AC 2009-104: DOES A SURVEY COURSE ON ENGINEERING CAREERS IMPROVE FIRST-YEAR ENGINEERING RETENTION?

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Abstract

With a need for more engineers in the United States, there is a strong interest in student success programs and curriculum changes that improve student retention. As a part of a research project to study the modeling of first-year engineering retention at the University of Michigan, the relationship between enrollment in an engineering survey course on engineering careers and first-year retention was studied. Experienced faculty teach the course on career opportunities in the engineering fields that are supported in the College of Engineering.

The retention rate of students enrolled in this first-year course on engineering careers was compared to students not enrolled. First-year retention of engineering students was 4.4% higher for students enrolled in this course compared to students who were not enrolled. This difference was statistically significant ($p \leq 0.05$). Other statistics on retention and this survey course are also discussed in this paper.

Many students come to engineering college without a clear understanding of an engineering career. The significance of this course in improving the first-year retention strongly supports the need for similar courses in engineering colleges. The empirical results in this paper are supportive of current research on first-year engineering retention.

Introduction

As the engineering community further considers the need for more engineers, it is imperative that students interested in an engineering career are mentored, encouraged and advised about the excitement of a career in engineering. The freshman year is a year of transition. Some students will decide to pursue another career. Yet, the question can seriously be asked whether engineering colleges are doing enough to educate first-year students on the career path of engineering and the career fulfillment associated with an engineering career.

This paper explores the college retention experiences of Michigan Engineering with its elective, first- year lecture course, Engineering 110, on "The Engineering Profession." This course presents the engineering career choices in a lecture format. It is different from the Engineering 100 courses in that its purpose is to give students information on choosing an engineering major and career. Most Engineering 100 courses discuss engineering design and provide hands-on experience for a typical engineering problem in one discipline of engineering. The "Engineering Profession" course is a broad-brush approach with lectures by experienced faculty on each discipline of engineering, its advantages and goals.

Research has indicated that family members influence students in their engineering college major. The Astin and Astin study[1] showed that a key factor for choosing an engineering major was having a father who was an engineer. This research finding was again supported by the Seymour and Hewitt study.[2] Even though more high schools are developing a career course required for all students, the evidence is still clear that most information about engineering

comes from a family member. Chubin et al.[3] reported that in the recent Academic Pathways Study, students indicated that the primary source for "knowledge about the engineering profession" came from family members. A recent American Society for Quality survey indicates that "only 20% of parents have encouraged/ will encourage their child/children to consider an engineering career".[4] In the same survey, 44% of the K-12 students indicated that they did not "know much about engineering." This survey's results continue to infer a lack of adequate information to K-12 students on engineering careers. Recent research by Ohland et al. indicates that there is less than 10% migration into engineering majors from other fields. [5] Thus, the pool of graduating engineers comes directly from the students matriculating into engineering college from high school and many of these students were influenced by their parents to consider an engineering career. Since not many students transfer into engineering, mentoring the current students to stay and persist in engineering is important for addressing the current shortage of engineers. From this perspective, there is strong support for a freshman-level survey course on engineering careers.

The following research literature review explores research that provides a background for a first-year course on careers in engineering and evidence that a course on engineering careers may influence retention in this field.

Literature Review

Several models for engineering student success include the identity of a student as an engineer as an important factor. Adelman's path model advocated a competitive model among STEM (science, technology, engineering and math) majors. Similar curricula are available in the first year of college; therefore, an engineering career may be viewed as one of several career choices. A number of factors can influence this competitive choice, including career identity.[6] In the Watson & Froyd transmission model, cognitive development, occupational choice development and self-identity are viewed as the paired lines of a transmission line. In their model, these three factors interact with each other. The occupational choice of being an engineer interacts with the cognitive development and self-identity of oneself as an engineer.[7]

Stevens et al. developed a three-dimensional model of engineering learning that included engineering knowledge, identity formation of an engineer and transitions within the engineering education process.[8] When a student transitions through high school and does well in math and science courses, he/she may consider an engineering major. As a student considers engineering more as a possible career, he/she may take AP courses and consider applying to an engineering college. Acceptance into an engineering college then is another navigational point in a process that establishes an identity as an engineering major and engineer. In addition, Stevens et al. discussed that engineering students tend to develop a shared identification with other engineering students in comparison to other student groups.[8]

Some empirical studies support the theoretical need for developing the identity of an engineer for retention in engineering. The Astin and Astin study found that having a peer group of engineering students was a significant factor for retention in engineering.[1] This is consistent with Stevens et al. findings.[8] Levin and Wyckoff and Besterfield-Sacre et al. found that students who had a good impression of science and engineering showed a higher first-year retention.[9, 10]

Leuwerke et al. found that there was a strong relationship between math knowledge as measured by the ACT math and a congruence index which measured the congruence between an individual's interests and an engineering career. They found that for students with strong math scores, an engineering college's effort to "increase these students' interests in the field could improve retention rates."[11] This is consistent with both the theoretical model of Watson and Froyd and the Stevens et al. three-dimensional model. Smith et al. discussed the substantial research on the importance of student engagement for learning based on the research of Astin, Light, Pascarella and Terenzini.[12]

Chubin et al. conducted an interesting study of retention of engineering students from a comparative analysis of the current generation of first-year engineering students to past generations.[3] The current generation is known as the Generation Net (abbreviated as Gen Net) with members born between 1982 and 1991. In evaluating this generation based both on national engineering student data and data from the Academic Pathways Study, the following trends were found for the Gen Net generation:

- Socially-connected
- Technology-savvy
- Idealistic, "They want to make the world a better place"
- Self-directed
- Value-oriented in their work

In support of Chubin et al. findings, Veenstra, Dey and Herrin found that entering first-year engineering students were as socially engaged as other student sectors.[13]

No literature was found that specifically addressed the teaching/learning experiences with a first-year survey course on engineering careers at U.S. engineering colleges. Based on research by Roberts,[14] Chubin et al. concluded that "the faculty role in engaging students remains unparalleled" since Gen Net students are looking for expertise and passion from faculty with a strong learning experience. Data from the longitudinal cohort of four colleges included in the Academic Pathways Study showed that experiences that were cited as having a positive impact on a career path of an engineer included "interactions with professors and teaching assistants."[5]

Although first-year retention rates for individual engineering colleges are generally not available, several engineering colleges reported their first-year retention rates associated with an integrated curriculum versus traditional first-year program.[15] The Ohio State University reported an 85-90 % first-year retention rate for their integrated curriculum versus 70% for the control group. At the University of Alabama, the integrated first-year curriculum demonstrated a 20% higher retention than for their traditional program. The University of Florida showed a 10% improvement from 50 to 60%. Thus, first-year engineering retention rates are quite variable and some engineering colleges have first-year retention rates close to 90%.

The disparity of interest in engineering by gender continues as a major concern. The UCLA/HERI Cooperative Institutional Research Program (CIRP) found that only 3.1% of the 2008 entering women students at all baccalaureate-granting institutions considered engineering as a major compared to 17.0% of the entering men students.[16] As a result of this pipeline issue, only 18% of the bachelor engineering graduates were women in 2007.[17] The highest percent of

women graduates are in biomedical, chemical, environmental and industrial engineering and much less in civil, mechanical and computer engineering. Women especially are "drawn to careers they feel positively impact humanity."[18]

African-American and Hispanic students continue to be under-represented in engineering. They account for only 11% of the bachelor engineering degrees in 2007.[17] This compares to a population percentage of 27%. The Watson & Froyd model suggests that to overcome the risk factors for persistence in engineering of under-represented minorities, that cognitive development, self-identity and occupational choice development must all be developed early in the engineering college curriculum.[7]

In summary, this literature review suggests that:

1) First-year engineering retention can be improved with courses or activities that increase students' interest in engineering.
2) There is theoretical education evidence that interactions exist between engineering knowledge, identity of being an engineer and first-year retention in engineering.
3) Several researchers have discussed the need to engage students and the need for engagement between faculty and students. The current generation of matriculating engineering students welcomes connections with faculty. Students are looking for passion from faculty in learning engineering.
4) The current generation is idealistic and wants to see a social value to engineering, especially among women students.
5) Identity with peer engineering students is a significant factor for engineering retention. It is important to have first-year engineering students identify with other engineering students. In addition, engineering students wish to be socially connected.
6) A course on engineering careers would help improve the retention of women and minority students.

Description of Engineering 110: The Engineering Profession

This first-year course provides exposure to each engineering discipline and helps undecided students select a major. Fundamentals from each engineering discipline are provided through formulating and solving simple engineering problems. Through this approach, it is expected that first-year students will make better, more informed and more stable choices of a major. Experienced faculty from each of the degree programs share experiences with 200 enrolled students in a theatre setting; Table 1 lists engineering disciplines discussed in the course. It is an academic course with example problems assigned for each discipline that was discussed every week. Each student receives a letter grade.

From 2004 through 2007, the class was conducted once per semester. This year, the course was offered to more than 400 students in the fall semester. The course is offered as a 2-credit elective course. Students either elect the course because of their interest or are encouraged by advisors to enroll. This survey course on engineering careers is offered in tandem with a foundations of engineering course, which involves a hands-on design, build, test opportunity coupled with technical communication and oral presentations. The course description is available at the College of Engineering website.[19]

Table 1: Engineering Disciplines Included in Engineering 110

Engineering Disciplines
Aerospace Engineering
Applied Physics
Atmospheric, Oceanic and Space Sciences
Biomedical Engineering
Chemical Engineering
Civil and Environmental Engineering
Electrical Engineering and Computer Science
Industrial and Operations Engineering
Materials Science and Engineering
Mechanical Engineering
Naval Architecture and Marine Engineering
Nuclear Engineering and Radiological Sciences

Methodology

This study of first-year retention improvement with enrollment in Engineering 110 was part of a larger retention study.[13, 20] From the data analysis, it became evident that enrollment in Engineering 110 could serve as a significant factor for first-year retention.

Two freshman classes (2004 and 2005) were included in this analysis, each with a matriculating class of approximately 1,200 students. Based on participation in the UCLA/Higher Education Research Institute Cooperative Institutional Research Program (CIRP) survey and permission given by students to include their data in this research, the sampling rate was 30%. Only first-time, full-time students were included in this sample. The retention effect of this course was based on the combined freshman classes of 2004 and 2005. This analysis included 735 students with 31% enrolled in Engineering 110.[20]

The following variables will be discussed in this paper:

College Retention – is defined as the percent of students who matriculated into the College of Engineering and enrolled in the College of Engineering for the third semester (fall semester of the second year).

University Retention – is defined as the percent of students who matriculated into the College of Engineering and were enrolled in a program in University of Michigan for the third semester. In this definition, engineering students who transferred to another college at University of Michigan are considered retained in the university.

GPA – acronym for grade point average; the grade point average for all courses taken in the first year of engineering college by a student.

High School Class Rank- The ranking of an engineering student in high school compared to all other students in the student's high school graduating class.

Concern about Finances – This is a question from the CIRP survey about a student's concern about financing his/her college education. The survey question is: "Do you have any concern about your ability to finance your college education?" The student may reply with one of three responses: none ("I am confident that I will have sufficient funds"); some (but I probably will have enough funds); or major ("not sure I will have enough funds to complete college").[17]

The Chi-square test for proportions from Minitab 15 was used for testing the hypothesis for no difference in the retention percentages between the students who enrolled in Engineering 110 and students who did not enroll in Engineering 110. A significance level of 0.050 or less was indicative of a statistically significant difference between the two retention percentages.

Results and Discussion

As part of a larger retention study, 735 students from the 2004 and 2005 freshman classes were included in this study. Twenty-six percent of the students were women and 8% were under-represented minorities. Of the 735 students, 31% elected to enroll in the first-year survey course on engineering careers, Engineering 110. The overall first-year college retention for this student sample was 93.9% and the first-year university retention was 97.6%. Because of the strength of the college GPA, the high school class rank and concern about finances as predictors of first-year engineering retention from the larger retention study[20], an empirical analysis was conducted, exploring the relationship between these predictors, enrollment in Engineering 110 and college retention. Figure 1 summarizes the overall trend in the college and university retention with respect to enrollment in Engineering 110 while Figures 2-4 and Tables 2-4 describe the relationship between college retention and enrollment in Engineering 110 with respect to the college GPA, high school rank and concern about finances. The results are reported as follows:

Engineering 110 Motivates Engineering Students to Continue in Engineering for Their Second Year of College

Figure 1 shows the comparison of the college and university retention for students who were not enrolled and enrolled in Engineering 110. In this study, of the 735 students, 228 students

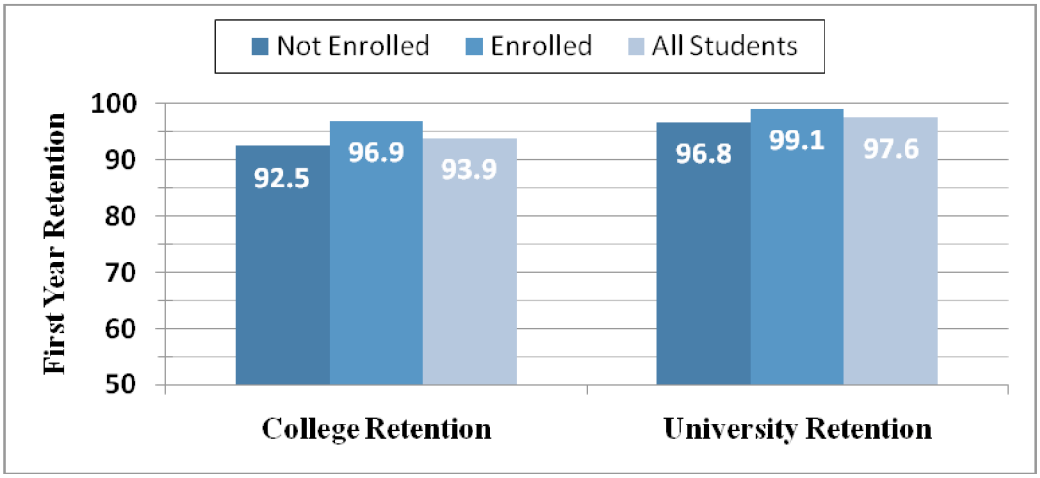

Figure 1: Enrollment in Engineering 110 Shows Higher Retention Rates

enrolled in Engineering 110 and 507 students chose not to enroll in Engineering 110. For retention in the College of Engineering, the college retention was 96.9% for students enrolled in Engineering 110 and 92.5% for students not enrolled. This difference of 4.4% was a statistically significant difference ($p<.05$). The overall college retention was 93.9%.

For the university retention, the increase in retention for students who enrolled in Engineering 110 was not statistically significant. The university retention includes the percent of students who were admitted to the College of Engineering as freshmen and returned to the university at the beginning of the sophomore year; this retention statistic includes students who may have transferred to another college within the university. The level of retention is noteworthy; in particular, of the students who enrolled in Engineering 110, 99% returned for their sophomore year, even if they decided to switch to another field of study. The overall university retention was 97.6%.

Enrollment in Engineering 110 Motivates Students With a College GPA Less than 3.500 to Stay in Engineering

Figure 2 shows a comparison of the college retention rate for students enrolled and not enrolled in Engineering 110 by the first year college GPA half-grade intervals. For both the grade interval of less than 2.500, and the interval of 3.000 to 3.500, there is a significant difference at $p \leq 0.05$ (see Figure 2). A Chi-square test for proportions was used to test for significance. Table 2 shows the sample sizes, differences in college retention between the two groups of students and whether the difference was statistically significant at $p \leq 0.05$.

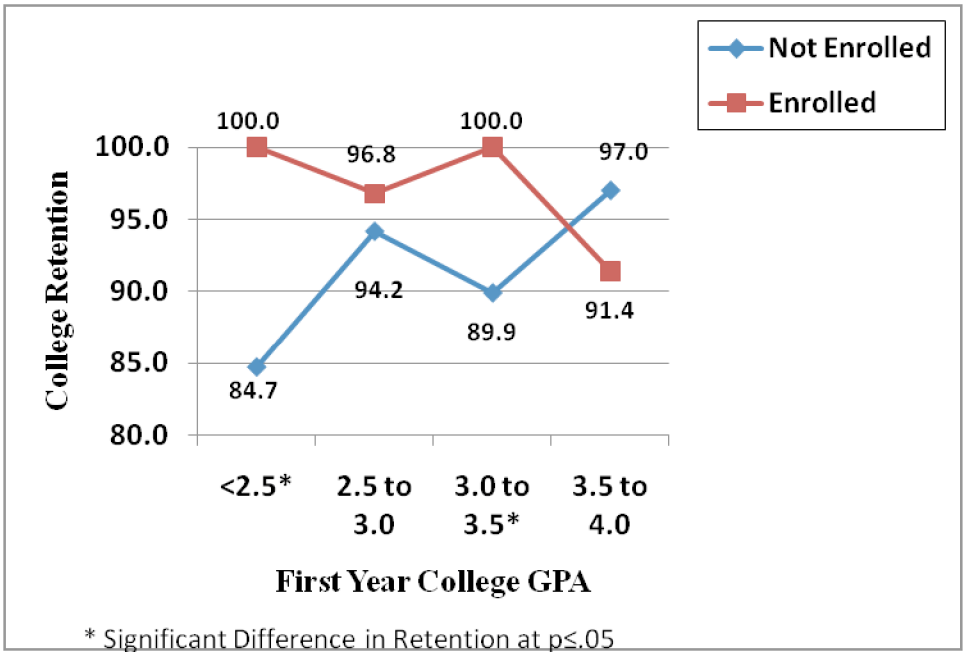

Figure 2: First-year College Retention Improves With Enrollment in Engineering 110 for Students with a First-year College GPA Less than 3.5 Compared to Students Not Enrolled in Engineering 110

Table 2: Summary of the Difference in College Retention for Students Enrolled in Engineering 110 Compared to Students Not Enrolled by College GPA

College GPA	Number of Students		Retention Improvement (Enrolled – Not Enrolled) (%)	Significant Difference? ($p \leq 0.05$) Yes/No
	Enrolled	Not Enrolled		
<2.5	27	72	15.3	Yes
2.5 to 3.0	62	120	2.6	No
3.0 to 3.5	81	149	10.1	Yes
3.5 to 4.0	58	166	- 5.6	No

The consistency of a level of retention at or close to 100% for the three lower grade intervals is indicative of an effective course in improving retention. This data supports that the Engineering 110 course is a positive force in retaining students in engineering, especially for students with low college GPAs.

Interestingly, the relationship switches for students with a college GPA of 3.5 to 4.0 with a lower retention for students who enrolled in the course. It is not statistically significant but a noteworthy trend. The university retention was also lower for the same subset of students compared to those who did not enroll in the course, indicating that some of these students left both engineering and the university. Two scenarios are possible. One is that because of their high first-year college GPA, these students wished to transfer to other engineering colleges or universities. The other is that as a result of enrollment in the course, they decided they did not wish to pursue an engineering degree. In fact, the decision to make a choice about whether engineering is the student's right career choice is one role of this course and the reason it is available to freshmen.

Course Motivates Students With a High School Rank of 96% or Less to Stay in Engineering

Because of the significance of high school rank as a predictor of college retention, the effect of Engineering 110 in terms of the high school rank was considered. The students were divided into three nearly equal groups by high school rank. The three groups were: students with a rank of 99%, students with a rank of 97 to 98%, and students with a rank of 96% or less. Figure 3 and Table 3 display the college retention for each high school rank group. For the group with a high school rank of 96% or less, the students who enrolled in Engineering 110 showed significantly higher college retention than students who did not (Chi-square test, p =.000).

There is a strong level of consistency in the first-year college retention for students enrolled in Engineering 110, with a range of 96% to 99% with no significant difference between the three student groups. However, there is much more variation in the retention across high school class rank for students who did not enroll in Engineering 110, with a range of 86% to 98%. Figure 3 shows a strong linear trend between high school class rank and first-year college retention.

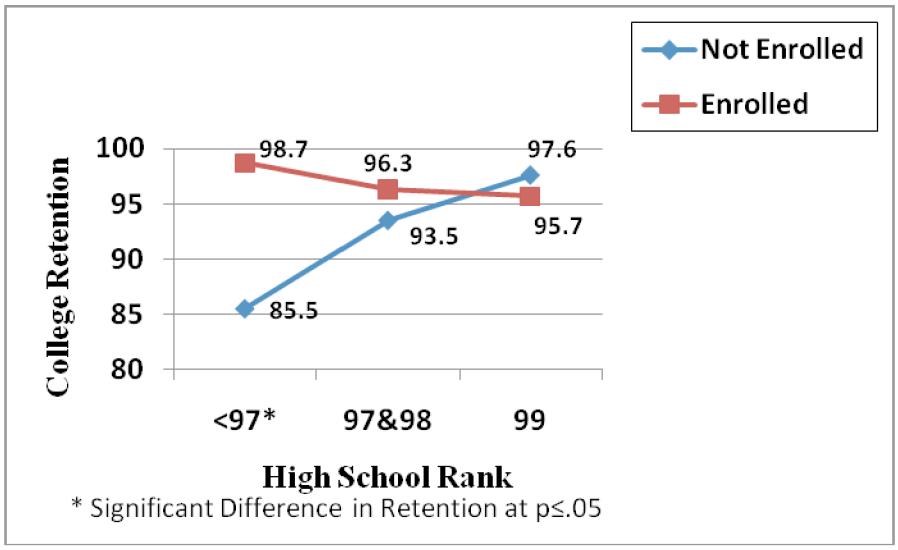

Figure 3: Significant Improvement in College Retention for Students Enrolled in Engineering 110 With a High School Rank of 96 % or Less Compared to Students Not Enrolled in Engineering 110

Table 3: Summary of the Difference in College Retention for Students Enrolled in Engineering 110 Compared to Students Not Enrolled by Class Rank

High School Class Rank	Number of Students		Retention Improvement (Enrolled–Not Enrolled) (%)	Significant Difference? (p≤ 0.05) Yes/No
	Enrolled	Not Enrolled		
<97	77	159	13.2	Yes
97&98	82	170	2.8	No
99	69	164	- 1.9	No

The improvement in retention of 13% for the high school class rank group of 96% or less taking into account the course is remarkable and indicates the success of the course in addressing student retention. As with the comparison using the college GPA, a crossover occurs in the relationships for the group with the highest class rank (see Figure 3). The differences in the college retention for both of the two higher class rank groups are within random variation.

Based on the literature review, it is hypothesized that for the students with a lower high school class rank, this course helps to build their identity and career development motivation as engineering majors. Some of the students in this group would be struggling in the competitive engineering curriculum. In building identity, the course may also generate more self-confidence, which then increases retention in the first year.

Relationship Between Enrollment in Engineering 110 and Concern About Finances

Figure 4 displays the relationship between the "concern about finances" variable on the CIRP survey and college retention. The CIRP survey question is: "Do you have any concern about

your ability to finance your college education? The student may reply with one of three responses: none, some concern ("but I probably will have enough funds") or major concern ("not sure I will have enough funds to complete college").[16] Due to a relatively small sample in the major concern category, the responses to "some" concern or "major" concern were combined into one category for this analysis.

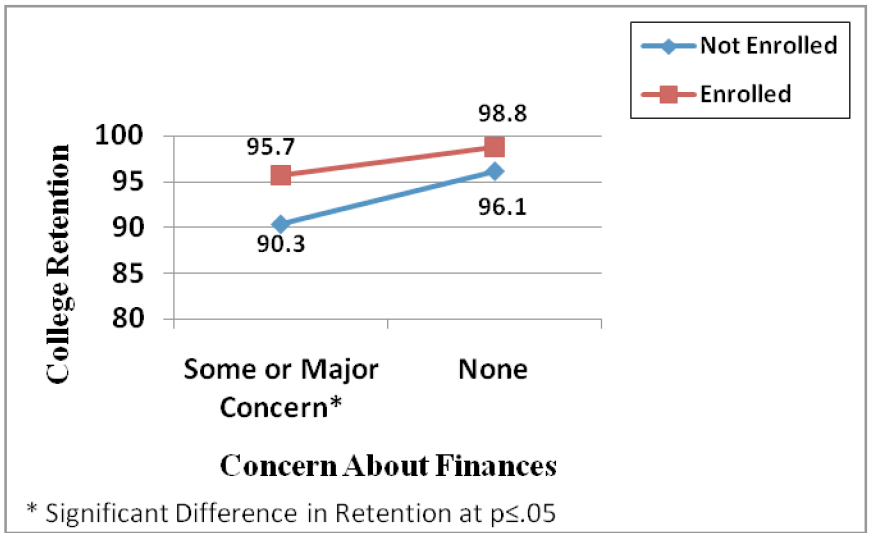

Figure 4: Significant Improvement in College Retention for Students Enrolled in Engineering 110 With Concern about Finances Compared to Students Not Enrolled in Engineering 110

Table 4: Summary of the Difference in College Retention for Students Enrolled in Engineering 110 Compared to Students Not Enrolled by Concern About Finances

Concern About Finances	Number of Students		Retention Improvement (Enrolled–Not Enrolled) (%)	Significant Difference? (p≤ 0.05) Yes/No
	Enrolled	Not Enrolled		
None	86	204	2.7	No
Some or Major	139	290	5.4	Yes

For both categories of concern shown in Figure 4, the college retention was higher for students who enrolled in Engineering 110 than for students who did not enroll in Engineering 110. The improvement in retention was significantly higher (p=.029) for the students who indicated some or a major concern about finances. It is concluded that the course increased the student's commitment to the engineering program despite a financial concern.

Update on College Retention

The analysis discussed in this paper was based on statistics from a larger research study conducted using student data from the 2004 and 2005 freshman classes, with a 30% sampling of these freshmen classes. The College of Engineering provided first-year retention percentages for the Engineering 110 course for 2004 through 2007. These retention percentages are presented in Table 5. Between 350 to 400 students enrolled in Engineering 110 each year. The 3% retention improvement for those students enrolled in Engineering 110 in comparison to those students not enrolled in the course for the entire 2004/2005 freshman classes compares well with the 4% improvement shown in this analysis using a 30% sample of these classes. In addition, the improvement in retention was repeatable with larger gains in retention in 2006 and 2007. In 2006, there was a 6% improvement in retention; and in 2007, there was a 5% improvement in retention.

Table 5: College of Engineering Course Retention Statistics

Year	First-year Retention of Students Not Enrolled in Engineering 110 (%)	First-year Retention of Students Enrolled in Engineering 110 (%)	Retention Improvement (%)
2004 & 2005	91.1	94.0	2.9
2006	90.6	96.1	5.5
2007	90.5	95.0	4.5

Conclusions and Recommendations

In their research on identification as an engineer and its influence on engineering retention, Stevens et al. (2008) concluded:

> "If identification with engineering is as important as we are arguing, then certain recommendations can be made. Engineering programs can do more during the early years of an undergraduate engineering education to ensure that students have some strong identification with engineering."[8]

Such a course of action includes a first-year survey course on engineering careers. Based on the literature review, it can be hypothesized that such a course would both increase identity due to peer association with other engineering students in the course; and the course content would help students in their thought process of deciding their career path in engineering.

In fact, for students enrolled in Engineering 110, the survey course on engineering careers, there was a significantly higher retention of students in the engineering program than students not enrolled in this survey course. An improvement of 4% retention is considered important in almost all engineering colleges. Verification with the retention statistics based on total class enrollment showed retention improvement from several years of 3 to 6%. (See Table 5)

In addition, there were patterns of significance for higher retention of students enrolled in this course associated with the first-year college GPA and high school rank. Of particular interest, for students who had a concern about their college finances, their enrollment in the course showed a statistically significant higher retention than for students not enrolled in this course ($p \leq .05$).

Students enrolled in the course either by self-selection or on the recommendation of an advisor. As a result, there may be differences due to a selection bias. For example, students who were more interested in an engineering career may have enrolled at a higher rate in the course. Although there was no control group, the fact that there were consistent differences across several variables and that an improvement in retention was seen over several years suggests that the course has influenced an increase in first-year engineering college retention.

The literature review supports the connection between the engagement of students and higher student retention. Most of the literature discusses smaller classrooms. It is very probable that in a course like this, professors are engaging students in the larger theater classroom through their experience.

In summary, it is hypothesized that this course significantly influences freshman retention for the following reasons:

- The course increases a student's identity as an engineering major; first by giving the student information that helps him/her to see a career path in engineering and second by associating with peer engineering students.
- The course builds on the idealism of the current generation of students and suggests the role of an engineer in effecting social "good" by designing innovative solutions to current engineering problems.
- The faculty are successful in providing meaningful lectures, examples and problems, which engages the students. As researchers have indicated, student engagement is important for learning and engineering retention.

Our recommendations include a stronger career development program in our high schools. In the referenced ASQ survey, only 20% of the parents surveyed discussed the possibility of engineering as a career with their children.[4] Thus, it is important for engineering colleges to encourage high schools to discuss engineering careers with their students.

By default, it becomes the responsibility of engineering colleges to educate freshmen and sophomores on opportunities in engineering. Ideally, based on each student's strengths and interest, engineering colleges help each student decide which engineering discipline is his/her choice. With the positive retention results reported in this paper, we recommend that more engineering colleges consider a survey course on engineering careers.

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