120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #7622

Comparing First-year Student Attitudes towards Engineering across a Liberal Arts University

Dr. Rick Olson, University of San Diego

Rick T. Olson is Associate Professor of Industrial and Systems Engineering at the University of San Diego. He teaches a broad range of classes at USD including first-year engineering, a core engineering statistics, and operations research and senior design to ISyE majors. His research interests lay in engineering student persistence, and applied operations research. He is active in outreach activities targeting underrepresented populations and has received NSF funding to support U.S. military veterans, community college transfer students, and innovative engineering math education. He has a B.S. in Mechanical Engineering, and M.S. in Industrial Engineering, and a Ph.D. in Mechanical Engineering with emphasis in Operations Research from the University of Illinois at Urbana-Champaign.

Dr. Truc T. Ngo, University of San Diego

Dr. Truc Ngo is an Assistant Professor of Industrial & Systems Engineering at the University of San Diego. Her research interests are in the areas of green materials and processes involving polymers and composites, organic semiconductors, and supercritical fluids. Dr. Ngo received her Bachelor's in 1997 and Doctor of Philosophy in 2001, both in Chemical Engineering from the Georgia Institute of Technology in Atlanta, Georgia. Before joining the University of San Diego, she had worked as a Senior Process Engineer at Intel Corporation in Hillsboro, Oregon and Santa Clara, California for nearly three years. She had also taught in the Engineering & Technologies Department at San Diego City College as an Associate Professor for five years, where she established the Manufacturing Engineering Technology program.

Dr. Susan M Lord, University of San Diego

Susan M. Lord received a B.S. from Cornell University and the M.S. and Ph.D. from Stanford University. She is currently Professor and Coordinator of Electrical Engineering at the University of San Diego. Her teaching and research interests include electronics, optoelectronics, materials science, first year engineering courses, feminist and liberative pedagogies, engineering student persistence, and student autonomy. Her research has been sponsored by the National Science Foundation (NSF). Dr. Lord is active in the engineering education community including serving as General Co-Chair of the 2006 Frontiers in Education (FIE) Conference, on the FIE Steering Committee, and as President of the IEEE Education Society for 2009-2010. She is an Associate Editor of the IEEE Transactions on Education. She and her coauthors were awarded the 2011 Wickenden Award for the best paper in the Journal of Engineering Education and the 2011 Best Paper Award for the IEEE Transactions on Education. In Spring 2012, Dr. Lord spent a sabbatical at Southeast University in Nanjing, China teaching and doing research.

Comparing First-Year Student Attitudes towards Engineering across a Liberal Arts University

Abstract

Many researchers have worked to identify how attitudes towards engineering affect a student's decision to pursue an engineering degree and persist in the program. High persistence has been found to be related to an entering student's general impression of engineering. Because most of these studies assessed only engineering students, their results may not be helpful in identifying why students choose to study engineering.

In this work, we investigate the attitudes of first time in college (FTIC) students in a variety of disciplines including engineering and non-engineering majors. During Fall 2012, 272 FTIC students completed a survey to explore their attitudes towards engineering. Factor analysis and regression analysis were used to identify which characteristics distinguish engineers from other students and which are shared among different groups. These results support prior work indicating that students who choose engineering have different attitudes towards technical topics than those who do not. This work also provides some evidence that attitudes of women to math and engineering are not different than those of men at our school. By better understanding the attitudes of students choosing different majors, engineering programs may be able to more effectively admit and recruit students.

Introduction

Finding effective ways to attract and retain engineering majors is of perennial interest to engineering schools and faculty throughout the U.S. Most of the academic research in these areas has focused on retention with the goal of identifying the characteristics that will help to predict whether a student will persist in engineering, change majors, or leave school. For example, students with strong analytical skills would be expected to be more successful than students with lesser skill. By identifying these factors that influence retention, strategies can be developed to make programs more effective and provide better support to at-risk students.

This work started with a different perspective. The University of San Diego (USD) is a liberal arts university, with a more homogeneous student population than many schools that offer engineering. The students are well-prepared academically. There are no barriers to entering engineering, and changing majors is comparatively easy. There are many students on our campus who we believe could be successful if they pursued an engineering degree. How can we attract more of those students to our classes? To begin to answer that question, a survey of entering first time in college (FTIC) students from across campus was conducted to assess their attitudes towards engineering. This paper presents the results of the initial effort to understand the survey results and identify the differences and commonalities among similarly qualified engineering and non-engineering students.

The next section includes a brief overview of the relevant literature that informs the current study. Then the salient characteristics of USD will be described. The process used to develop the survey instrument will be explored, and results of applying factor analysis to the survey responses will be shown. Regression results will be discussed, and opportunities for further study will be proposed.

Literature on Student Attitudes towards Engineering

Researchers have used academic measures, demographic information, and survey instruments, to try to develop an understanding of how students decide to major in engineering and the persistence of those students in engineering programs. Most commonly, statistical procedures were used to relate high school performance, standardized test scores, and demographic information to retention in engineering, or engineering GPA. For example, one study applied logistic regression to a database of more than 80,000 students to assess the impact of high school GPA, SAT scores, gender, ethnicity and citizenship affected graduation rates.[1] They concluded that GPA and SAT math (SAT-M) scores were universally significant predictors of performance, but that some other factors were also significant for some institutions. Classification trees and logistic regression were applied to academic and demographic data from a large, state university and high school and freshman year GPAs were important contributors to engineering persistence.[2] The use of classification trees provided further insight into how the important factors influence persistence. For example, rather than merely stating that high school GPA is significant, the trees could reveal whether there are critical GPA values that precipitate leaving, and whether the critical values are influenced by race/ethnicity or gender.

In an effort to reach beyond objective measures of student abilities, some research has assessed how student attitudes or motivations affect their pursuit of engineering degrees. Besterfield-Sacre et al.[3,4,5] developed the Pittsburgh Freshman Engineering Attitude Survey (PFEAS) to capture the attitudes of students towards engineering, and then used the results of the survey to explain persistence among their students. The 50-item Likert questionnaire was used to distinguish how a student felt about 13 factors influencing attitudes to engineering including academic confidence, career prospects, family influence, and the impact of the profession on society. Along with measures of high school academic performance, these attitudes were initially used to explain some of the differences among stayers, switchers, and leavers[3] and were combined with open-ended surveys and interviews to evaluate changes in programs at their university.[4] Finally, with data collected from 17 schools, differences in attitudes across gender and race were explored.[5] This work revealed that women generally conveyed less confidence in the basic engineering skills and abilities, and a lower perception of how engineers contribute to society than the men.

Other researchers have built on the foundation of the PFEAS. Hilpert et al. refined the PFEAS eventually developing PEAS-R, a 28 item survey that represents 7 factors.[6,7,8] Their work was limited to developing the survey instrument; they have not reported conclusions from its application. Burtner[9] applied discriminant analysis to PFEAS survey results to predict whether students would persist in engineering, change majors, or leave the university within three years of entering engineering. This work concluded that confidence in the ability to perform college-level math and science, and a belief that engineering degrees improve job security were important predictors of persistence. The 115 item Persistence in Engineering (PIE) survey was used in a longitudinal study of 8,000 students at 29 schools.[10] This instrument assesses more than 20 factors related to student attitudes to engineering including their motivation to study engineering, confidence in their abilities, and parental or other personal influences. This work concluded that confidence in math and science and influences from parents and high school mentors were important contributors to persistence.

Although most studies focused on engineering students, some considered a broader population. Veenstra et al.[11] surveyed entering freshmen and identified nine “success pillars” comprising 19 factors in areas related to high school academic performance, objective and subjective assessment of analytical skills, study habits, social engagement, and commitment to educational goals. Factor analysis and regression were used to compare engineering students to pre-Med students, other science, technology and math majors and non-Science, Technology, Engineering, and Math (STEM) majors. They concluded that high school rank and GPA were important predictors of first year GPA in all fields. Otherwise, success in each discipline was driven by different factors. For engineering, scores on quantitative standard tests, and confidence in math skills engineering were most important.

Factor analysis has been used to compare the attitudes of engineering and non-engineering students by Li et al.[12] A 25-question assessment instrument was developed, and 19 of the questions were used to identify four factors: the appeal of engineering, the effort needed to succeed in engineering, the rewards associated with an engineering degree, and the societal impact of engineering. The study concluded that most college students thought that it took significant effort to get an engineering degree. Engineering majors were more likely to find engineering appealing, but non-engineers perceive the rewards from the degree to be greater than the engineers do. Both groups thought that engineers provided value to society, but the engineers had a significantly higher assessment of the value.

Overall, these studies show that many factors influence the success of engineering students including success in high school, high scores on standardized tests, and confidence in math and science. They also show that the attitudes of students can help explain student persistence in some settings. In this work, the focus is on the attitudes of FTIC students, including engineers and non-engineers, and how those attitudes may reflect the choice of major.

Engineering Students at the University of San Diego

At many universities, students apply to a specific major, and the admission criteria may change with the major. Furthermore, enrollments in some majors may be capped. In these cases, high school performance, or SAT or ACT scores are often used to determine which students are admitted. Where engineering programs have restricted admissions, this can mean that students with high grades and test scores, but modest aspirations to become engineers may be admitted over highly motivated students with lesser academic credentials. While the characteristics of students in the differing programs can be compared, the differences that are identified will partially reflect the admissions practices, and not just the performance or attitudes of students who are interested in engineering. USD provides a unique population of students from which to make comparisons because of several characteristics of our students and university policies.

USD is a private, faith-based, national liberal arts university. Students applying for admission do not apply to specific majors, and there are no enrollment caps on any major; any new student can pursue any major. Students are not required to declare a major until the end of the sophomore year. Consequently, students with a keen interest in engineering can pursue it even if their high school preparation may not have qualified them for engineering at another university. At the same time, it is common for people who may be only curious about engineering to enroll in engineering classes knowing that they will be able to change to another field if they decide that engineering does not meet their needs. In Fall 2012, 84 of 1102 FTIC students chose engineering.

All engineering students must complete the same 60-unit core curriculum required of students in the College of Arts and Sciences and School of Business Administration. The engineering programs require 4.5 years to complete and students receive a dual B.S./B.A. in their engineering field. Because of the core requirements, it is believed that USD tends to attract fewer engineering students who have narrow, technical interests, and more students who are interested in a broad, liberal arts education. Thus, the attitudes of these engineering students may not reflect those of students at large public universities, or institutions with an emphasis on engineering or science.

Table 1 summarizes the academic preparation of the Fall 2012 entering first year students at USD. Although the average SAT-M score of the engineering students is higher than that of the non-engineers, the critical reading scores (SAT-CR) and high school grade point average (HSGPA) are similar.

Table 1. Summary of Academic Preparation of Fall 2012 First Year Students

	# of Students	Average SAT-CR	Average SAT-M	Average HSGPA
Non-Engineering	990	601	611	3.86
Engineering	84	593	664	3.94

An important feature of the first-year experience at USD is the *Preceptorial* program. Every fall, a broad selection of classes are identified as preceptorial classes that can only be taken by entering students. These classes have an average enrollment of approximately 16 students and are taught by tenure-track faculty who serve as the students' academic advisor until the students declare a major. The small classes and early interaction with faculty are designed to build strong connections that will help ensure students integrate into the university and receive appropriate academic advising.

Because students do not declare majors when they apply for admission, every entering student completes an advising questionnaire. This questionnaire asks students to identify three majors they are interested in pursuing. It also asks for preference for preceptorial classes and rankings of other core classes. The questionnaires are used by faculty to create student schedules. All students expressing any interest in engineering are scheduled by an engineering faculty member to take an engineering preceptorial class. This is done even if engineering is listed as a student's third preference because demands of the engineering major necessitate having an engineering advisor. Most students of all majors enroll in a preceptorial class in an area of interest, but occasionally schedule conflicts may result in a different preceptorial. For example, although everyone interested in a science, math, or computer science (SMCS) major will be placed in appropriate SMCS classes, their preceptorial class may satisfy a general core requirement such as English, logic, or history.

Because of the homogeneity of the student population, admission practices, and the processes used to create initial schedules, students who are not taking engineering classes do not want to take them. In this work, enrollment in a preceptorial section was used as a proxy for a student's academic interest. Thus, attitudes to engineering students in different preceptorial sections can be used to gain insight into how those attitudes related to their academic interests.

Methodology

To determine how attitudes towards engineering varied among students in different preceptorial classes, students were asked to complete a questionnaire similar to the PFEAS survey. Because the PFEAS, or PEAS-R include many items that assume the participant is an engineer (e.g. "My parents were very influential in my decision to pursue engineering"[13]), it was necessary to adapt the original questions to this study, rewording as appropriate. Furthermore, some items (e.g. "I am confident that I could do well in college math classes.") ask students to assess their own abilities, while other items (e.g. "Engineers are creative.") ask about their opinions about the engineering profession. The survey used included 20 Likert-style questions that were intended to address nine of the factors considered by PFEAS or PEAS-R. It has been included as an appendix. The survey was approved by USD's Institutional Review Board.

During Fall 2012, USD was phasing in new *Living-Learning Communities* (LLCs) for half of the incoming first-year class. Each LLC comprises several different preceptorial classes organized around a common academic theme. Students in an LLC live in the same dorms and the faculty work together. Three of the five sections of the first engineering class participated in the LLC program. Because of this transition to LLCs, university administrators were conducting an unusually high number of surveys of incoming students during Summer 2012, and it was determined that the engineering attitude survey could not be distributed to all students to reduce "survey fatigue". Instead, the survey was distributed to approximately 40% of the entering class of 1074 students. All students enrolled in all five sections of the first engineering course received the survey, as did students in all of the preceptorial classes that were in LLCs affiliated with engineering classes. All students enrolled in the university's honors program were also included. Several other preceptorial sections were identified to receive the survey to reach a representative pool of students across the university.

Participation in the survey was voluntary. To increase participation, a paper survey was used, and the survey was administered by the course instructors who encouraged students to participate. Most instructors had students complete the survey during introductory meetings that took place before classes started, or on the first day of class. A few instructors allowed students to complete the survey outside of class, and then return the paper. Students who participated in the survey were enrolled in a drawing for $10 gift cards.

The survey was offered to 443 students and 272 useable responses were returned. Anecdotal feedback has indicated that 20-25% of the students did not complete the survey because they were not yet 18 years old. Table 2 summarizes the distribution of responses receivedSMCS includes all STEM disciplines except engineering. Compared to the distribution of declared majors at the university, engineering and humanities were overrepresented in the population and the social sciences were underrepresented. Business majors are not clearly defined in this table. Although approximately 40% of all degrees are awarded in the School of Business Administration, the only related course taken during the first semester is microeconomics. Two sections of that course participated in the survey and are included in the Social Science classification. High School GPA and SAT scores for respondents were obtained from university administration and used in analysis.

Table 2. Distribution of Completed Survey Responses

	Engineering	Fine Arts	Humanities	Social Science	SMCS	Total
Male	39	5	29	28	20	121
Female	14	12	43	53	29	151
Total	53	17	72	81	49	272

Factor Analysis

Before using the survey results to make inferences about student attitudes, exploratory factor analysis was used to validate the survey, and consolidate questions into factors that represent different dimensions of attitudes towards engineering. Analysis was performed using base R[14] along with packages car[15], nFactors[16], and psych[17]. To find the final collection of factors, many combinations were tested. The following general guidelines (derived from Field[18], Stevens[19], Thompson[20], and common practices) were used to assess each solution:

- To avoid multicolinearity, the R-values of the correlation matrix for the question responses should be less than 0.9 and the determinant should be < 0.00001.
- To confirm sampling adequacy, the overall Kaiser-Meyer-Olin (KMO) coefficient should be > 0.7, and most individual KMO values should be > 0.5.
- The number of factors to extract was guided by the results of a scree plot, the Kaiser criterion, and parallel analysis. In many cases, one factor more or fewer than the recommendations were considered.
- Principle axis factoring was used because the responses were not assumed to be normally distributed, and oblimin rotation was used because the resulting factors were expected to be correlated.
- Factors having loadings > 0.4 were retained.
- Communalities should be > 0.5.
- Factor correlations should be < 0.7.
- If all the preceding criteria were satisfied, Cronbach's alpha was calculated for each factor to assess internal consistency.
- Factor scores were calculated using multiple regression to maximize the validity of the estimates. [21]

The initial solution using all 30 questions proposed nine factors, but four of the questions were not used in any factor, the average communality was 0.49, and some of the factor grouping combined questions in non-intuitive ways. To develop a better solution, a stepwise series of analyses was conducted. The *iclust*[17] cluster analysis procedure was used to identify which questions appeared to be related and the resulting tree was used to identify an initial 5 factor solution that used 14 questions. Then the cluster results were used to add or remove groups of questions. The appropriateness of the solution was evaluated at each iteration. The final model uses 16 questions to form five factors and is summarized in Table 3. *Questions Used in Factor* refers to the number of the question in the survey presented in the Appendix.

Table 3. Summary of Final Factor Model

Factor	Attitude Measured	Questions Used in Factor	Average Communality	Cronbach Alpha
APP	Subject's mechanical, technical and computer aptitude	6, 8, 14	0.56	0.74
CREATE	Subject's perception of the creativity of engineers	2, 5, 15	0.35	0.58
PROB	Subject's affinity for working on open-ended problems.	18, 23, 27	0.46	0.70
SOC	Subject's perception of engineering contributions to society.	1, 21, 22	0.53	0.72
STEM	Subject's confidence and enjoyment of STEM subjects	11, 12, 25, 28	0.64	0.85

The magnitude of all factor loadings are between 0.44 and 0.92 and each question is associated with only one factor. Some communalities are smaller than preferred, but are consistent with values reported by other researchers.[7,12] Factor correlations range from 0.07 to 0.36 indicating modest correlation between factors and supporting the use of oblimin rotation. The alpha values are lower than generally recommended. This might indicate that the questions within a factor are not measuring the same concept, but low values of alpha can also be seen when a small number of questions is used and the internal validity is acceptable.[22]

Several of the attitudes identified by other researchers did not appear in this result. The cluster and factor analyses grouped questions related to parental/mentor influence, career opportunities, financial considerations, and the personal rewards of engineering into appropriate groupings. However, in our study, unlike some previous work, the statistical validity of these groupings were inadequate for inclusion in the final model.

Analysis of Student Attitudes

As a first step in understanding attitudes, the means of the responses corresponding to each factor were calculated after reverse coding the answers where needed. These results are summarized in Table 4. Because the averages did not account for the relative importance of different questions, or correlation between responses, they cannot be used in statistical analyses, but they do show general trends. A 5-level Likert scale was used in the survey where a five indicated strong agreement. Overall, these results show that students across all disciplines agree that engineers are creative (CREATE) and contribute to solving societal problems (SOC), although the engineers rated those areas more highly. Consistent with other studies, engineers appeared to feel more confident about their technical aptitude (APP) and STEM capabilities, although most men had positive attitudes in those areas, and SMCS women had positive feelings about science and math. Only women in liberal arts disciplines had low assessments of their abilities in technical areas. Interestingly, all groups of students showed a positive attitude to solving open-ended problems (PROB).

Table 4. Summary of Average Survey Responses to Survey Questions Related to Each Factor

Preceptorial Discipline	Factor					Overall Average
	APP	CREATE	PROB	SOC	STEM	
ENGR	3.89	4.20	4.20	4.42	4.04	4.15
Men	3.97	4.22	4.27	4.39	3.99	4.17
Women	3.64	4.14	4.00	4.50	4.18	4.09
Fine Arts	3.04	4.02	3.25	3.98	2.82	3.42
Men	3.40	3.73	3.47	3.93	2.65	3.44
Women	2.89	4.14	3.17	4.00	2.90	3.42
Humanities	3.00	4.02	3.64	3.98	2.95	3.52
Men	3.39	3.86	3.78	3.91	3.03	3.59
Women	2.74	4.12	3.55	4.02	2.90	3.47
Soc. Science	2.89	3.97	3.39	3.88	2.59	3.34
Men	3.18	3.88	3.77	3.88	3.08	3.56
Women	2.74	4.01	3.19	3.89	2.33	3.23
SMCS	3.06	4.10	3.61	4.14	3.59	3.70
Men	3.37	4.10	3.80	4.35	3.41	3.81
Women	2.85	4.09	3.47	4.00	3.72	3.63
Overall Average	3.15	4.05	3.65	4.07	3.16	3.62

Table 4 also shows that some of the patterns observed by other researchers were not repeated in this study. In particular, women studying engineering and SMCS expressed higher agreement or more positive attitudes towards STEM than the men, although their reported aptitudes appeared lower. In addition, the women's perception of engineering's role in society was different here where women in some groups reported a slightly higher perception of engineering. This will be explored more precisely using factor scores rather than the survey responses in the next paragraph. The results also suggest that there might be some small differences in attitudes towards engineering across the liberal arts disciplines. Because of the small sample size from fine arts, and because business majors are likely to be found in any non-STEM discipline, fine arts, humanities, and social science have been merged into a *Liberal Arts* discipline for subsequent analysis.

Multiple linear regression was used to determine whether there were any statistically significant differences between the disciplines and genders.[23] Instead of the survey responses, the factor scores for each student and factors derived during the factor analysis were used as the measures of each student's attitude. These factor scores considered correlations between questions and the relative importance of each question in representing a factor. Factor scores were also scaled so that the mean was zero. Consequently, a negative factor score means that a response was lower than average, and not necessarily that the student had a negative perception of the factor. The standard deviations of the factor scores ranged from 0.81 for CREATE to 0.95 for STEM.

In addition to using gender and preceptorial discipline as predictors, HSGPA and SAT scores have also been used because of their potential for explaining student confidence in STEM areas. Because the response variable (factor score) was being treated as a function of both categorical variables (gender and discipline) and continuous (HSGPA and SAT score), analysis of variance (ANOVA) and analysis of covariance (ANCOVA) were both used. To validate their use, the correlation of the continuous variables was tested. The correlation between SAT-M and SAT-CR was found to be high (R=0.494), so SAT-CR was omitted to avoid multicolinearity. Levene's test for homogeneity of variances of factor responses was performed with gender and discipline as grouping variables.[15] The tests passed for APP, CREATE and SOC, but failed at the α=0.05 level for PROB and STEM with p-values of 0.0484 and 0.0314 respectively. Because Levene's test is sensitive to Type-I error as the sample size increases, and ANOVA procedures are robust, these results were accepted.[19]

Stepwise linear regression was performed to find the best fit of each factor score as a function of the predictor variables and their interactions. The *lm* procedure was used to fit each model; ANOVA tables were used to identify the significant variables. Every factor score could be fit using a simple linear model with no interaction terms of the form:

$$Factor\,Score = \beta_0 + \beta_1 LiberalArts + \beta_2 SMCS + \beta_3 Female + \beta_4 SAT\text{-}M$$

where β_0 is the average response of men in engineering preceptorial classes, *LiberalArts* and *SMCS* are binary variables that equal 1 if a student is in the corresponding preceptorial discipline, *Female* equals one for women, and *SAT-M* is a student's raw SAT-Math score. $\beta_{1...}\beta_4$ are the corresponding regression coefficients. The statistically significant ($p < 0.05$) coefficients are summarized in Table 5. All other coefficients may be considered to be 0 with the exception of the β_0 coefficient for PROB which is required by the model.

Table 5. Coefficients of Regressions Model for Predicting Factor Scores

	APP	CREATE	PROB	SOC	STEM
ENGR Men=β_0	0.96***	0.20*	-0.79	0.55***	-1.18*
Liberal Arts	-0.88***	-0.32**	-0.56***	-0.76***	-0.88***
SMCS	-0.77***		-0.42*	-0.42*	
Women	-0.49***		-0.47***		
SAT-M			0.0024**		0.0030***

Coefficient significance: *$p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

The regression coefficients provide insight into the attitudes of students. Compared to male engineers, women engineers had lower attitude scores for APP (mechanical, technical, and computer aptitude) and PROB (open-ended problems), but the scores were similar for CREATE (creativity of engineers), SOC (engineering contributions to society), and STEM (confidence and enjoyment of STEM). This is a different result than what has been reported previously in the literature, which could reflect the demographics of this student population including the perspectives of students who might be attracted to USD because of the strong liberal arts component required of all engineers. Table 4 shows that women engineers had higher average responses to SOC and STEM survey questions than the men did, but Table 5 reflects the correlation between similar questions and weights the responses according to their contribution to the factor that is estimated, so Table 5 is a more appropriate indicator of the differences between students.

Other general trends do appear from the regression results. The β*'s* for *Liberal Arts* and *SMCS* reflect changes in attitude compared to engineers, so negative β*'s* indicate that non-engineers generally had lower attitude scores than engineers. Similarly, SMCS students were more similar to engineers than liberal arts students were.

Conclusion

A unique contribution of this work is that it considers both engineering and non-engineering students at a university where all students can pursue any major. Consequently, a non-engineering student does not represent someone who may have wanted to pursue engineering, but whose preference was blocked by impacted enrollments. All students expressing an interest for engineering in the pre-enrollment course preference survey were enrolled in engineering. This makes it easier to distinguish the attitudes of students having different interests. Student respondents to our survey included those enrolled in the first engineering course as well as those in courses outside of engineering including Fine Arts, Humanities, Social Sciences, Math, Science, and Computer Science. Overall, the academic qualifications of the participants were similar with the only difference being that those who choose engineering tend to have higher SAT-M scores.

Factor analysis and regression analysis were used to identify which characteristics distinguish engineers from other students. The final factor model included five factors: APP (mechanical, technical, and computer aptitude), PROB (open-ended problems), CREATE (creativity of engineers), SOC (engineering contributions to society), and STEM (confidence and enjoyment of STEM activities). Student respondents in all disciplines agreed that engineers are creative and contribute to solving societal problems. Consistent with prior research, students who chose engineering tended to have more positive feelings about their technical aptitude and STEM capabilities. The results also provide some evidence that attitudes of women toward math and engineering are not different from those of men at our private, liberal arts-oriented school. The only differences between men and women engineers were seen in APP and PROB but not SOC or STEM as have been reported in other studies. Men in all disciplines rated themselves higher in APP and PROB than women suggesting that gender socialization might be a more important factor than discipline in these cases. Student respondents in all disciplines showed a positive attitude to solving open-ended problems; this did not differentiate engineering. As expected, engineers' attitudes were most similar to those of students in math, science, and computer science.

Overall, the most significant differences seen in our study were that students who chose engineering were more confident in their technical aptitude and ability to succeed in STEM. Thus, although it is not possible to conclude whether high confidence causes students to pursue engineering, or whether low confidence causes students to avoid engineering, these results suggest that improving student confidence in their ability to apply math and science to engineering problems may result in more engineering students. Of course, these attitudes begin to form before students enter college and are likely to be influenced by their experiences in math and science curricula throughout their K-12 experience.

Because this study was not designed to identify causal relationships between attitudes and enrollment, it is difficult to use the results of this limited survey to draw conclusions about what practices will increase engineering enrollments across all types of students. Still, the results provide insights that may help to identify effective practices or guide future research. For example, the observation that the attitudes of SMCS students are sometimes between those of the engineers and the other majors suggests a closer examination of SMCS students to determine whether students in different SMCS majors have different attitudes towards engineering. It may also be valuable to look more closely at whether the difference in attitudes towards the creativity and social contribution of engineering directly affect a student's decision to pursue an engineering career.

Acknowledgements

The authors gratefully acknowledge the assistance of the 28 USD preceptorial professors who administered the survey in their classes. This work was supported in part by the National Science Foundation (NSF), award DUE-0817332: National Model for Engineering Mathematics Education. The opinions expressed in this article are those of the authors and do not necessarily reflect the views of the NSF.

References

1. Zhang, G. L., Anderson, T. J., Ohland, M. W. & Thorndyke, B. R. Identifying factors influencing engineering student graduation: A longitudinal and cross-institutional study. *Journal of Engineering Education* **93**, 313–320 (2004).
2. Mendez, G., Buskirk, T. D., Lohr, S. & Haag, S. Factors Associated With Persistence in Science and Engineering Majors: An Exploratory Study Using Classification Trees and Random Forests. *Journal of Engineering Education* **97**, 57–70 (2008).
3. Besterfield-Sacre, M., Altman, C. J. & Shuman, L. J. Characteristics of Freshman Engineering Students: Models for Determining Student Attrition in Engineering. *Journal of Engineering Education* **86**, 139–149 (1997).
4. Besterfield-Sacre, M., Altman, C. J. & Shuman, L. Engineering Student Attitudes Assessment. *Journal of Engineering Education* **87**, 133–141 (1998).
5. Besterfield-Sacre, M., Shuman, L. J. & Wolfe, H. Modeling undergraduate engineering outcomes. *International Journal of Engineering Education* **18**, 128–139 (2002).
6. Hilpert, J., Stump, G., Husman, J. & Kim, W. An Exploratory Factor Analysis of the Pittsburgh Freshman Engineering Attitudes Survey. in *Frontiers in Education Conference, 2008. FIE 2008. 38th Annual* F2B–9 (2008).
7. Hilpert, J. *et al.* Steps toward a sound measure of engineering student attitudes: Pittsburgh engineering attitudes scale-revised. in *Frontiers in Education Conference, 2009. FIE'09. 39th IEEE* 1–6 (2009).
8. Hilpert, J. C., Stump, G. & Husman, J. Pittsburgh engineering attitudes scale—Revised: Evidence for an improved instrument. in *Frontiers in Education Conference (FIE), 2010 IEEE* T2G–1 (2010).
9. Burtner, J. The use of discriminant analysis to investigate the influence of non-cognitive factors on engineering school persistence. *Journal of Engineering Education* **94**, 335–338 (2005).
10. Eris, O. *et al.* Outcomes of a Longitudinal Administration of the Persistence in Engineering Survey. *Journal of Engineering Education* **99**, 371 (2010).
11. Veenstra, C. P., Dey, E. L. & Herrin, G. D. Is Modeling of Freshman Engineering Success Different from Modeling of Non-Engineering Success? *Journal of Engineering Education* **97**, 467–479 (2008).
12. Li, Q., Swaminathan, H. & Tang, J. Development of a Classification System for Engineering Student Characteristics Affecting College Enrollment and Retention. *Journal of Engineering Education* **98**, 361–376 (2009).

13. Hilpert, J. C., Stump, G. & Husman, J. *A Brief Manual for the use of the Pittsburgh Engineering Attitudes Scale – Revised*. 1–6 (Arizona State University, 2010).
14. R Core Team *R: A language and environment for statistical computing. R Foundation for Statistical Computing*. (2012). at <http://www.R-project.org/>
15. Fox, J. *An R companion to applied regression*. (SAGE Publications, 2011).
16. Raiche, G. *nFactors: an R package for parallel analysis and non graphical solutions to the Cattell scree test. R package version 2.3.3*. (2010). at <http://CRAN.R-project.org/package=nFactors>
17. Revelle, W. psych: Procedures for Psychological, Psychometric, and Personality Research. (2012). at <http://personality-project.org/r/psych.manual.pdf>
18. Field, A. P. *Discovering statistics using SPSS*. (SAGE Publications, 2005).
19. Stevens, J. *Applied multivariate statistics for the social sciences*. (Lawrence Erlbaum Associates, 2002).
20. Thompson, B. *Exploratory and confirmatory factor analysis: understanding concepts and applications*. (American Psychological Association, 2004).
21. DiStefano, C., Zhu, M. & Mindrila, D. Understanding and Using Factor Scores: Condiserations for the Applied Researcher. *Practical Assessment, Research & Evaluation* **14**, 1–11 (2009).
22. Tavakol, M. & Dennick, R. Making sense of Cronbach's alpha. *International Journal of Medical Education* **2**, 53–55 (2011).
23. Crawley, M. J. *Statistics: an introduction using R*. (J. Wiley, 2005).

Appendix

The attitude survey used in this study is shown below. The response headings have been modified to fit on this page. The headings *SD/D/N/A/SA* appeared as *Strongly Disagree*, *Disagree*, *Neutral*, *Agree* and *Strongly Agree* in the survey completed by the students.

Freshman Attitudes to Engineering

This survey has been design to elicit the opinions and feelings about engineering held by first-year college students. Your responses will be held confidential and will be aggregated with those of other students. Individual responses will not be published or shared with course instructors.

For each statement, **circle the number** that corresponds to how strongly **you personally** disagree or agree with the statement. If you change your answer, please make your final choice clear.

	SD	**D**	**N**	**A**	**SA**
1. Engineers play an important role in improving the welfare of society.	1	2	3	4	5
2. Engineers are creative.	1	2	3	4	5
3. People with engineering degrees will have no problem finding a job.	1	2	3	4	5
4. From what I know, engineering is boring.	1	2	3	4	5
5. Engineers are innovative.	1	2	3	4	5
6. I consider myself mechanically inclined.	1	2	3	4	5
7. I have a family member, neighbor, or close friend who is an engineer.	1	2	3	4	5
8. I consider myself technically inclined.	1	2	3	4	5
9. Engineering is an occupation that is respected by other people.	1	2	3	4	5
10. My parent(s) want me to be an engineer.	1	2	3	4	5
11. I am confident that I could do well in college math classes.	1	2	3	4	5
12. I am confident that I could do well in college chemistry and physics classes.	1	2	3	4	5
13. I am confident of my speaking and writing skills.	1	2	3	4	5
14. I am confident of my computer skills.	1	2	3	4	5
15. Most people think that engineers are not imaginative.	1	2	3	4	5
16. The future benefits of studying engineering are worth the effort.	1	2	3	4	5
17. I feel I know what an engineer does.	1	2	3	4	5
18. I enjoy problems that can be solved in different ways.	1	2	3	4	5
19. My parent(s) were very influential in my choice of a career.	1	2	3	4	5
20. I can think of several other majors that would be more rewarding than engineering.	1	2	3	4	5
21. Engineers contribute greatly to fixing problems in the world.	1	2	3	4	5
22. Most people think that engineers contribute to making the world a better place.	1	2	3	4	5
23. I enjoy solving open-ended problems.	1	2	3	4	5
24. Financial success is one of the main reasons someone would study engineering.	1	2	3	4	5
25. I enjoy the subjects of science and mathematics the most.	1	2	3	4	5
26. Engineers are well paid.	1	2	3	4	5
27. I have strong problem solving skills.	1	2	3	4	5
28. I enjoy taking liberal arts courses more than math and science courses.	1	2	3	4	5
29. In general, I would expect engineering to be an enjoyable career.	1	2	3	4	5
30. Creative thinking is one of my strengths.	1	2	3	4	5

The questions on this survey were derived from:
Pittsburgh Freshman Engineering Survey © University of Pittsburgh
Pittsburgh Engineering Attitudes Scale - Revised © Arizona State University