activities and internships, approachable faculty with convenient office hours, access to career-related information, and positive peer interaction through group work and other programs were cited by students as being important motivators. Faculty at high institutions appear to have more traditional views about giving priority to their research in order to be successful and the fact that one must sacrifice personal time that could be spent with one's family in order to be successful. When such views are conveyed to women inadvertently, this could affect the degree to which a career in engineering is seen as attractive, or not, to females.

Across institutions, students cited extrinsic rewards such as salary potential and employment opportunities as factors encouraging them to remain in engineering more than clubs or other programmatic initiatives aimed at facilitating retention. An interest in engineering subject matter was a motivating factor as well; female students at high institutions were more likely to cite opportunities for engagement as factors encouraging them to remain in engineering. The amount of time required for engineering coursework, especially in comparison to peers enrolled in other majors, coupled with the competition in engineering courses proved discouraging to all students.

In interviews, female students reported a greater need for gender-based initiatives given their feelings of isolation. They felt that they had less support from family and friends in their pursuit of a career in engineering and talked about experiences with discriminatory behavior within the immediate instructional environment as well as during interactions with the larger university community. Negative experiences such as these may contribute to less positive long-term career goals among female students and less confidence in their ability to manage work-life issues than male counterparts. Female students also indicated less engagement with faculty than male peers but more frequent participation in social events and outreach activities. At the same time, females were less confident in their academic ability than male counterparts.

Views were mixed among faculty and students about the importance of creating women-centered interventions in order to recruit and retain women students in engineering. During interviews, some faculty did not see gender-based initiatives as important and had trouble citing specific examples of interventions or initiatives that were underway to create supportive and inclusive climates within engineering departments.

In terms of creating instructional experiences that facilitated the success of female and male students, faculty recognized benefits associated with student participation in hands-on applications of subject matter through participation in research activities. Male faculty were more likely to consider competition an important part of the instructional experience for students and see attrition as a direct result of being less prepared for a career in engineering.

The answer to our original question about how to recruit and retain more females in undergraduate engineering appears to be more complex than a set of simple guidelines to be followed. A supportive environment, accessible faculty members, an emphasis on hands-on and group projects, events that emphasize networking, effective mentoring, and co-op or internship experiences seem to combine in ways that help women see themselves as becoming competent engineers. In order to be successful, these programs require a commitment of time and resources by engineering faculty and administrators.

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