Comparing Entering Freshman Engineers: Institutional Differences in Student Attitudes[i]

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Abstract

EC 2000 will cause engineering educators to learn more about their students. This includes having a more informed understanding of students' underlying attitudes as they begin their engineering studies and tracking how these attitudes affect learning. Previous research indicates that students enter their first year with a range of perceptions and attitudes about engineering. However, little is known as to how student attitudes vary across institutions. Are initial attitudes correlated with the type of school the individual attends? Do students who attend a private (versus public), or large (versus small) engineering school enter with different perceptions of engineering and their abilities to succeed in engineering? Do students' choice of environment (urban versus rural) and the subsequent culture it provides or whether the institution has a "research" (versus "teaching") focus contribute to their initial attitudes about engineering and about themselves? Such knowledge is important since attitudinal differences among institutions may help to explain differences in academic performance, interest in the engineering pedagogy, and attrition out of or persistence in the program. We have investigated such differences among the freshman classes of 17 US engineering schools.

Introduction

Prior research indicates that the attitudes freshman engineering students have about themselves and about engineering provide valuable information for both better understanding student academic performance and for assessing major engineering program changes. Utilizing the *Pittsburgh Freshman Engineering Attitudes Survey* (PFEAS), we have conducted extensive research on different aspects of freshman engineers' initial attitudes and their changes over the course of the first year, first at the University of Pittsburgh and now at over seventeen US engineering schools. Our previous research has found that initial attitudinal differences are attributable to the students' gender and ethnic background [1, 2]. The PFEAS has also been used to evaluate innovative changes to several freshman engineering curriculums [3]. Our research has confirmed what others have found; i.e., student attitudes are related to freshman retention in engineering. Our closed-form instrument also has been used to develop empirical models for identifying (*before*

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they begin their first year) those freshmen who potentially may transfer out of engineering in good academic standing [4]. Finally, in investigating the nature of attrition in engineering, several studies, including ours, have indicated that retention in engineering is more linked to students' attitudes about the engineering field and about their own abilities to succeed than it is to their academic credentials.

We recently proposed [5] that students' initial attitudes may also be indicative of the type of institution they choose to attend; i.e., across institutions, differences in student attitudes might be correlated with other institutional differences. Possible factors to examine include type of institution (public or private); size of engineering school/program (small, medium, or large); the teaching versus research focus of the institution; and the institutional location (urban or rural). To date, little engineering education research has been conducted with respect to these factors. Astin [6] looked at institutional type at a national level for freshman of all disciplines and found few strong correlations. Specific to the engineering discipline, Felder [7] found differences in performance and overall persistence between students at the North Carolina State University who came from rural areas compared to those from more urban environments. Takahira, Goodings, and Byrnes examined differences in performance and persistence in statics between male and female students across 17 US schools with respect to the institution's size and selectivity (as defined by the acceptance rates and standardized test scores) [8]. They found that male students were more likely to persist at more selective institutions and females were more likely to persist at less selective institutions.

Although a number of investigators have studied various factors related to attrition out of engineering, few have taken a comprehensive, multi-institutional look at the possible factors associated with attrition. Currently our PFEAS questionnaire has been adopted by a number of engineering programs as a freshman-level evaluation tool. Most of these institutions are also participating in our national cross-institutional study of freshman engineering attitudes [9,10], and thus have provided us with a rich database for additional studies. This three-year longitudinal study involves approximately 20 US engineering schools and almost 7,000 students. We are investigating pertinent factors that potentially affect students' performance, attitudes and retention. These factors will be examined at both the freshman level, where earlier studies have indicated that at least half of engineering attrition occurs, and at the sophomore and junior years, where the remaining attrition occurs and where differences associated with such factors may become more magnified.

At the freshman level we are measuring students' attitudes at the beginning of their studies and over the course of the year to determine:

- Attitudinal differences among various student populations (i.e., demographics and characteristics of the student, demographics and characteristics of the institution)
- The impact of certain programmatic initiatives on attitudinal changes (i.e., integrated curriculum vs. conventional curriculum, traditional teaching methods vs. new approaches), and
- The extent that attitudes and these factors are correlated with retention and academic performance in engineering.

This paper documents a subset of the variables that are being examined. Specifically, this paper examines the attitudes of entering engineering freshman in order to identify institutional differences: public or private, size of the engineering school, the institution's research focus, and it's environmental setting. Several significant differences were been found in each of the variables that were examined.

Methodology

Seventeen participating engineering schools administered the PFEAS (pre-questionnaire) to their incoming freshman engineering students before or early in the fall semester of the 1998-99 academic year. PFEAS is a closed-form questionnaire originally developed and tested at the University of Pittsburgh to gather information about incoming engineering students' initial attitudes and their changes during the students' first year. Since its initial use in 1993, over twenty institutions have adopted the instrument as an assessment tool. The PFEAS questionnaire measures several facets of engineering student attitudes. In addition to assessing their opinions about the engineering profession and their reasons for studying engineering, students are asked to rate their self-assessed confidence in the pre-requisite background knowledge and skills, and in their perceived ability to succeed in engineering. Further, students rate their study skills and their interest in working in groups. The pre-questionnaire contains 50 items that are rated on either a Likert scale or an ordinal-based self-assessed confidence scale. The 50 items have then been statistically clustered into 13 attitude and self-assessment measures, shown in Table 1[ii].

Table 1. Student Attitude and Self-Assessment Measures and Their Definition, 97-98

Student Attitude and Self-Assessment Measures	Definition	Rating Value
General Impressions of Engineering	How much a student likes engineering	1 – does not strongly like engineering 5 – strongly likes engineering
Financial Influences for Studying Engineering	Belief that engineers are well paid; having an engineering degree provides career security	1 – does not strongly hold this belief 5 – strongly holds this belief
Perception of How Engineers Contribute to Society	Belief that engineers contribute to improving the welfare of society	1 – does not strongly hold this belief 5 – strongly holds this belief
Perception of the Work Engineers Do and The Engineering Profession	Considers engineering to be an innovative, respected profession.	1 – does not strongly hold this belief 5 – strongly holds this belief
Enjoyment of Math and Science Courses	Preference for math and science courses over liberal arts courses	1 – does not strongly hold this preference 5 – strongly holds this preference
Engineering Perceived as Being an "Exact" Science	Belief that engineering is an exact science	1 – does not strongly hold this belief 5 – strongly holds this belief
Family Influences for Studying Engineering	Belief that parents are influencing student to study engineering	1 – does not strongly hold this belief 5 – strongly holds this belief
Confidence in Basic Engineering Knowledge and Skills	Self-assessed confidence in knowledge of calculus and physics, chemistry and computer skills	1 - has low confidence 5 - has high confidence
Confidence in Communication and Computer Skills	Self-assessed confidence in writing, speaking and computer skills	1 - has low confidence 5 - has high confidence
Adequate Study Habits	Beliefs about the adequacy of current study habits	1 - not comfortable with study habits 5 – comfortable with study habits
Working in Groups	Preference for working in groups	1 – prefer working alone 5 – prefer working in groups
Problem Solving Abilities	Belief that one has the creative thinking and problem solving abilities required for engineering	1 – does not strongly hold this belief 5 – strongly holds this belief
Engineering Attributes	Belief that one is innovative; has good mechanical and technical attributes.	1 – does not strongly hold this belief 5 – strongly holds this belief

[ii] The clustering of the attitude measures has been statistically updated to reflect instrument use across many institutions; thus, deriving a true cross-institutional instrument.

The post-questionnaire is then given at either the end of the freshman year or during the last week of first semester, depending on the institution. The post-questionnaire includes 20 additional items that require the students to assess their confidence about the outcomes (EC 2000) of their engineering education to date.

We have divided engineering schools into three size categories based on the number of incoming engineering freshmen: small (<200), medium (200-499), and large (500+). This resulted in four small, nine medium-sized, and four large schools in our cross-institutional study. Five schools are private and twelve are public institutions. The nine schools designated as either research university I or II according to the Carnegie Foundation classification [11] were considered to have a "research" orientation; the other eight were considered to be "teaching." Eight schools are located in urban settings; the other nine schools are located in non-urban settings [12]. Table 2 provides a profile of each engineering school in the cross-institutional study.

Table 2. Participating Institutions for the 1998-99 Academic Year

Institution	Size of Engineering School (n)	Public/Private	Research/ Teaching Focus	Institutional Setting
A	Small (95)	Private	Teaching	Non-Urban
B	Small (70)	Public	Research	Urban
C	Small (120)	Private	Teaching	Urban
D	Small (180)	Public	Teaching	Non-Urban
E	Medium (250)	Public	Research	Non-Urban
F	Medium (250)	Public	Research	Non-Urban
G	Medium (250)	Public	Teaching	Urban
H	Medium (300)	Public	Research	Urban
I	Medium (350)	Public	Teaching	Urban
J	Medium (350)	Private	Teaching	Non-Urban
K	Medium (400)	Public	Research	Urban
L	Medium (300)	Private	Teaching	Non-Urban
M	Medium (450)	Public	Teaching	Non-Urban
N	Large (550)	Public	Research	Non-Urban
O	Large (650)	Private	Research	Urban
P	Large (1100)	Public	Research	Urban
Q	Large (1300)	Public	Research	Non-Urban

Non-parametric statistics are used, since prior analyses has revealed that many of the attitude metrics violate the normality assumption. Non-parametric statistics are generally more conservative than statistics that assume normality; thus a test that yields a significant difference using a non-parametric test will likely be significant using a normality-based test. For engineering school size, Kruskal-Wallis non-parametric tests (analogous to the one-way analysis of variance) were conducted on the pre-questionnaire to determine if differences existed between small, medium, and large engineering schools. A Bonferroni protection for multiple comparisons[iii] was applied to a significance value of 0.05 resulting in an adjusted P-value ≤ 0.001 for each school category. For those significant differences that were detected, assumed normality-based post-hoc Bonferroni multiple comparison and Duncan's multiple range tests were conducted to determine which school size category(s) were significantly different. The post hoc tests were conducted for each attitude measure resulting in a Bonferroni protection adjusted P-value ≤ 0.01.

[iii] The purpose of using a Bonferroni adjustment is to protect against making a Type I error.

Mann-Whitney non-parametric tests (analogous to t-tests) were used to determine if relationships exist between students' attitudes and the institution's public/private status, urban (versus non-urban) location and research (versus teaching) focus. This test was performed for each type of school resulting in a Bonferroni adjustment P-value of 0.002. For all analyses described, SPSS for Windows™ (release 8.0) statistical software package was used.

Discussion of Results

Table 3 provides a summary of the 6,721 participating students' demographic information. Although optional, most students completed this part of the survey. In total, 21.9% of the responding students are female; 69.8% are Caucasian; 5.0% are African-American, 10.0% are Asian Pacific, and 10.3% are Hispanic. Almost all of the students (96.9%) are full-time; 93.0% are 'true' first semester students who have not attended another post-secondary institution.

Table 3. Student Demographics
(6,721 Respondents)

Gender		**Ethnicity**		**Enrollment**		**Transfer**	
Male	4660 (78.1%)	African American	299 (5.0%)	Full time	5023 (96.9%)	No	4831 (93.0%)
Female	1309 (21.9%)	Asian Pacific	599 (10.0%)	Part time	159 (3.1%)	Yes (<12 hours)	147 (2.8%)
		Hispanic	615 (10.3%)			Yes (+12 hours)	216 (4.2%)
		Native American	51 (0.9%)				
		White Caucasian	4181 (69.8%)				
		Other	242 (4.0%)				
Missing	752 (11.2%)	Missing	734 (10.9%)	Missing	1539 (22.9%)	Missing	1527 (22.7%)

The results for each analysis are presented next. Even though conservative statistics were employed, several significant differences were found between the different factor groups. Although the differences in magnitudes are not large (around 0.10), such differences provide insights to the characteristics of freshman engineering students.

<u>Size of Engineering Schools</u>

Table 4 presents the averages and standard deviations (*in Italics*) calculated for the pre-questionnaire measures by institution size. Of the thirteen attitude and self-assessment measures, the Kruskal-Wallis tests revealed differences between institution sizes for four of the measures. However, post hoc analyses revealed only significant differences for two attitude measures, "Enjoyment of Math and Science Courses" and "Adequate Study Habits," at the prescribed P-value ≤ 0.01. This may be due to the fact that the post hoc tests assume an underlying normal distribution and that the mean difference between the mean was small (0.07 for "Perception of How Engineers Contribute to Society" and 0.03 for "Perception of the Work Engineers Do and the Engineering Profession”). For the attitude measure “Enjoyment of Math and Science Courses,” students at the “small” engineering schools rated their enjoyment significantly less than did students from “medium” and “large” schools. Our earlier research indicates that students who do not enjoy math are more likely to leave engineering. However, other attitudes that may be attrition indicators are not significantly lower than the other two size groups. These latter factors include liking engineering less, as measured by students’ “General Impressions of Engineering,” or having a poor self-assessed “Confidence in their Basic Engineering Knowledge and Skills” (e.g. physics, math, chemistry and computer skills).

For the attitude measure “Adequate Study Habits” the post-hoc analysis reveals that students at “large” engineering schools are significantly more comfortable with their study habits than are students at “small” or “medium” sized schools. However, in general, the data suggests that students begin their engineering studies with relatively low self-assessed confidence in their study habits and acknowledge needing to spend more time studying.

Table 4. Differences Among Institution Size

Student Attitude and Self Assessment	**Small** *n = 414*	**Medium** *n = 2791*	**Large** *n = 3210*	**P-value**
General Impressions of Engineering	4.20 *0.46*	4.22 *0.51*	4.23 *0.55*	
Financial Influences for Studying Engineering	3.55 *0.58*	3.56 *0.61*	3.53 *0.70*	
Perception of How Engineers Contribute to Society	3.27 *0.73*	3.29 *0.79*	3.34 *0.82*	< 0.001
Perception of the Work Engineers Do and the Engineering Profession	4.11 *0.43*	4.08 *0.51*	4.09 *0.65*	< 0.001
Enjoyment of Math and Science Courses	3.87 *0.85*	4.04 *0.79*	4.00 *0.81*	< 0.001
Engineering Perceived as Being an “Exact” Science	3.57 *0.71*	3.46 *0.80*	3.46 *0.86*	
Family Influences to Studying Engineering	2.34 *0.80*	2.35 *0.78*	2.39 *0.79*	
Confidence in Basic Engineering Knowledge and Skills	3.68 *0.60*	3.68 *0.58*	3.69 *0.66*	
Confidence in Communication and Computer Skills	3.54 *0.78*	3.49 *0.78*	3.45 *0.82*	
Adequate Study Habits	2.65 *0.83*	2.67 *0.80*	2.76 *0.77*	< 0.001
Working in Groups	3.29 *0.72*	3.27 *0.75*	3.24 *0.74*	
Problem Solving Abilities	3.84 *0.52*	3.87 *0.56*	3.85 *0.68*	
Engineering Attributes	3.66 *0.62*	3.62 *0.66*	3.61 *0.75*	

<u>Private Versus Public Institutions</u>

Table 5 presents the averages and standard deviations (*in Italics)* from the pre-questionnaire results for public and private institutions. Six of the thirteen attitude and self-assessment measures were found to be significant. Mann-Whitney non-parametric tests revealed several significant differences between students attending public and private institutions. Students from private engineering schools rated their “General Impressions of Engineering” significantly higher (i.e., more favorable) than did students from public schools. This is a positive result for private institutions, as previous research indicates that students who enter engineering with lower impressions are more likely to leave in engineering in good standing [13]. No differences between public and private schools were found for the other attitude measures linked to attrition – students’ self-assessed “Confidence in Basic Engineering Knowledge and Skills” and “Enjoyment of Math and Science Courses.” Students at private schools also rated their enjoyment for “Working in Groups” higher than did students at public institutions. This result needs to be examined further since two of the five private schools have an integrated freshman engineering programs, which utilize extensive teamwork. To what extent did having these integrated curricula influence the students’ choice of a school?

Table 5. Differences Among Public and Private Institutions.

Student Attitude and Self Assessment	**Public** *n = 4999*	**Private** *n = 1416*	**P-value**
General Impressions of Engineering	4.20 *0.52*	4.32 *0.54*	< 0.002
Financial Influences for Studying Engineering	3.52 *0.62*	3.63 *0.78*	< 0.002
Perception of How Engineers Contribute to Society	3.30 *0.78*	3.34 *0.88*	
Perception of the Work Engineers Do and the Engineering Profession	4.08 *0.53*	4.13 *0.73*	< 0.002
Enjoyment of Math and Science Courses	4.00 *0.81*	4.05 *0.79*	
Engineering Perceived as Being an “Exact” Science	3.46 *0.80*	3.50 *0.91*	
Family Influences to Studying Engineering	2.38 *0.77*	2.33 *0.85*	
Confidence in Basic Engineering Knowledge and Skills	3.70 *0.58*	3.61 *0.75*	
Confidence in Communication and Computer Skills	3.49 *0.77*	3.39 *0.90*	< 0.002
Adequate Study Habits	2.75 *0.78*	2.58 *0.80*	< 0.002
Working in Groups	3.24 *0.74*	3.33 *0.75*	< 0.002
Problem Solving Abilities	3.87 *0.59*	3.83 *0.74*	
Engineering Attributes	3.61 *0.68*	3.63 *0.81*	

Students attending private schools rated their “Financial Influences for Studying Engineering” higher than did those at public institutions. This possibly indicates that students from private schools are pursuing engineering degrees for more extrinsic reasons. In addition, it was found that students attending private schools have a statistically greater “Perception of the Work Engineers Do and the Engineering Profession” compared to students at public schools, which suggests more intrinsic reasons for studying engineering. (However, the mean difference in the average rating for this attitude measure is relatively small.)

Interestingly, students attending private schools begin their engineering students with less confidence in their study habits ("Adequate Study Habits") and are less confident in their "Communication and Computer Skills" than are students at public schools. However, students from private institutions are no more influenced by their families to study engineering than are students attending public institutions. It was initially thought that parents, who are paying higher private school tuition, might feel stronger about their sons and daughters persisting in engineering.

Research Versus Teaching Institutions

Table 6 gives the averages and standard deviations (*in Italics*) for the pre-questionnaire attitudes and self-assessed measures for students at "research" and "teaching" institutions. The Mann-Whitney test revealed significant differences for six of the attitude measures.

Table 6. Differences Among Research and Teaching Institutions

Student Attitude and Self Assessment	**Research** *n = 4019*	**Teaching** *n = 2396*	**P-value**
General Impressions of Engineering	4.18 *0.54*	4.30 *0.51*	< 0.002
Financial Influences for Studying Engineering	3.51 *0.64*	3.61 *0.69*	< 0.002
Perception of How Engineers Contribute to Society	3.29 *0.79*	3.34 *0.82*	
Perception of the Work Engineers Do and the Engineering Profession	4.07 *0.55*	4.12 *0.63*	< 0.002
Enjoyment of Math and Science Courses	3.96 *0.82*	4.08 *0.78*	< 0.002
Engineering Perceived as Being an "Exact" Science	3.46 *0.81*	3.48 *0.85*	
Family Influences to Studying Engineering	2.39 *0.77*	2.34 *0.81*	
Confidence in Basic Engineering Knowledge and Skills	3.70 *0.60*	3.65 *0.67*	
Confidence in Communication and Computer Skills	3.50 *0.77*	3.41 *0.85*	< 0.002
Adequate Study Habits	2.76 *0.78*	2.65 *0.80*	< 0.002
Working in Groups	3.24 *0.74*	3.28 *0.75*	
Problem Solving Abilities	3.86 *0.60*	3.86 *0.66*	
Engineering Attributes	3.60 *0.68*	3.63 *0.75*	

Students attending "teaching" institutions had significantly higher "General Impressions of Engineering" and "Enjoyed Math and Science Courses" more than students who are attending a research I or II university. In addition, they had a higher "Perception of the Work Engineers Do and the Engineering Profession" compared to students at "research" institutions although the mean difference between the two ratings was relatively small (0.05).

Students who attend "teaching" institutions rated their "Financial Influences for Studying Engineering" higher than did students from research focused institutions. In addition, students attending "teaching" schools begin their engineering program with lower confidence in their study habits ("Adequate Study Habits") and are less confident in their "Communication and Computer Skills" compared to students at "research" schools. Note that four of the five private institutions in the cross-institutional studies are teaching focused; the other four "teaching" institutions are public, suggesting some intercorrelation.

Urban Versus Rural Institutions

Table 7 shows the averages and standard deviations (*in Italics*) for the pre-questionnaire attitudes and self-assessed measures for the differences between students who attend urban schools and those students who attend non-urban institutions.

Table 7. Differences Among Urban and Non-Urban Institutions

Student Attitude and Self Assessment	**Urban** *n = 2950*	**Non-Urban** *n = 3465*	**P-value**
General Impressions of Engineering	4.26 *0.52*	4.19 *0.54*	< 0.002
Financial Influences for Studying Engineering	3.57 *0.68*	3.53 *0.65*	
Perception of How Engineers Contribute to Society	3.32 *0.80*	3.30 *0.80*	
Perception of the Work Engineers Do and the Engineering Profession	4.13 *0.61*	4.06 *0.56*	< 0.002
Enjoyment of Math and Science Courses	3.97 *0.81*	4.04 *0.80*	< 0.002
Engineering Perceived as Being an "Exact" Science	3.46 *0.86*	3.47 *0.80*	
Family Influences to Studying Engineering	2.35 *0.81*	2.39 *0.77*	
Confidence in Basic Engineering Knowledge and Skills	3.69 *0.65*	3.68 *0.60*	
Confidence in Communication and Computer Skills	3.50 *0.83*	3.44 *0.78*	< 0.002
Adequate Study Habits	2.66 *0.78*	2.76 *0.80*	< 0.002
Working in Groups	3.28 *0.75*	3.23 *0.73*	< 0.002
Problem Solving Abilities	3.85 *0.65*	3.87 *0.60*	
Engineering Attributes	3.64 *0.71*	3.60 *0.71*	

We did not expect to find significant difference related to the environmental setting of the institution. However results indicate that students at non-urban schools have significantly lower "General Impressions of Engineering," less positive "Perceptions of the Work Engineers Do and the Engineering Profession," lower ratings for their "Enjoyment of Math and Science Courses," less self-assessed "Confidence in Communication and Compute Skills" and lower ratings towards "Working in Groups." In contrast, they do have significantly higher confidence in their "Study Habits."

These findings are somewhat different than the results shown in Tables 5 and 6, although many of the urban versus non-urban significant differences are not large in magnitude (≤ 0.07 in most cases). Note that both the public (2470 and 2980 students respectively) and private (770 and 745 students respectively) institutions are proportionally split between urban and non-urban settings. There are five urban "research" schools and four non-urban "research" with 2520 and 2350 students, respectively. Further four of the "teaching" schools are urban and five are non-urban (720 and 1375 students, respectively). This seems to suggest that the two public, "teaching," non-urban institutions are influencing the results to some extent, but further investigation with other factors, such as selectivity of the institution or curriculum focus, is necessary before reaching definitive conclusions.

Conclusions and Future Work

Several significant differences were found in students' attitudes as they relate to the type of institution that they attend. There appear to be consistent differences in how entering students assess their attitudes at private, teaching-focused, small or urban institutions. These attitude measures include: "General Impressions of Engineering," "Perception of the Work Engineers Do and the Engineering Profession," "Enjoyment of Math and Science Courses," "Financial Influences for Studying Engineering," as well as students' self-assessed "Confidence in Communication and Computer Skills" and "Adequacy in One's Study Habits." Given these results, students who choose to attend private or teaching-focused institutions tend to like engineering more and have a higher perception of the engineering profession than do students who attend public or research oriented schools. However, these same students also may have lower self-assessed confidence in their communication and computer skills and their study habits. Interestingly, in previous studies that looked at differences in gender and ethnicity, we consistently found that female and minority engineering students tended to have lower self "Confidence in their Basic Engineering Knowledge and Skills" and in their "Problem Solving Abilities." There were no such differences exhibited in analyzing variables related to the type of school a student attends. In a forthcoming paper we will discuss differences between institutional type and different student groups. How these attitudes potentially relate to the students' academic background, performance in the freshman year, and retention in the program also will be analyzed.

The study described here is an initial beginning to an extensive in-depth analysis to determine those critical student characteristics and attitudes, and those institutional factors (including type, curriculum, and pedagogy) that are related to student performance and retention in engineering. The analyses presented here provide a new perspective on what the characteristics are of our freshman engineering students, as measured by the choice of institution they attend and their attitudes. One finding is clear – students have different characteristics depending on their choice of an engineering school.

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