Freshman Engineering Retention: A Holistic Look

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Introduction

The ability of colleges to retain engineering students contributes to the overall goal of increasing the number of engineers in the workforce. This case study takes a holistic look at a freshman engineering cohort to answer the following question: What, if any, are the differences between students who continue to study engineering, switch out of engineering, or leave the university after one year?

Although there has been a plethora of research done using valid statistical models to try to answer this question, these models typically addressed only a limited view of the complex issue of student retention. The authors believe retaining students in engineering is a complex issue involving many interrelated variables, and taking a holistic look at a group of engineering students could add to the knowledge base and potentially lead to a better understanding of students' decisions. The ultimate goal of this study was to form recommendations for K-12 educators, engineering faculty and engineering professional societies that might improve retention of engineering students.

This study was guided by the theoretical framework of Bean and Eaton's (2001) psychological model of college student retention. The variables investigated in this study (past behavior, personality, initial self-efficacy, motivation to attend, initial attributes, and skills and abilities) are all considered entry characteristics in Bean and Eaton's model.

Past research shows that engineering students who left university had different characteristics from students who switched to another major. It has also been shown that students who left engineering early had some different characteristics from students who left later (Besterfield-Sacre, Atman & Shuman's, 1997; Min, Zhang, Long, Anderson & Ohland, 2011). Based on these results, the current study investigated separately those students who left the university verses those that switched to other major. Whether the student left after one semester or one year was also considered.

For the purposes of this study, retention rate was defined as the percentage of engineering students who continue to pursue a degree in engineering after one year. Recommendations identified could have a broader impact to other engineering colleges and other science, technology, engineering and math (STEM) majors. When we took a holistic look at our students, some interesting findings emerged that were not found when canvassing the literature on engineering retention. These findings add to the body of knowledge on retention of engineering students, with the realization that they are a small piece of the very complex issue of increasing the number of engineers in the workforce.

Related Literature

There is a wealth of research on students' experiences in college and why some remain in college while equally qualified students do not. Some believe the academic demands of engineering school, and other issues unique to engineering, warrant that engineering students be researched as a separate unit (Veenstra, Dey, & Herrin, 2009). Hence, an extensive body of research involving only engineering student retention has flourished. While some research has focused solely on the retention of women and minorities, other research has focused on all engineering students. The issue has been studied qualitatively and quantitatively, within one university and among multiple universities.

Many of these studies include entry characteristics from Bean and Eaton's model, such as past behavior, personality, initial self-efficacy, initial attributions, normative beliefs, coping strategies, motivation to attend, and skills and abilities. All the studies reviewed herein contained some measures of skills and abilities. Table 1 contains a representative group of studies with different combinations of variables used to measure ability. The level of significance, a measure of confidence that the variable is related to retention, has been included when reported in the article. The multicollinearity (interrelatedness) between variables measuring ability, as well as variables measuring other characteristics included in the model, affects the level of significance of each variable.

The study by Zhang, et al. (2004) showed the complexity of fitting a model to retention for engineering students. They used a multi-university database which contained information on 87,176 students from nine universities to predict graduation using six variables (ethnicity, gender, high school GPA, SAT Math score, SAT Verbal score and citizenship status). Models fit to each university resulted in different variables being significant and the R^2 values for the models with all available variables ranged from .05 to .21. While all six variables were significant in at least one model, only two variables, high school GPA and SAT Math score, were significant in all the models.

Entering characteristics not directly measuring ability have also been shown to have a significant relationship with retention. These include study habits, various elements of personality, initial self-efficacy and motivation to enroll in engineering (Lichtenstein, McCormick, Sheppard, & Puma, 2010; Veenstra, 2009; Doolen & Long, 2007; Felder, Felder & Dietz, 2002; Moses, et al., 2011; Besterfield-Sacre, et al. ,1997; Marra, Shen, Rodgers & Bogue, 2009).

Factors in Bean and Eaton's model in areas other than entry characteristics have been related to retention. For example, academic interactions as mea-

	High School GPA	High School Rank	SAT or ACT Math	SAT or ACT Verbal	Calculus or Algebra Readiness
Besterfield-Sacre, Atman & Shuman, 1997		*	*		
Moller-Wong & Eide,1997		*	*	not sig.	
Moses, Hall, Wuensch, DeUrquidi, Kauffman, Swart & Dixon, 2011	.05		not sig.		.001
Levin & Wyckoff, 1988	.01		.01	.10	.01
Zhang, Anderson, Ohland, & Thorndyke, 2004	.01+		.01+	++	
French, Immekus & Oakes, 2005		.05	.05	not sig.	

+ Ran models for 9 schools from the same database. GPA and SAT Math were significant for all nine models.
++ Not significant in all models significant levels ranged from p<.0001 to .044
*Stated significant, but no significance level reported

Table 1: Sample of Ability Variables and Level of Significance

sured by relationship to faculty and teaching methods and social integration have been examined (Amelink & Creamer, 2010; Doolen & Long, 2007; Felder, Felder, & Dietz, 2002; Hong & Shull, 2010; Kendall-Brown, Hershock, Finelli, & O'Neal, 2009; Kvam, 2000; Marra, Shen, Rodgers, & Bogue, 2009; Seymour & Hewitt, 1997; Heller, Beil, Dam, & Haerum, 2010; Marra et al., 2009; Olds & Miller, 2004). Personal characteristics studied have included gender, students' attitudes towards engineering, and the students' commitment to getting a degree in engineering (Borrego, Padilla, Zhang, Ohland, & Anderson, 2005; Matusovich, Streveller, & Miller, 2010; Seymour & Hewitt, 1997; Zhang, Anderson, Ohland, & Thorndyke, 2004; Besterfeld-Sacre, Atman, & Shuman, 1997; Veenstra, 2009).

Not all of the studies with overlapping variables came to the same conclusions on the significance, magnitude and/or direction of the impact of the variables on retention. For example, in Moller-Wang & Eide (1997) gender was not a significant variable in defining lower or higher risk for leaving engineering, while in Borrego, et al. (2005) females were more likely to switch quickly out of engineering. Among other things, this might be because of multicollinearity between variables included in the study and the population sampled.

Quasi-experimental studies have also been published that evaluated changes in retention and performance after implementing changes to engineering programs. Changes include forming research partnerships between undergraduate students and faculty, adding an entrepreneurial aspect, implementing learning communities, and having a series of classes all taught by the same professor (Nagda, Gregerman, J., VonHippel, & Lerner, 1998; Dabbagh & Menasce, 2006; Olds & Miller, 2004; Felder, Felder & Dietz, 1998). All of these authors stated the changes had a positive effect on retention.

The extensive list of variables associated with engineering retention found in the literature shows the complexity of the issue. This was the main reason the authors chose to take a more holistic look at their institution's students through a case study of the 2010 freshman engineering cohort.

Research Design

This case study attempts to take an in-depth look at quantitative information about a 2010 cohort of engineering students with the hopes of learning more about what affected their decisions on whether to remain in engineering, change majors or leave the university entirely. The guiding concept for this study was that retention of freshman engineering students is a complex issue and there is no simple solution to increasing retention. The study focuses on the retention from first to second year, since data at our university, as well as data from a large longitudinal database show more students leave engineering between first and second year than any other time period (Min, et al., 2011).

Sample

The students who participated in this study were all first-time, full-time freshman at an ABET accredited engineering college in a large, public, research institution. The cohort was 86 percent Caucasian, 5 percent Hispanic/Latino and 9 percent other. Sixteen percent were female and 84 percent were male. Ninety-eight percent of the students had graduated high school in 2010.

Source of Data

This IRB approved study used data from three sources: the Cooperative Institutional Research Program (CIRP) Freshman Survey, the Freshman Engineering Survey and official university student records. The CIRP Freshman Survey includes topics related to academic preparedness, admissions decisions, expectations of college, interactions with peers and faculty, student values and goals, and student characteristics. This survey has been administered in over 1,500 universities for over 40 years and is used in many published studies. The survey was given to the incoming freshman 2010 cohort during summer orientation ($n = 296$, which represented a 92 percent response rate).

The Freshman Engineering Survey was designed by faculty who teach Introduction to Engineering, a required course that provides an introduction to the university's academic environment, the various engineering disciplines, critical thinking, the design process, professionalism, ethics, diversity, communication, time management skills, team building skills, and some computer applications. Some of the questions on the Freshmen Engineering Survey were similar to questions asked on the CIRP Freshman Survey, but were rewritten to apply specifically to this population of engineering students. The survey includes questions related to past and expected study habits, self-rated knowledge of engineering related topics, potential obstacles/challenges to completion of their degree, commitment to their current field of study and the university, factors that influenced the student's decision to pursue an engineering degree, interaction with university personnel or peers, and student characteristics. Where possible, cross validation was done between questions that were similar on both surveys. The Freshmen Engineering Survey was administered to both the 2010 and 2011 freshman at the beginning of the fall semester and again at the end of the semester in the Introduction to Engineering class. Ninety-eight percent of the 2010 students ($n = 312$) took the pre survey and 92 percent took the post survey ($n = 296$). Of the 25 students who did not take the post survey 60 percent (15 students) were not in the program by the end of first year, but they are included in this analysis to the extent possible.

Complete and matching data from the 2011 cohort were not yet available; however when available, preliminary results from the 2011 cohort were used to verify 2010 data to the extent that the survey responses followed similar patterns. There was one variable of interest that was asked of the 2011 cohort that was not asked on the 2010 cohort that is also included in the analysis.

Characteristics of Engineering Students

The first goal of this study was to use the data from the surveys to create a portrait of our students. Appendix A contains a list of some demographic characteristics of our students that will help readers decide if results of this study might be applicable to their institutions.

Consideration of Other Professions

Reviewing the surveys brought to light some interesting characteristics of our students. Seventy-one percent of the students had considered possible majors/career paths other than engineering. The majors and career paths considered were all encompassing and included art, music, culinary arts, ministry, mechanic, teacher, pilot, and actor. Other more predictable careers included professions within the STEM fields, such as mathematics, physics and medicine. Seventy-one percent of the 2011 cohort also reported they had considered equally diverse majors/career paths. This result is important to help faculty understand that the majority of the students are not exclusively interested in engineering.

Optimistic About Their Abilities

When asked to rate themselves on 24 different abilities as (1) lowest 10 percent, (2) below average, (3) average, (4) above average or (5) top 10 percent, the majority of the students rated themselves high even on abilities not normally associated with engineering students. The top five abilities, (average score between 4 and 5) were *academics, mathematics, work with diverse people, drive to achieve,* and *tolerance of people with different views*. Some of these would be expected from a group of engineering students. Others, such as *working with a diverse group of people,* were a surprise. The five abilities with the lowest rating, which were still around 3, were *artistic, public speaking, spirituality, popularity,* and *social self-confidence*.

The tendency to think highly of their abilities might explain their optimism when asked the likelihood they would have at least a B average at the end of their first semester. The average GPA after one semester was 2.89 and yet on the Freshman Engineering Survey given at the end of the first semester, but before final exams, 72 percent of the students thought they had a good or very good chance of having a B average.

Since much can be lost by looking at averages, the data were also evaluated to determine what happened to the smaller number of students who were on the periphery, those not like the average. Although the average rating of computer ability was 3.7 (close to above average), 4 percent of the students rated themselves below average and 47 percent of the students rated themselves as average. Since these students are all millennials, it is often assumed that they are good with technology. Since these are engineering students, it is assumed they understand technology. Some studies have shown that the millennials are not as knowledgeable in computer skills as is often assumed (Bennett, Maton, & Kervin, 2008). The implications of this for faculty designing instruction are to step back and evaluate students' computer skills before assuming a high level of knowledge.

	Top Reason	2nd	3rd	% in the Top Three Reasons
That holds my interest	34%	16%	13%	64%
Confident jobs will be available when I graduate	21%	16%	20%	56%
That pays well	10%	23%	21%	53%
Confident I can be successful	11%	15%	15%	40%
I can do meaningful work	13%	13%	7%	33%
Allows money to pursue interests outside of work	6%	7%	9%	22%
Has good opportunity for advancement	3%	7%	11%	21%
I can work with like-minded people	1%	4%	4%	9%
Other	1%	0%	1%	2%

Table 2. Factors Considered When Choosing a Career

The data showed only 4 percent of the students viewed themselves as average or below average in academic ability and 6 percent as average or below average in math abilities. Yet when asked what they thought was a potential challenge to becoming an engineer, 33 percent of the students selected *lack of adequate high school preparation in math and/or science*. Also, 27 percent rated themselves as average or below in intellectual self-confidence. The correlation between academic ability and intellectual self-confidence (.291) and between mathematical ability and intellectual self- confidence (.274) were significant at $\alpha = .05$, but were lower than expected. This seems to demonstrate that thinking highly of their abilities does not necessarily lead to high intellectual self-confidence.

Why Students Choose Engineering and What Factors They Consider When Making Career Choices

McIlwee & Robinson (1992) looked at why students choose to study engineering and concluded the top reason is because the student was good at math and science. On the Freshman Engineering Survey the students were asked this question and were free to choose multiple answers. The answer chosen most frequently was *good at math and science* (88 percent), followed very closely by *heard engineering had good job opportunities* (82 percent) and then *researched what engineers do and think I'd like it* (69 percent). The lowest response was a *parent recommended it* (29 percent) (only about 14 percent of our students had a parent who was an engineer). The average number of reasons selected was 3.7 (out of 7 options). Since only 6 percent ($n = 20$) of students chose *good in math and science* as the only reason they chose engineering, it is misleading to conclude the majority of students are choosing engineering solely because they are good at math and science.

The 2011 cohort was asked to rate the top three factors out of nine used to determine what career to pursue. The results are summarized in Table 2. The top reason measured by both the percent of students who chose it as their top reason as well as the number that chose it in the top three was *holds my interest*. In Seymour and Hewitt (1997) lack of interest in science, engineering and math was one of the top contributing factors in the decision to switch out of STEM fields.

The second highest response in our study was *confident jobs would be available*. Although some have written about this generation of students wanting to do meaningful work (Zemke, 2001), only 14 percent of the students rated this as number one and 33 percent rated it in the top three factors.

High School Study Habits

The final observation of interest is the reported high school study habits:

- 44 percent frequently were bored in class
- 27 percent frequently and 57 percent occasionally studied with others
- 29 percent frequently and 60 percent occasionally asked teachers for advice
- 5 percent frequently and 48 percent occasionally did not turn in homework

From these responses, one can conclude many students are in the habit of talking with their teachers. On the Freshman Engineering Survey given at the beginning of the first semester, the students reported they were more likely to communicate regularly with their college professors than they did on the survey at the end of the semester. Over 50 percent of the students at some time did not turn in homework.

Characteristics of the Students Who Left the University or Switched Out of Engineering

Analysis showed a difference between the students who left the university or switched out of engineering after one semester, and those who left or switched by fall semester of the second year. The results have been separated below.

The Early Leavers

After one semester, six students left the university. Of the five who had completed the CIRP Freshman Survey, four reported neither of their parents had a bachelor's degree and the other student reported having ADHD. Their average high school GPA (3.34), average first semester college GPA, (.59) and average ACT composite score, (24.8) were statistically different from the students still enrolled after one year. Their ACT math score was not statistically different. The early leavers included one female, five males; all were Caucasians.

Although the students who left the university after one semester had significantly lower high school GPAs, 57 percent of the students with the lowest 9 percent high school GPAs were still in engineering after one year. Also 54 percent of the students who scored in the lowest 11 percent on their ACT Math and 63 percent of the students who scored in the lowest 13 percent on ACT composite were still in engineering at the end of one year. Therefore, it is not accurate to say a student cannot make it in engineering if they do not have a stellar high school GPA and test scores.

	No parent with a bachelor's degree (n = 75)	One parent with a bachelor's degree (n = 84)	Both parents with a bachelor's degree (n = 130)
After 1st semester			
Enrolled in engineering	89%	92%	92%
Transfer out of engineering	7%	8%	8%
Left University	5%	0%	<1%
After 1st year			
Enrolled in engineering	73%	73%	83%
Total who transferred out of engineering	13%	18%	12%
Total who left the university	13%	10%	5%

Table 3. Parent Education versus Student Status after 1st Semester and 1st Year

	Enrolled in engineering	Transferred out of engineering	Left the university	Overall
Lack of preparation in math and science	30%	48%	45%	33%
Financial	17%	23%	38%	20%
Lack of time to study	23%	27%	31%	24%
Lack of interest in engineering	9%	16%	7%	10%
None	41%	25%	28%	38%
Other	7%	9%	3%	7%
n of N=	236 of 246	44 of 45	29 of 30	309 of 321

Table 4. Potential Challenges Versus Status after One Year

The Early Switchers

Twenty-three students switched out of engineering to another unit within the university after one semester, and of those, five had left the university by the start of their second year. The majority of them had at least one parent with a college degree and there was no statistical difference in high school, first semester GPA, ACT Math or composite ACT scores between them and the students that were still enrolled in engineering after one year. These results contrast with results from Mendez, Buskirk, Lohr and Haag (2008), who found that freshman GPA was the most important variable to predict retention in engineering. The students who switched to another unit consisted of three females and 15 males, four Hispanics/Latinos, 13 Caucasians, and one of two or more races. Hartman and Hartman (2006) found a significant difference in GPA between those who stayed in engineering and those who switched out for the males but not the females.

After One Year

Gender and ethnicity. The one year retention rate in engineering was 76 percent for both males and females. This supports results from Besterfeld-Sacre, et al. (1997) and De Cohen and Deterding (2007) who also found males and females had equal retention rates in engineering. Ten percent of the males and 6 percent of the females left the university and 13 percent of the males and 18 percent of the females switched to other majors at the university. Less than 60 percent of the African Americans, Hispanic/Latinos and those of two or more races remained in the engineering school. All eight of the Asians remained in engineering.

Parents' education. Students who had neither parent with a bachelor's degree were more likely than other students to leave the university after the first year. Students who had both parents with a bachelor's were more likely to remain in engineering after one year. See Table 3 for details. Higher retention of students whose parents have a degree is well supported in the literature (Pike & Kuh, 2005).

Self-identified potential challenges. Table 4 shows the results of the question "Are any of the following potential challenges to you becoming an engineer?" versus status after one year. Students who transferred out of engineering were much more likely than students who stayed in engineering to select *lack of interest in engineering and lack of preparation in math and science.* This result was consistent with Seymour and Hewitt (1997). Students who left the university were more likely than either group that stayed at the university to select *financial concerns.* A high number of the students who left the university also selected *lack of preparation in math and science* as a potential challenge.

Homework. The frequency of doing homework in high school seemed to be related to some students' ability to remain in engineering. Of the 15 students who reported frequently not doing homework in high school, only 53 percent remained in engineering compared to 85 percent for the students who always did homework. Of the students who said they frequently studied with others, 86 percent ($n = 78$) were still in engineering. Only 67 percent ($n = 48$) of the students that never studied with others remained. In a meta-analysis of the benefits of homework, Cooper (1989) included increased knowledge and self-discipline as benefits of completing homework.

Drive to achieve. Overall, the students thought their drive to achieve was high. The few students who rated themselves with lower drive left the university at a much higher rate than the other students. Only one student rated their drive to achieve in the lowest 10 percent and he was no longer at the university after a year (he also had below average high school GPA and ACT scores). Five rated their drive below average; of these, 40 percent had left the university.

Self-efficacy. Responses to questions related to self-efficacy were mixed. All of the students with lowest level of intellectual self-confidence (self-rated themselves lowest 10 percent , $n = 11$) were still in engineering after one year, and 80 percent of the students who left the university had self-reported above average intellectual self-confidence. Almost 50 percent of the students who switched to other majors had selected *lack of high school preparation in* *math and/or science* as a potential challenge to becoming an engineer. This compared to 30 percent of students who stayed in engineering. Other studies have shown self-efficacy or confidence as having a positive effect on retention (Eris, et al., 2010).

ADHD. Of the students who reported having ADHD, 77 percent were still enrolled in engineering after one year, 5 percent had transferred to another unit, and 18 percent were not enrolled at the university. Although the percentage remaining in engineering was one percentage point higher than the overall retention rate, the rate which students with ADHD who left the university was over twice the rate of students without ADHD.

The average high school GPA and average first year GPA of the students with ADHD were significantly lower at $\alpha = .05$ than the students who did not report having ADHD. The average difference between the high school GPA and first year GPA was also significant (1.42 for students with ADHD and .87 for students who did not report having ADHD). The variability in the first year GPA and the difference between high school and first year GPA between the two groups were significant, with the variability in the group with ADHD being higher. Although 41 percent of the ADHD students had first year GPAs under 2.0, compared to 16 percent overall, 27 percent had earned a GPA between 3.0 and 3.8.

Students taking introductory calculus versus calculus. After approximately three weeks of calculus and numerous evaluations, students at our university are given the opportunity to take a preparatory calculus class (review of algebra, trigonometry and basic calculus). The class does not count as credit towards their engineering degree; it does count as a general education mathematics course if the student transfers to another unit. Thirty-five percent of the students decided to take this class. This group had a 66 percent retention rate in engineering, compared to 85 percent for the students who stayed in engineering calculus. As other studies have shown, students who perform better in calculus were more likely to stay in engineering, but again there were exceptions (Moses, et al., 2011). For example, 38 percent of the students who receive Fs in calculus remained in engineering after one year, and students with As and Bs in calculus left engineering. Also, a higher percentage of students with Ds in calculus stayed compared to the percentage of students with Cs. (Note that the number of students with Ds was much lower than the number of students with Cs).

Why students chose engineering. Table 5 summarizes the results for students who remained in engineering, switched to another unit or left the university. The most interesting observation was that the students who remained in engineering on average had selected more reasons for choosing engineering (4), compared to the students who switched majors (2.7) or who left the university (2.3). This contradicts the results from Seymour and Hewitt (1997), who gathered information from 335 science, math and engineering (SME) majors, some of which had already switched out of SME. In their study, students who switched out of SME majors on average gave twice as many reasons for choosing engineering as students who remained in engineering.

The top two reasons for all three groups were *good at math and science and engineers get good jobs*, but the order of the two was different. For the students who switched majors or left the university, the number one reason was *engineers get good jobs*, but *good at math and science* was the number one reason for students who remained. Only 4 percent of the students who remained in engineering did not choose *good at math and science,* compared to 36 percent of the students who switched and 30 percent of the students who left the university.

Students who stayed in engineering chose *know an engineer* more than three times as often as the students who left the university and almost twice as often as students who switched. Another big discrepancy was in the percentage of students who chose *parents recommended* (33 percent of students who stayed, 25 percent of the students who switched and 11 percent of students who were out of the university) and students who chose *recommend by others* (41 percent of students who stayed, 23 percent of the students who switched and 15 percent of students who were out of the university). This also goes against Seymour and Hewitt's (1997) results where a higher percentage of students who switched out of SME majors, as compared to students who remained, had selected *Active Influence of Others* as a reason they originally chose to major in a SME field.

	Still in engineering school	Switched to another unit	Left the university
Good at math and science	96%	64%	70%
Get good jobs	87%	66%	74%
Researched what engineers do and like it	73%	57%	56%
Know an engineer	50%	27%	15%
Parents recommend	33%	25%	11%
Others recommend	41%	23%	15%
Other	15%	7%	19%
Avg. number selected per student	4	2.7	2.3

Table 5. Reasons Students Chose To Study Engineering

New Fields of Study for the Students Who Switched Out of Engineering

Twenty-seven percent of the students who had considered fields other than engineering left engineering after one year. This compares to 16 percent of the students who had not considered other fields. Overall, 14 percent of the students switched from engineering to another college within the same university. Of these students, 36 switched to the College of Arts and Sciences (biology (5), chemistry (3), physics (3), math (3), administration of justice (2), psychology (2), and one each to art, atmospheric science, geography, and political science; the rest were undecided). Seven students switched to the College of Business (computer information systems (2), finance (2) accounting (1), and undecided (2)). One student switched to middle and secondary education, and one student switched to music. The breath of these fields was not surprising given the variety of other professions the students had considered.

Summary, Limitations, Recommendations and Future Research

To quickly revisit the questions of this study, a great deal was learned about our students. They did not fit into a nice mold, but were a rather eclectic group. Generalizations can be made about the students at the risk of missing the diversity in the group. Instead of creating a model with a few significant factors, we chose to take a holistic look at our students with the idea of gaining additional insight that might help our college as well as other colleges of engineering better understand the wide range of factors that affect students' decisions.

There were some similar characteristics in the students who left the university which have been documented in other studies, but these same characteristics existed in students who stayed. The students who left the university had significantly lower high school GPA and ACT composite scores, but there were students with low high school GPAs and low ACT composite scores still at the university and still in engineering after one year.

Eighty percent of our early leavers and about 50 percent our students who had left the university after one year did not have a parent who graduated from college. The study showed that students who more frequently studied with others in high school were more likely to continue to study engineering. The issue of ADHD is not easily found in the literature on engineering schools. The analysis in this study showed that 17 percent of the engineering students who left the university had ADHD, which is twice the percentage of students in the program with ADHD (7.7 percent). The Center for Disease Control (http://www.cdc.gov/nchs/fastats/adhd.htm, October 11, 2011), estimates that 8.4 percent of all 3-17 year olds have ADHD. This appears to be an issue needing future research.

Recommendations

Acknowledging that many of the characteristics investigated in this study are related to each other and due to the design of this study, causal relationships cannot be proven. It is still reasonable to look at the relationships found in this study and form recommendations that have the potential to improve retention in engineering programs. The following are offered to K-12 educators, university faculty and engineering professional societies. The recommendations are most likely also applicable to other STEM fields.

K-12 Educators

- Since students who were less likely to do homework in high school were more likely to leave the university or switch to other majors, homework policies, especially in math and science classes should be designed to help students develop the habit of completing homework.
- Since students who studied together in high school more frequently were more likely to continue in engineering, opportunities for students to develop the habit of studying with others should be provided. (An example might be to design a small portion of a test that is completed outside of class and can be completed as a group.)
- Since such a high percentage of students are concerned about lack of preparation in math and/or science, higher level high school math and science classes should be more closely aligned with the expectations of an engineering curriculum so students feel well prepared. Students interested in engineering need to be encouraged to take high level math and science classes in high school.
- Since students who remained in engineering chose *know an engineer* more frequently than those or switched as a reason they studied engineering, provide opportunities for students to meet engineering professional. This will allow students to gain a better understanding of the profession.
- Since students selected interest as the most important factor is selecting a career, students should be encouraged to draw connections to their area of interest and engineering principles. (For example the National Science Foundation has a series of two to six minute videos on applying engineering and sciences principles to football and the Olympics. http://science360.gov/files/)

University Faculty

- We were surprised by some of the characteristics of our students and recommend faculty and staff take time to learn about their students.
- Since first generation students and those with ADHD are more likely to leave the university, faculty should understand and advertise available services to assist students, especially first generation students and students with ADHD.
- Since many students feel they are not adequately prepared for math and science classes in engineering, encourage students to use resources outside the class and college (for example Khan academy videos for calculus, chemistry and physics http://www.khanacademy.org/).
- Since a higher percentage of students who studied together in high school remained in engineering, encourage group studying by designing a variety of assignments that can be completed with other students.
- Since many students expect to communicate with faculty outside of class, provide opportunities for communication.
- Since students have many interest outside of engineering, challenge students to apply engineering principles to their other areas of interest.
- Since some students identify themselves as not having high computer skill, do not assume students are skilled in computer applications; assess students' skill level and provide outside classroom assistance for those who need it.
- Since students had high performance in the past, many are overly optimistic about their abilities and have high expectations for their performance in college. Strive to create a more reasonable expectation by sharing the distribution of high school GPA and college GPA for students in the program.

Engineering Professional Societies

- Strive to be more visible to students, especially in states with a low percentage of engineers.
- To help maintain interest in engineering, talk about how engineering can be applied to different areas of interest.
- Since students are making career decisions based on interest, market engineering as an interesting career.

Limitations and Threats to Validity

The data presented in this article were gathered from one university with characteristics described above and in the appendix. Although our college and student body are different from others, we do share things in common with many engineering schools, such as the drop in GPA from high school to first semester of college, similar rates of retention, and students who are accustomed to performing at the top of their class.

As with all self-reported survey data there is a threat to construct validity. It is impossible to know how seriously students took the surveys or how accurately they completed them.

Conclusion

Improving freshman retention is a small part of the solution to increase the number of engineering graduates. The findings and recommendations in this study and similar studies at different types of universities can be useful to university faculty to help increase retention of freshman engineering students. These findings and recommendations can also help K-12 educators and engineering professional societies contribute to increasing the number of engineering graduates. Engineering colleges must understand their student populations in order to design interventions that will improve retention of their students. One must conclude that framing engineering as meaningful work and promoting good jobs for engineers might not be enough to increase the number of engineering graduates. Students need to be truly interested in engineering. Most likely this interest needs to be fostered long before a student enters college, and it can be impacted by K-12 educators and engineering professional societies as well as college faculty.

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Appendix A

University and 2010 Cohort Characteristics

- Public, state university
- State has one of the lowest percent of engineers per employees in the country
- An average of 490 students per year graduate in engineering (all degree level, five year average)
- Engineering graduates represent an average of 11% of the graduates per year (five year average)
- 98% traditional students directly out of high school
- 100% fulltime
- 16% female, 84% male
- 86% Caucasian, 5% Hispanic, less than 5% Asians, African American, two or more races or resident alien
- 78% of the students' homes were within 100 miles of campus
- 65% of freshman were living in resident dorms, 24% were living with family or other relative
- Approximately 40% of the parents did not have college degrees and for 26% of the students neither their mother nor father had a college degree
- 14% of the fathers and one mother were engineers and 8% of the fathers and five mothers were in a computer related field
- 37% of the students had a 4.0 or greater high school GPA and the overall average high school GPA was 3.75
- 35% of the students were not performing adequately after two week of calculus class and made the decision to move to an introductory calculus class
- 7.7% of the students self-reported they had ADHD compared to a U. S. average of 8.4% (Center for Disease Control, accessed October 15, 2011)
- 11% of all engineering students (and 32% of the bioengineering) were using their engineering degree to prepare for another career