

## **AC 2009-213: A CROSS-INSTITUTIONAL COMPARISON OF EDUCATIONAL FACTORS PROMOTING OR DISCOURAGING THE INTENT TO REMAIN IN ENGINEERING**

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## **A Cross-Institutional Comparison of Educational Factors Promoting or Discouraging the Intent to Remain in Engineering**

### **Introduction**

Interest in the declining numbers of U.S. students choosing careers in science, mathematics and engineering (SME) emerged as a topic for discussion in the 1980's. Numerous reports documented this early decline and called attention to the need to understand reasons for and to prevent migration out of SME fields.<sup>1,2</sup> Gender losses were observed by Astin and Astin<sup>1</sup> to be greater among men, but given the greater proportional loss of women, their under-representation was magnified during the undergraduate years. Confounding this overall decline was the observation that SME losses came from a pool of disproportionately able undergraduates.<sup>3,4,5</sup> Efforts to identify the causes of student migration out of SME courses and measures to improve outcomes have continued over two decades with various steps taken such as the revitalization of science teaching at the high school level, improvements in undergraduate teaching of SME courses in college, attempts to raise the respectability and prestige of college teaching, and investigations to understand the differences in retention and completion rates in smaller, selective colleges versus larger research institutions.<sup>6,7,8</sup>

Prior to 1990 there were no studies that took a comprehensive approach to understanding the attrition among both male and female undergraduates in SME majors. Two national data bases, National Longitudinal Survey and the High School and Beyond Report, found two main reasons for attrition out of SME: students found non-SME majors more attractive and the SME work too difficult.<sup>9</sup> These findings led to more questions to fully understand what made other majors more attractive and exactly what was too hard about SME courses? Various approaches were taken to investigate the reasons for SME attrition. Seymour and Hewitt identified five bodies of research which attempted to understand how students process their experiences in SME classes and the conditions under which they are successful.<sup>9, 10, 11, 12, 13, 14, 15</sup> In one of these studies, Manis and her colleagues interviewed high ability women deciding not to enter science majors; women who entered them and then left; women who remained through to senior year; and matched samples of men.<sup>13</sup> They found negative experiences in SME classes as a major contributor to discouraging the continuation in SME majors. Characteristics such as poor teaching or organization of material, hard or confusing material, loss of confidence in ability to do science, cut-throat competition in assessment systems or "weed out" philosophies, dull subject matter, and grading systems that did not reflect what students felt they had accomplished were reasons given by females for leaving SME majors. The competitive atmosphere, the grading system, and the dullness of subject matter was much less troubling for males in the same study. These findings illustrate discouraging factors for retention related to classroom climate and activities and begin to paint a more comprehensive picture of obstacles to retention. Do these same factors vary by institutional type?

To more fully understand the institutional context for discouraging and encouraging factors for SME retention, Seymour and Hewitt designed a multi-institutional

ethnographic study of three private and four public universities in four different geographical areas.<sup>10</sup> Institutions were selected on the basis of their private or public funding, their mission, the level of prestige accorded their research activities, and the size and composition of their graduate and undergraduate populations with a concentration on institutions in which the majority of undergraduates received SME education. Initially 335 students were interviewed by phone; interviews were recorded, transcribed, and coded. A second round of interviewing with an additional 125 students on six extra campuses led to a total of 460 students in the study. Findings from this comprehensive study revealed students who had switched out of SME majors and those who chose to remain were more similar than different in abilities, motivations, and study-related behaviors. Those students retained had developed coping strategies and had experienced faculty intervention at critical decision points in their academic or personal life. The issues and concerns of students who left SME and those who stayed were the same across all seven campuses regardless of institutional type or size. The four most commonly cited reasons for leaving SME majors were: loss of interest in science, belief that a non-SME major holds more interest, poor teaching by SME faculty, and feeling overwhelmed by the pace and load of curriculum demands. These findings point to the importance of faculty in both teaching and support roles as major contributors to encouraging student retention.

While previous studies have identified elements of the educational experience that are related to student persistence in SME degree programs most have been either quantitative or qualitative in nature. Our study is different in that it utilizes a mixed method approach to explore both extrinsic and intrinsic factors that engineering undergraduate students have identified as being related to student persistence to degree. Specifically, differences by gender and institutional type among factors that encourage and discourage motivation to remain in engineering programs are explored in this study. The research questions for this study included:

1. What are the top three factors encouraging undergraduate student persistence in engineering and do they differ by institutional type and gender?
2. What are the top three factors discouraging undergraduate student persistence in engineering and do they differ by institutional type and gender?

## Methods

This study used a mixed methods research design. The sample involved faculty and students in engineering at nine institutions distributed throughout the U.S. The preliminary sample of institutions consisted of nine institutions that supplied a letter from the dean of a college or school of engineering to accompany a grant application indicating their willingness to participate in the project and to designate an institutional liaison to work with the project over the course of two years. Using information from *2003 Profiles of Engineering and Engineering Technology Colleges*<sup>16</sup>, private and public institutions were selected based on the number and percentage of women completing an undergraduate engineering degree in 2003. From among institutions graduating at least 50 female engineers in 2003, we labeled a group of universities as “high” where the graduation rate was significantly above the national average (28%) and as “low” where 17% or less of the total number of graduates from the college of engineering were

women. In placing institutions into high or low status consideration was also given to the retention rates of women and the history of gender-based initiatives targeting female engineering undergraduates. The number of women engineering graduates and proportion of women engineering undergraduates were verified using the *2007 Profiles of Engineering and Engineering Technology Colleges*<sup>17</sup> to determine if there were substantial changes in graduation rates during the course of the study. The final classification of institutions included three institutions as “low” and six institutions as “high.” More information about these institutions are included in Table 1.

*Table 1. Number of Students in Engineering, Number and Percent of Females in Engineering, by Institution – 2007 Data*

Institution	Number of Students in Engineering	Number and Percent Female Students in Engineering	Bachelor’s Degrees in Engineering Awarded 2007 (Number and Percent Awarded to Females)
1: Boston U.	1046	261 (25%)	252 (45; 18%)
2: Brigham Young U.	1966	302 (15%)	472 (45; 10%)
3: Dartmouth	318	91(29%)	128 (32; 26%)
4 Tufts	714	197 (28%)	159 (47; 30%)
5: U. of KY	1558	234(15%)	391 (50; 13%)
6: Cal Poly – Pomona	4262	559 (13%)	572 (81; 14%)
7: RIT	2283	297 (13%)	392 (39; 10%)
8: Oregon State	2928	417 (14%)	574 (89; 16%)
9: MIT	1777*	693(39%)*	578 (219; 38%)

\*First-Year student enrollment data was not available; freshmen do not admit to a major.

Data collection procedures occurred in two phases within a six-month window. During the first phase, an institutional liaison at each site worked with one of the principal investigators to negotiate human subjects approval and to provide contact information for full-time undergraduate students enrolled in engineering. The Survey Research Center (SRC) at the home institution administered the on-line distribution of the questionnaires and oversaw the follow-ups. The SRC removed any connection to personal identifiers before distributing a copy of the data set of questionnaire respondents for each institution. A total of 1,629 students completed the survey and submitted their responses. Student respondents were mostly male (70.0%) and white (79.6%).

The second phase of data collection involved qualitative data collected during campus visits at each institution conducted by one of the three project principal investigators. In all but one case, the investigator was accompanied by a second person who in most cases was an engineer. Three site visits were conducted in each of three academic years (2005-2006, 2006-2007, 2007-2008) with each institution being visited one time. Interviews

were conducted within two departments identified by the institutional liaison. The departments selected were either those thought to have the best climate for women or those with the largest number of female undergraduates. Group interviews were conducted with undergraduate students in the selected departments. All interviews were recorded and transcribed. Students received a \$10 incentive for participating in the group interviews.

Members of the research team developed a student questionnaire. Some parts of *The Student Persisting in Engineering Survey* developed as part of the Assessing Women and Men and Engineering Project (AWE) were used in the student questionnaire. *The Engineering Student Survey* contains 114 questions. After a set of demographic items, the questionnaire is organized in seven sections: (a) Important Factors in Career Choice, (b) Self-Assessment of Abilities, (c) Classroom Experiences, (d) Support Networks, (e) In- and Out-of-Class Engagement, (f) Opinions about University and Departmental Climate, and (g) Family and Educational Background.

Following the first year when separate interview protocols had been developed for each group, a single semi-structured interview protocol was refined and used for every interview conducted during the campus visits. The interview protocol contained questions about (a) characteristics of undergraduates, (b) skills and abilities required to complete an undergraduate degree, (c) experiences considered essential to educating an undergraduate engineer, (d) strengths and weaknesses of the institution in supporting undergraduates, and (e) recommendations about what the institution could do to promote participation of women in engineering.

Quantitative and qualitative analyses were conducted to examine the data and answer the research questions for this study. In order to examine which educational factors were the top three that encouraged or discouraged students from pursuing a degree in engineering a series of 13 response items from a portion of the survey that asked students, “In the current academic year, to what extent did the following factors encourage or discourage you to continue as an engineering major?” were used as the independent variables. Items listed included career related variables such as future employment opportunities and salary potential as well as elements of the educational environment such as quality of teaching in engineering classes, grades, experiences in teams that are part of engineering classes, internship experiences, competition in engineering courses, and amount of time required for engineering coursework. Intrinsic motivators such as perceived math ability, and enjoyment of engineering subject matter as well as extrinsic motivators such as engineering clubs, engineering student organizations, and study group members were also included. For each of the 13 items students could select Much Discouragement, Some Discouragement, Some Encouragement, Much Encouragement, or Not Applicable. Any Not Applicable responses were removed from the data set.

To answer the first research question, frequencies were computed by gender and institutional type to determine whether there were differences by gender and institutional type on encouragers or discouragers of pursuing an engineering major. This analysis made it possible to determine what the top three encouragers by gender and institutional

type were by examining the percentage that responded Much Encouragement or Some Encouragement for each independent variable. To identify the top three discouragers by gender and institutional type the percentage that responded Much Discouragement or Some Discouragement for each independent variable was examined.

Once the top three items were identified through the analyses outlined above, transcripts from focus group interviews with students were reviewed for similar themes as well as for discrepancies between reported survey results and experiences as relayed during focus group interviews.

### Results

Findings provide insight to retention issues across engineering colleges and influences of gender and institutional type on persistence to degree. First we discuss the top three encouragers and discouragers by institutional type and by gender. Results from interviews with students that underscore the findings from the survey data are then discussed.

At both high and low institutions, students ranked extrinsic motivators including salary and future employment opportunities as top factors linked to their persistence to degree. In addition, all students identified enjoyment of engineering subject matter as a factor motivating them. Discouraging elements of the educational experience for students at both institutional types included amount of time required for coursework, grades, and competition in engineering courses.

*Table 1: Top Three Factors Encouraging Persistence and Discouraging Persistence Among Students by Institutional Type*

	High Institutions	Low Institutions
Encouragers	Salary potential (97.1%, n=961)	Salary potential (98.0%, n=602)
	Future employment opportunities (95.2%, n=966)	Future employment opportunities (97.0%, n=589)
	Enjoyment of, or interest in, engineering subject matter (92.9%, n=982)	Enjoyment of, or interest in, engineering subject matter (95.2%, n=609)
Discouragers	Amount of time required for engineering coursework (61.0%, n=942)	Amount of time required for engineering coursework (48.0%, n=581)
	Grades (36.0%, n=947)	Grades (28.3%, 591)
	Competition in engineering courses (31.2%, n=769)	Competition in engineering courses (23.2%, n=526)

Note: Percentages reported for Encouragers include the percent of students responding Much Encouragement or Some Encouragement; percentages report for Discouragers include the percent of students responding Much Discouragement or Some Discouragement.

The data were also analyzed to determine the top three factors that served to encourage and discourage students by gender. Results of the top three factors encouraging students show that across institutions and gender, salary potential and future employment opportunities are influential factors encouraging retention among engineering undergraduates. Differences were seen in the items that ranked third in motivating them. Females identified peer support in the form of student organizations as important while males cited enjoyment of engineering subject matter among the factors encouraging them to remain in an engineering degree program. Among both males and females, discouraging elements of the educational experience included amount of time required for engineering coursework, competition in engineering courses, and grades.

*Table 2: Top Three Factors Encouraging Persistence and Discouraging Persistence Among Students by Gender*

	Women	Men
Encouragers	Salary potential (97.6%, n=456)	Salary potential (97.3%, n=681)
	Future employment opportunities (96.0%, n=451)	Future employment opportunities (95.9%, n=1046)
	An engineering student organization (94.9%, n=278)	Enjoyment of, or interest in, engineering subject matter (95.9%, n=1046)
Discouragers	Amount of time required for engineering coursework (57.2%, n=460)	Amount of time required for engineering coursework (55.4%, n=1047)
	Competition in engineering courses (34.6%, n=396)	Grades (32.4%, n=1066)
	Grades (34.3%, n=466)	Competition in engineering courses (24.7%, n=895)

Note: Percentages reported for Encouragers include the percent of students responding Much Encouragement or Some Encouragement; percentages report for Discouragers include the percent of students responding Much Discouragement or Some Discouragement.

While it is surprising given previous studies that suggest greater differences, survey results revealed few differences between high and low institutions and by gender. Qualitative data associated with the study further illuminate major factors across institutional type that encourage the persistence of male and female undergraduates to attain a degree in engineering.

Students explained that future opportunities for prestigious employment coupled with high salaries motivated them to continue pursuing an engineering degree. These two factors were seen as a way to compensate them for onerous and time-consuming coursework. Survey results illustrate that motivating factors for female students, more so than male students, were formal engineering student organizations. Qualitative findings

underscore this finding further. Females explained that it was the intrinsic benefits received from participation in such programming that served as motivation. Attending engineering-related events was viewed as a means to integrate themselves into the department and helped diminish feelings of tokenism. Additional benefits included connecting with other females who were undergoing similar challenges and who also shared a similar passion for engineering.

While social activities were valued because they provided a venue to meet other female engineering undergraduates, these engineering-based events or programs were seen as the primary means through which to receive mentoring. Mentoring opportunities, whether peer mentoring or with females already established in an engineering career, were identified as important factors motivating female students to remain enrolled.

In terms of elements of the educational experience that served to discourage students, the amount of time required for coursework was primary. Females, especially, explained that they often felt as though course requirements left little time to pursue any other interests. Students felt that despite the time they put into coursework there was little opportunity to discuss the material they were learning.

Male and female students acknowledged that they wanted to be successful in their engineering courses and that grades were a key measure of their achievements. This mindset created a competitive academic environment despite the fact much of the work was accomplished through teams or group work. While the competition students described was not necessarily a 'cut-throat' mentality it served to make female students self-conscious of their ability. Females that were interviewed explained that they were hesitant to ask males for clarification of topics discussed in class.

Overall, the findings point to key areas that educators, regardless of type of institution, can address to make the educational experience a positive one for both males and females. In addition, results highlight important initiatives that can be undertaken to improve the retention of females.

## Discussion

Across institutional type, results show that once enrolled similar factors both encourage and discourage persistence to degree among both males and females. These findings begin to counter commonly held beliefs that females are more likely to be motivated solely by humanitarian applications of engineering subject matter. Administrators responsible for recruitment programs can use this information when designing materials that recruit students into engineering degree programs, highlighting both the possibility of high paying jobs as well as application of engineering subject matter in solving societal problems. Career counselors and academic advisors who work with engineering undergraduates can also use this information when discussing co-op or internship opportunities. Regardless of gender, students at all institutional types would benefit from out of classroom opportunities that help them understand what skills they need to attain for future positions. In addition, given the importance of potential salary in motivating students, administrators and faculty would be well served to make sure that students are receiving correct information from verifiable sources in relation to salary scales and the



training necessary to attain desired salaries. They may also want to gauge whether students are aware of the diverse employment opportunities in the engineering field or whether they are basing career and salary information on just a few more well-known positions. Having career counselors make a presentation during an engineering student organization meeting might be an appropriate venue to discuss some of these topics in more detail with students.

Other findings underscore results from previous studies<sup>10, 18</sup>. For both males and females across institutions the amount of time required for coursework was cited as a discouraging element of the educational experience. Administrators and faculty may want to consider how the engineering course load is structured and whether projects assigned to students provide any opportunity to inspire discussion, as students explained that in addition to feeling as though their lives were absorbed by engineering coursework they had little opportunity to discuss what was being learned in courses. In addition, faculty can use this information when designing projects that are part of coursework, providing ample opportunity early on in degree programs for students to realize how the subjects they are studying in the classroom have real-world applications. Understanding how the information they are learning can be applied in the future may help diffuse resentment that so much time is required to attain an engineering degree and help motivate students.

While results from the survey highlight extrinsic factors that encourage students, qualitative data shows that salary and future job opportunities are only two of the factors that serve to motivate students. When students have the chance to discuss and apply the knowledge that they are gaining in the classroom to real-world problems, findings show that enjoyment of the subject matter becomes a primary motivator.

Formal student organizations and programming that go beyond social activities and provide a more meaningful forum to discuss career goals are important elements of the educational experience for females. While mentoring was not an item included on the survey, results from the qualitative analysis shows that programs that facilitate peer mentoring or mentoring with females established in an engineering career serve to provide female engineering undergraduates with the additional confidence they need to stay motivated.

Finally, feedback from faculty in the form of grades is an important indicator of success for students and impacts their motivation. In order to diffuse competition between students, faculty should consider ways other than graded assignments to provide feedback to students on their progress. In addition, assigning individual grades rather than grades to groups may also serve to counter feelings that grades are something that should be discussed between peers. Other forms of feedback besides grades assigned to coursework may provide students with additional indicators of their progress as well as serve to encourage students if the feedback is presented in a way that allows them to correct behaviors that are impeding their success.

Overall, findings from this study show that elements of the undergraduate experience that are well within the control of administrators and faculty can be enhanced to facilitate

student persistence in engineering degree programs across institutional type. Among both male and females, practices within engineering classes can serve to motivate students if coursework is designed so that students are engaged in the learning experience.

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