A Comparison of Demographic Factors and Academic Performances between Students Graduated in Engineering and Other Disciplines

Guili Zhang, Brian Thorndyke, Rufus Carter, Matthew Ohland, and Tim Anderson

Educational Psychology Department, University of Florida / Department of Physics, University of Florida / Educational Psychology Department, University of Florida / Department of General Engineering, Clemson University / Department of Chemical Engineering, University of Florida

Abstract

In this study, demographics and academic performance measures of undergraduate engineering students were compared with science and non-science majors. This study crossed 9 institutions, spanned 13 years, and examined the pre-factors gender, citizenship, high school GPA, SAT math and verbal scores, as well as several indicators of success in college such as time to graduation, cumulative GPA, number of major changes, semesters to graduation, cumulative semester hours, and average hours/semester. Using multivariate statistical methods, we determined that engineering majors differed significantly from science and non-science majors on several variables.

I. Introduction

It seems intuitive that undergraduate engineering students, by virtue of admission and course requirements, should rank particularly high in mathematical and analytical skills when compared with the non-science majors. It also stands to reason that higher demands of the engineering curriculum might negatively impact certain measures of academic performance like GPA and time to graduation. These contentions have generally been supported by various quantitative studies [1,2]. It is not clear, however, how engineers compare to non-engineers with regard to factors such as demographic background. Furthermore, to our knowledge, no studies have yet investigated these differences across two or more institutions, thus limiting findings to institution-dependent conclusions.

Several schools have tabulated pre-entrance academic data on arriving freshman. For example, the University of Massachusetts (Amherst) reported their admission variables by major area [1]. The results from their 1998-2000 Factbook indicate that engineers had the highest SAT math score, as well as the second highest SAT verbal score, among all majors. In addition, engineers entered with an average high school GPA higher than all other majors, although the natural sciences and mathematics trailed closely.

One of the most significant longitudinal studies comparing the performance of students throughout the course of their studies has been the work of Astin [2], which suggested that engineering has a negative impact on a variety of factors, including persistence, graduation, time to graduation, and grade point averages. While the study provided supplemental information gathered from survey data, its statistical power was limited because only a sample of the student population was studied.

In previous work [3,4], we performed cross-institutional studies to determine the effects of various factors on graduation and retention of engineering undergraduates. Our results demonstrated that SAT math scores, SAT verbal scores, high school GPA, gender, ethnicity and citizenship all play a significant role in both graduation and retention rates. Given that these have been shown to be important to success in engineering, it is interesting to see how engineering students compare to other groups. In particular, we chose to examine 1) science majors (but not in engineering), and 2) non-science majors, and compare these groups to the engineering majors. As in previous work, our investigation spanned 9 institutions and tens of thousands of undergraduate students enrolled over a 13-year period, supporting the generalizability of our results.

II. Data Collection

Our study uses the Southeastern University and College Coalition for Engineering Education (SUCCEED) longitudinal database (LDB). The LDB contains data from eight colleges of engineering involving nine universities: Clemson University, Florida A&M University, Florida State University, Georgia Institute of Technology, North Carolina A&T State University, North Carolina State University, University of Florida, University of North Carolina at Charlotte and Virginia Polytechnic Institute and State University. The data from all nine universities have been placed in a common format, making it possible to carry out appropriate cross-institutional studies. More extensive descriptions of the SUCCEED LDB can be found elsewhere [5,6,7]. The SUCCEED LDB is a unique resource that has been and continues to be studied [3-13].

SUCCEED is an ongoing project, and the LDB continues to be updated as data becomes available. As of the current study, the LDB contained demographic, entry, term and graduation records of all undergraduate students in these institutes from 1987 through 1998 (and for some institutions, through 2000). According to the Engineering Workforce Commission of the American Association of Engineering Societies, SUCCEED schools enroll over 28,000 engineering undergraduates and award 1/12 of all U.S. engineering degrees, a higher percentage of all U.S. engineering degrees awarded to women (1/10), and a very significant portion (1/4) of the U.S. engineering degrees awarded to blacks; this sample size helps ensure that the results can be applied to other institutions in the country's engineering education system [14,15]. While the LDB contains data on both transfer students as well as first-time-in-college (FTIC) students, we limited the study to FTIC students only.

Among the demographic information available, we focused on gender and citizenship. Students were placed in one of three citizenship categories: citizens, resident aliens, and non-citizens. This information was available for virtually every student record. The demographic comparisons were done for all students enrolled as freshmen in 1987 or later, and graduated by the last term in the LDB.

Entry records provided us with baseline academic data such as student SAT scores (both math and verbal) and high school GPAs. While generally complete, one university lacked high school GPAs, while two others lacked both SAT scores and high school GPAs. These institutions were not included in the analysis on their missing variable(s).

Finally, term and graduation data permit us to examine performance indicators such as the number of times a student changed major, average semester hours, cumulative semester hours, number of semesters enrolled, time to graduation, and final cumulative GPA. This information was complete for all institutions and virtually every student record.

III. Results

In the first analysis, we provide a summary of demographic differences between engineering students, science majors and non-science majors. In the second analysis, we go further to determine significant differences in academic entry and performance measures among these groups.

Demographic Differences

In all our demographic and performance comparisons, we divided the graduated students among those in engineering (ENG), those in science fields (SCI) and those in non-science disciplines (NSCI). Differences in gender and citizenship are presented in Table 1 and Table 2. While ENG, SCI and NSCI groups showed very similar patterns for citizenship, they had strikingly different male/female ratios.

1) Gender. The percentage of females in ENG was substantially lower than the percentage of males (Female: 21.89% vs. Male: 78.11%). The difference was much less marked in SCI, but reversed in NCSI. It is additionally observed that the percentage of female students in ENG is about half that in SCI and one third that in NSCI. The actual percentages varied substantially between schools, but the trends were consistent.

2) Citizenship. Citizens represented, by far, the majority of students (> 95%), followed by non-citizens (< 3.5%) and then resident aliens (< 1.5%). Interestingly, the percentage of both non-citizens and resident aliens combined was highest in ENG, slightly above SCI but almost double the percentage in NCSI.

Table 1: Difference in gender among ENG, SCI and NSCI undergraduates.

GROUP / GENDER	ENG (%)	SCI (%)	NSCI (%)
Female	21.89	44.88	57.30
Male	78.11	55.12	42.70

Table 2: Difference in citizenship among ENG, SCI and NSCI undergraduates.

GROUP / CLASS	ENG (%)	SCI (%)	NSCI (%)
Citizen	95.34	96.07	97.64
Resident Alien	1.35	0.69	0.18
Non-Citizen	3.31	3.24	2.18

Academic Differences

We investigated the following academic characteristics (or variables) among the three groups: SAT verbal and math scores, high school GPA, time to graduation, cumulative GPA, number of major changes, cumulative semester hours, and average semester hours. Our questions were simple:

(1) Do ENG, SCI and NSCI differ in any of the variables?
(2) On which variable(s) do ENG, SCI, and NSCI differ?
(3) For a given variable, to what extent do ENG, SCI, and NSCI differ?

The first question was answered by a multivariate omnibus test. A Shaffer-Holm procedure was used to answer the second and third questions: An ANOVA was used to identify the variable(s) on which the three groups differ, and pair-wise comparisons among the three groups on the identified significant variables were done to determine the extent of their differences.

1) Multivariate Omnibus Test

A multivariate omnibus test was done first to determine whether there is an overall group effect. Its null hypothesis is that the three groups do not differ in any of the nine variables. The test was done using SAS 8.1 procedure for General Linear Models (PROC GLM) through a Multivariate Analysis of Variance (MANOVA) with the group (ENG, SCI and NSCI) as the between-subjects factor and the nine academic characteristics as dependent variables. The MANOVA test criteria and F approximations for the hypothesis of no overall group effect using Pillai's Trace are shown in Table 3. In order to protect individual and institutional privacy, the universities have been randomly assigned a letter from A – I, and the degrees of freedom related to Pillai's trace have been omitted. Notice that aggregate values are obtained for all nine universities as well as a subset consisting of six universities: The subset of six excluded those institutions for which the LDB did not contain SAT math scores, SAT verbal scores or high school GPAs. The null hypothesis was rejected with $p < 0.0001$ for the individual institutions as well as their aggregates, providing strong evidence for us to conclude that the ENG, SCI and NSCI groups differ significantly in at least one of the academic characteristics.

Table 3: Pillai's Trace and p-values for the Multivariate Omnibus Test.

University	*Pillai's Trace, p-value*
A	F=296.98, p<.0001
B	F=154.65, p<.0001
C	F=45.18, p<.0001
D	F=136.79, p<.0001
E	F=76.17, p< 0.0001
F	F=136.71, p<.0001
G	F=317.58, p<.0001
H	F=46.77, p<0.0001
I	F=145.84, p<.0001
All 9 universities	F=1805.73, p<.0001
6 universities	F=1563.99, p<.0001

2) ANOVA on Individual Variables

The multivariate omnibus test having definitively shown that the three groups differ on at least one variable, we would like to determine which of the variables are significant. This is done with an ANOVA on each variable. For a given variable, the null hypothesis is that the three groups do not differ on that particular variable.

The ANOVA p criterion was .05 for all variables tested. The ANOVA F tests on individual variables give $p < 0.0001$ for all schools combined, and $p < 0.0001$ for most of the individual schools. We note that in every case $p < 0.05$, giving us enough evidence to conclude that the three groups differ on each academic characteristic.

3) Pair-wise Comparison among Groups

Because the ANOVA omnibus null hypotheses were rejected for all the variables on both individual and aggregate university data, the extent of the variation among the three groups was subsequently tested using pair-wise comparisons. The Shaffer-Holm procedure was used to control the family-wise error rate for each of the families of pair-wise comparisons. That is, for each of the nine families of pair-wise comparisons, the test statistic and p values were ranked from the smallest to the largest in terms of the p values, resulting in three stages. The p-value criterion was .05 for all three stages of each family of pair-wise comparisons, so that a specific null hypothesis was rejected if $p < 0.05$.

Descriptive statistics from all nine universities on the available six of the nine variables as a function of group are presented in Table 4A. Statistics on the three additional variables from the reduced set of six universities are presented in Table 4B. Pillai's Trace indicates a significant difference among the three groups. Means and standard deviations of the variables are listed with a superscript attached to each mean. Means with different subscripts within the same row indicate the groups are significantly different in that variable.

1) SAT math score. ENG majors had significantly better SAT math scores than both SCI and NSCI students.

2) SAT verbal score. ENG majors had SAT verbal scores comparable to those of SCI majors, but were significantly higher than NSCI majors.

3) High school GPA. Both ENG and SCI majors came in with better high school GPAs than NSCI students, although the difference between ENG and SCI was not significant.

4) Time to graduation. ENG students took significantly more months to graduate than both NSCI and SCI students. This measure included all time from the beginning to the end of a student's degree, including non-enrolled semesters.

5) Cumulative GPA. ENG majors had higher cumulative GPA than NSCI students but lower cumulative GPA than SCI majors, and while these differences were not large they were statistically significant.

6) Number of changes of major. ENG students changed major significantly fewer times than NSCI students, but more times than SCI majors.

7) Semesters to graduation. ENG students took an average of two more semesters to graduate over SCI students and approximately three more semesters to graduate over their NCSI counterparts. This measure included only enrolled semesters. Since ENG students averaged about 4 ½ years and 13 ½ semesters to graduate, it follows that a significant number of students were enrolled year-round throughout their degree.

8) Cumulative semester hours. ENG students took significantly more credit hours, in total, to graduate, than both SCI and NSCI majors. Although the ENG average is higher than many would expect (167 semester hours), the data includes *all* FTIC students in the SUCCEED database. These students comprise an unbiased set of traditional ENG students, suggesting that the actual total number of credit hours taken during an engineering degree is typically much higher than the standard (4 year x 30 hrs/year = 120 hrs) credit requirement.

9) Average semester hours. ENG majors took slightly fewer hours each semester, on average, than SCI and NSCI students. While the average for ENG students may seem low (12.67 hours), it should be remembered that Summer semesters (with their typically low credit hours) are included in the calculation, implying the Fall and Spring semesters have averages closer to the canonical 15+ credit course load.

Table 4A: Pair-Wise Comparisons Among ENG, SCI and NSCI Groups: All Nine Universities

Variable	Statistic	ENG	SCI	NSCI
	N	19305	10490	71208
Time to Graduation (months)	M SD	55.73^{a} 10.13	52.02^{b} 11.37	51.90^{b} 10.90
Cumulative GPA	M SD	3.00^{a} 0.55	3.04^{b} 0.66	2.96^{c} 0.53
Number of Major Changes	M SD	0.91^{a} 0.83	0.88^{b} 0.91	1.25^{c} 1.01
Semesters to Graduation	M SD	13.66^{a} 4.36	11.48^{b} 3.64	10.67^{c} 2.73
Total Cumulative Hours	M SD	167.10^{a} 42.17	143.90^{b} 36.67	133.64^{c} 27.38
Average Semester Hours	M SD	12.67^{a} 2.23	12.89^{b} 1.97	12.79^{c} 1.75

Note: Means within the same row with different superscripts are significantly different controlling the family-wise error rate.

Table 4B: Pair-Wise Comparisons Among ENG, SCI and NSCI Groups: Six Universities

Variable	Statistic	ENG	SCI	NSCI
	N	13325	6616	41549
SAT math score	M SD	635.62^{a} 85.81	608.51^{b} 98.98	549.27^{c} 94.28
SAT verbal score	M SD	517.75^{a} 88.52	519.00^{a} 97.98	487.45^{b} 88.90
High School GPA	M SD	3.58^{a} 0.41	3.57^{a} 0.47	3.31^{b} 0.51

Note: Means within the same row with different superscripts are significantly different controlling the family-wise error rate.

Pair-wise comparisons for individual institutions mimic these results.

IV. Conclusion

We have compared both demographic and academic differences among engineering, science, and non-science undergraduates, using a very large collection of undergraduate data spanning 9 universities and 13 years. We have looked at gender, citizenship, high school GPA, SAT math scores, SAT verbal scores, time to graduation, cumulative GPA, number of major changes, semesters to graduation, cumulative semester hours and average semester hours. Through careful analysis involving MANOVA and ANOVA tests, we have found that engineers differ from both science majors and non-science majors in the vast majority of these measures. In addition, engineering and science students were closer to each other on some factors (SAT verbal scores and high school GPA) than to their non-science counterparts.

Some of the observed trends between engineering and non-engineering students follow patterns observed by Astin [2]: Engineers take longer to graduate as measured by time, semesters, or credit hours. Other observations run counter to Astin's findings: Whereas Astin found that majoring in engineering had a negative influence on GPA, our study finds that ENG students have higher GPAs than NSCI majors, and very similar GPAs to SCI students. Other studies using SUCCEED's LDB will investigate more closely whether the findings of Astin still have applicability within engineering.

The size of the database and diversity of the institutions suggests these differences may be inherent throughout engineering programs in the United States. These findings, of course, lend credence to the commonly held belief that engineering students are fundamentally different than those in science and non-science disciplines. This work contributes to the understanding of the precise nature and extent of this difference.

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[15] Engineering & Technology Degrees (2000), *The American Association of Engineering Societies,* available at http://www.aaes.org/content.cfm?L1=1&L2=4Guili Zhang is a Ph.D. candidate in Educational Research and Statistics, Department of Educational Psychology, University of Florida. She received a B.A. in British and American Language and Literature at Shandong University, China, and a M.Ed. in English Education at Georgia Southern University. She has published extensively and has won numerous awards at the national and regional level in the area of educational research in China. She teaches Measurement and Assessment in Education at the University of Florida. Her research interests involve applied quantitative research designs, categorical data analysis, and structural equation modeling.

Author Information

GUILI ZHANG is a Ph.D. candidate in Educational Research and Statistics, Department of Educational Psychology, University of Florida. She received a B.A. in British and American Language and Literature at Shandong University, China, and a M.Ed. in English Education at Georgia Southern University. She has published extensively and has won numerous awards at the national and regional level in the area of educational research in China. She teaches Measurement and Assessment in Education at the University of Florida. Her research interests involve applied quantitative research designs, categorical data analysis, and structural equation modeling.

BRIAN THORNDYKE is a Ph.D. candidate in the Quantum Theory Institute, Department of Physics, University of Florida. He received a M.Sc. in High Energy Physics at the University of Montreal, and an M.S. in Computer Science at the University of Florida. His research interests involve computational methods applied to the dynamics of mixed quantum/classical molecular systems.

RUFUS CARTER is a Ph.D. student in Educational Research and Testing, Department of Educational Psychology, University of Florida. He received a B.S. in Psychology and Sociology from the University of Virginia, Wise. His research interests involve test and survey validation, generalizability of high stakes performance exams, classroom and project assessment and evaluation, and methodologies for setting performance standards.

MATTHEW OHLAND is Assistant Professor in General Engineering at Clemson University. He has a Ph.D. in Civil Engineering with a minor in Education from the University of Florida, and served as the Assistant Director of the SUCCEED Coalition until 2000. His research is in freshman programs and educational assessment. He is the President of Tau Beta Pi, the engineering honor society, and will serve in that role until October 2006.

TIM ANDERSON is Chairman and Professor in the Department of Chemical Engineering, University of Florida. He received a Ph.D. at the University of California-Berkeley in 1979. His research interests include electronic materials processing, thermochemistry and phase diagrams, chemical vapor deposition, bulk crystal growth and advanced composite materials.