AC 2009-201: THE DIFFERENCE BETWEEN ENGINEERING AND SCIENCE STUDENTS: COMPARING BACKGROUNDS AND HIGH SCHOOL EXPERIENCES

Geoff Potvin, Department of Engineering & Science Education, and Department of Mathematical Sciences, Clemson University

Robert Tai, Curry School of Education, University of Virginia

Philip Sadler, Science Education Department, Harvard-Smithsonian Center for Astrophysics

The difference between engineering and science students: Comparing backgrounds and high school experiences

Keywords: secondary science, college intentions, recruitment

Abstract

This paper analyzes the differences between engineering and science students, as measured by their intended college major at the end of high school. The data used in this analysis was taken from the nationally-representative Factors Influencing College Science Success (FICSS) survey. Implemented in 2003, this survey was completed by over 8000 college students (53% female) across the U.S. who were enrolled in first-year science courses (biology, chemistry, and physics). The topics covered on the survey focused on the experiences of the students in their last high school science class, as well as their out-of-school interests, demographics, and academic performance.

This paper categorizes students based on their response to the survey question “When you were a senior in high school, what major did you think you would pursue in college?” The available responses were “A science discipline”, “Engineering (includes computer science and technology)”, “Preparation for professional school”, “Mathematics”, “Social science”, “Non-science related field” and “Had no idea”. There were 1707 students (58% female) whose sole response was “A science discipline” and 1074 (16% female) whose sole response was “Engineering”. We compared the responses of these two groups of students (denoted hereafter as “science” and “engineering” students, respectively) to correlate different experiences, attitudes and backgrounds with their stated college intention.

Engineering students had lower socio-economic backgrounds compared to science students (measured by the highest level of parental education, $p<0.05$). They were more likely to have taken Calculus in high school (any calculus, $p<0.001$; or AP calculus, $p<0.001$). They had, on average, higher SAT math scores ($p<0.001$) but had lower grades on other indicators (last high school English grade, $p<0.001$; SAT verbal score, $p<0.001$) Also, engineering students were more likely to report that they were encouraged by their guidance counselor ($p<0.01$) but less likely to report that they were encouraged by their science teacher ($p<0.001$).

The two groups of students reported significantly different experiences on some items. In particular, engineering students reported that they spent less time studying outside of class each day ($p<0.001$) and that they spent less time reading from the textbook ($p<0.001$). They were less likely to report that they prepared for their laboratories the day before doing it ($p<0.001$) but they were more likely to report that they prepared for the laboratories immediately before starting ($p<0.05$). Furthermore, they indicated that their laboratories more frequently addressed their real-world beliefs ($p<0.001$), and that they had more freedom in designing/conducting their labs ($p<0.01$).

Introduction

The lack of science and engineering graduates in the United States has been a concern for some time[1,2]. The National Science Board recently found that "the number of native-born science and engineering graduates entering the workforce is likely to decline unless the Nation intervenes to improve its success in educating S & E students.(p. 1)"[3] Post-secondary education in these disciplines suffers from disproportionately low retention rates. The Committee on Science, Engineering & Public Policy notes that "undergraduate programs in [science and engineering] disciplines report the lowest retention rates among all academic disciplines, and very few students transfer into these fields from others. Throughout the 1990s, fewer than half of undergraduate students who entered college intending to earn a science or engineering major completed a degree in one of those subjects.(p. 98)"[2]

On top of the general problem of low STEM recruitment and retention rates at the post-secondary level, it has been argued that engineering programs have particularly high rates of attrition. Indeed, data from the National Science Board supports this[4]. In 1996, the fraction of freshman students in STEM disciplines who identified engineering as their intended major was 29.2 %, whereas the natural sciences (including the physical and biological sciences) were identified 30.8% of the time, and mathematics (including computer science) 13.1% of the time. Four years later, in 2000, the fraction of STEM bachelor's degrees in engineering was only 14.9%, while the natural sciences were at 25.5% and mathematics nearly unchanged at 12.3%. (The social/behavioral sciences made up for most of the proportional shift in STEM bachelor's degrees). This picture of disproportionate attrition in engineering disciplines is consistent with other work[5] , which has found that the fraction of freshman engineering students who actually go on to graduate in engineering was around 40%.

Doubtless, there are numerous significant differences in the career paths for science and engineering majors which, as has been suggested[6,7], likely contribute to the differential rates of attrition. The academic cultures, frames of reference, and ideological goals for the sciences and engineering are quite distinct. Whereas science "seeks to uncover the laws of nature, expand and deepen our knowledge of basic physical and biological phenomena...", engineering "seeks to delineate answers to client-posed problems within the constraints of time and resources.(p. 38)"[7]. Adelman also pointed out that "engineering is confused with science in the public consciousness, and that, one can hypothesize, is a noteworthy factor in field attrition.(p. 37)"[7] Since high school students have not yet had a chance to be fully exposed to scientific practice, let alone engineering practice, their choice of a science or engineering discipline as a major in college is only a partly-informed decision. One fundamental ambiguity for the students who are bound to enter STEM fields in college is that the preparation for many of these fields requires similar coursework: mathematics classes and physics, chemistry and/or biology classes.

Seymour & Hewitt's influential work considered college attrition in science, mathematics and engineering disciplines[6]. In their study, students who left engineering majors were more likely to indicate "inappropriate choice as contributing to their ... decision, and the ill-founded choices of engineering switchers more commonly included a predominantly materialist motivation" than those students who left science and mathematics majors (p. 48). Furthermore, "engineering students entered their major expecting more in material terms from their future careers careers than did science and mathematics freshman (though they did not necessarily know more about the nature of the jobs they might undertake). The discomforts of the weed-out system, including the competitive ethos, were also greater in engineering. (p. 48)" On top of this, engineering students had clearer pictures about the career paths available to them after graduation and so were more likely to tolerate a competitive atmosphere than other students, who were less apt to see their educations in cost-benefit terms.

Specific to the problem of retention rates in engineering programs, several studies have looked at factors that predict success in college engineering programs (usually measured by freshman GPA or similar scores). The factors that have been found to be correlated with undergraduate success can be categorized as follows:

- Pre-college academic indicators, including GPA, SAT/ACT scores, measures of mathematics skills and science grades[8-12],
- Motivation and attitude measures[10,13-15],
- Family support and socioeconomic status[16].

Note that the literature on this topic has particularly focused on the first category. There is a broad consensus amongst studies on the important impact of pre-college academic indicators on future success in undergraduate engineering. However, as is generally acknowledged by these studies, there are other domains that are also important to success. Furthermore, despite strong correlations between pre-college and college academic indicators, it is not always clear exactly what these indicators are measuring with regards to students' abilities, aptitudes or attitudes—whether it is specific study/learning habits, test-taking abilities, problem-solving skills, or certain states of mind that lead to high performance in this domain.

Of particular interest to the current work is Veenstra, Dey, & Herrin[12]. These authors reported on a comprehensive study of freshman students at the University of Michigan. Comparing four groups of students (engineering, pre-med, other STEM, and non-STEM), with approximately 100-200 students in each group, they found significant correlations between academic indicators in high school and freshman GPA for all groups. On the other hand, they found several highly significant factors to be purely discipline-specific. For example, a construct representing "quantitative skills" was significant for the engineering group only, while a construct representing "study habits-homework" was significant only for the non-engineering STEM group.

In this paper, we undertook an exploration of the relationship between pre-college factors (including academic backgrounds; out-of-class experiences; attitudes, family and demographic backgrounds; and classroom experiences) and students' science or engineering career intentions, as measured by their self-identified intended college major at the end of high school. Essentially, we have focused on the question of identifying the experiences and profiles of students who are recruited into engineering and science rather than the question of how students are retained, as recently suggested by the work of Ohlund et al[17]. Thus, our approach is different from earlier work that has modeled college success indicators, as discussed above. One advantage to this approach is that it allows for a discussion of which factors might contribute to students' selection of their career path, rather than focusing on which factors might contribute to students' persistence, once they have chosen their major. This is especially important for highlighting factors associated to extrinsic motivations (e.g. family encouragement) that may lead to later attrition. Furthermore, we chose a comparative examination of two such paths, that of engineering and of science, similar in spirit to Veenstra, Dey & Herrin[12]. This allows for the elucidation of certain details that are potentially crucial to the recruitment of engineers or scientists that would not be identifiable if these groups were examined either monolithically or in complete isolation.

Research Question

Using students' self-identified intended choice of college major at the end of high school to group "engineering" and "science" students separately, we explored the following question:

- What, if any, are the differences in the academic backgrounds, out-of-class experiences, attitudes, family and demographic backgrounds, and classroom experiences of engineering and science students?

Methodology

The data used in this study came from the Factors Influencing College Science Success (FICSS) study, a large-scale survey of students in introductory biology, chemistry, and physics courses at randomly selected colleges across the US. (Project FICSS was supported by the Interagency Educational Research Initiative, NSF-REC 0115649. Any opinions, findings and conclusions, or recommendations expressed do not necessarily reflect the views of the NSF, the U.S. Department of Education or the NIH.) The three versions of this survey focused on students' high school biology, chemistry, or physics class experiences, respectively, and the primary intent of the survey was to determine how these experiences influence success in college courses[18]. The questionnaires were based on a previous pilot survey of 2000 college physics students conducted in 1994[19] plus a series of interviews with 20 high school science teachers and 22 college professors that focused on the factors that influence student success in college.

The survey methodology applies a cross-sectional approach relying upon the natural variation in the experiences and background of the sample students. The FICSS project used a representative, stratified, random sample taken from a comprehensive list of four-year colleges and universities in the U.S. The stratification accounted for the size of the institution and prevented an over-sampling of the smaller, but numerous, liberal arts colleges in the U.S. In total, 63 of these colleges agreed to participate in the survey. From the participating institutions, the college courses that were surveyed consisted of biology, chemistry, and physics courses that satisfied first-year requirements for STEM majors. For each of the three subjects in college, the appropriate survey (biology, chemistry, or physics) was administered, during the fall semester of 2003. At the end of the term, professors reported each student's final grade. In total, over 8000 students completed one of the three versions of the survey, 53% of whom were female. Note in particular that, due to the retrospective nature of the methodology, the variability in students' backgrounds and prior experiences is large. Students reported that they came from homes in 4027 different zip codes across the U.S.

The final version of the survey included 66 questions about student demographics, earlier math and science enrollment and achievement (including the types of courses taken, the level of courses, the year courses were taken in high school, final grades, and AP test scores), the pedagogies employed in students' last high school science course (in the discipline of their current college enrollment), and a section for the college professor to enter the student's final grade. (For a complete sample survey, visit http://www.ficss.org and click on "About the Research".) The survey's validity was determined through focus group interviews with college science students as well as further consultation with high school science teachers and college professors. This feedback led to the rewriting of some survey items. In order to assess the degree of reliability in participant responses to the survey questions,a test-retest study was performed in which the same 113 college chemistry students completed the survey two weeks apart and their responses were compared. In an analysis of the results, on any given individual survey item at least 90.7% of the responses were within one choice of the original response with 60% of the responses identical. This result translates into reliability coefficients ranging between 0.5 and 0.7 for the various items in the survey. According to Thorndike, in an analysis of groups of 100 participants, a reliability coefficient of 0.5 corresponds to a 0.04% likelihood of a reversal in the direction of difference[20]. This means that the survey instrument has a high degree of reliability. As discussed by Thorndike, the reason for such a strong reliability stems from the sample size: while the responses of any given individual may vary, overall trends found in large groups tend to be quite stable.

Another possible concern about the reliability of the FICSS survey is the time gap between students' last high school science classes and the administration of the questionnaire. Although all of the college classes that participated in the survey were introductory-level, the overall sample of students consisted of 49.4% freshmen, 27.8% sophomores, 16.5% juniors, and 6.3% seniors. Considering the fact that students were asked to respond to the survey based on the last high school science course in the discipline of their college enrollment, one might worry whether the variable gap of time between their last high school course and the FICSS survey might have an effect on responses. However, it has been consistently found that in this data, student year-of-enrollment (as a proxy for this time gap) is not significantly correlated with responses to other survey items[21]. In other words, the responses by sophomores, juniors, and seniors have been found to be not significantly different from those of freshman.

One question, of particular relevance to the current analysis, that appeared on the three versions of the survey asked students: "When you were a senior in high school, what major did you think you would pursue in college?" The available responses were "A science discipline", "Engineering (includes computer science and technology)", "Preparation for professional school", "Mathematics", "Social science", "Non-science related field" and "Had no idea". Students were instructed that they could mark *all* responses that were applicable. In the current analysis, students are grouped according to their response to this question. It is particularly useful to consider this question because it is an indicator of students' career *intentions* when exiting high school and it allows for an analysis of the pre-college factors that are associated with these intentions. In this work, two groups of students are compared and contrasted: those that *only* indicated that their expected major had been "Engineering" (hereafter called "engineering students") and those that indicated *only* "A science discipline" (hereafter called "science students."). The reason for this methodological choice was to identify the students who finished high school with the most unambiguous intentions to major in engineering or science. Additionally, in the questionnaire itself, students who had not taken a high school science course in their college-enrolled discipline (such students appeared primarily in the physics sub-sample) were instructed to skip over the sections of the FICSS survey that dealt with their high school classroom experiences (including teacher evaluations). Such individuals have also been excluded in this work, as there were few survey items upon which to analyze their experiences.

According to the above classification, then, there were 1074 students categorized as engineering students (16% of whom were female) and 1707 students categorized as science students (58% female). In order to develop a comparative profile of these two groups, a series of tests were performed to see how they responded differently to the various questions that appeared on the FICSS survey including their academic backgrounds, out-of-class experiences, attitudes, family and demographic backgrounds, and classroom experiences.

For the questions in the survey that had linearized responses, a set of t-tests were performed in order to compare the average responses of engineering and science students. (See Huck & Cormier[22] for a detailed discussion of the methods used throughout this paper.) However, t-tests were not appropriate to analyze several questions on the survey in which responses were dichotomous in nature. For example, students were asked to indicate (from a list) which mathematics courses they took in high school. Since there is no meaningful metric that can be applied to measure the "distance" between an affirmative and a negative response, a more general test needed to be applied. The Mann-Whitney U-test calculates whether there is a statistically significant difference in the average ranking of the two groups of students (ie. the relative proportion of each group that answered in the affirmative to a dichotomous question). This provides an analogous test in order to compare groups. For all of the tests in this paper, the minimum level of significance that was considered was an alpha level of 0.05.

Results

The results of the various t- and Mann-Whitney U-tests are summarized in Tables 1 and 2, respectively. Only tests that had a statistically significant difference for the two groups of students are quoted; in total, 11 linear and 18 dichotomous variables showed significant differences. Tests for related variables are grouped together in each table: first, academic background variables (in grey); second, demographic, family, and affective variables (in white); and, third, classroom and laboratory experience variables (in grey).

Table 1 is organized as follows: for each variable, the mean and standard error is given for engineering and science students, respectively. The higher mean is listed in **bold**. The level of statistical significance is indicated in the final column using the following convention: * represents a statistical significance of less than 0.05 but greater than or equal to 0.01, ** represents a statistical significance of less than 0.01 but greater than or equal to 0.001, and *** represents a significance of less than 0.001. This convention allows for a quick but meaningful evaluation of the significance of each test (see, for example, Dawson[23]; Farenga & Joyce[24]). Similarly, Table 2 outlines the results of the Mann-Whitney U-tests. In order to provide analogous statistics as Table 1, the percentage of each group answering in the affirmative are listed, followed by the level of statistical significance estimated by the Mann-Whitney U-tests.

Table 1: T-tests for linearized variables.

Variable	Engineering Students (Mean ± Std. Error) N=1074	Science Students (Mean ± Std. Error) N=1707	Level of Significance (*: p<.05, **:p<.01, ***:p<.001)
SAT Math Score	**621 ± 3**	591 ± 2	***
SAT Verbal Score	561 ± 3	**581 ± 2**	***
Last high school English grade (scale: 1(F) to 5(A))	4.50 ± 0.02	**4.62 ± 0.01**	***
How supportive was home environment of science (scale: 0—not supportive; 4—very supportive)	1.82 ± 0.04	**2.20 ± 0.03**	***
Parent's highest level of education (scale: 0—did not finish high school; 4—graduate school)	2.77 ± 0.03	**2.85 ± 0.03**	*
Length of pre-demonstration discussions (min)	**8.92 ± 0.24**	8.22 ± 0.17	*
Length of post-demonstration discussions (min)	**11.7 ± 0.3**	11.0 ± 0.2	*
Daily length of time spent reading textbook, both in class and as homework (min)	17.1 ± 0.4	**19.9 ± 0.3**	***
Daily time spent working or studying on subject out of class (minutes)	21.2 ± 0.5	**24.2 ± 0.4**	***
Frequency of labs that addressed real-world belief (scale: 0—never; 4—almost every lab)	**1.24 ± 0.03**	1.08 ± 0.03	***
Freedom in conducting/designing labs (scale: 0—none; 4—complete)	**1.72 ± 0.04**	1.57 ± 0.03	**

Table 2: Mann-Whitney U-tests for dichotomous-outcome variables.

Variable	% of Engineering Students Indicating (N = 1074)	% of Science Students Indicating (N = 1707)	Level of Significance (*: p<.05, **:p<.01, ***:p<.001)
Took Algebra I in high school	58.9	**68.4**	***
Took calculus in high school	**27.9**	20.1	***
Took AP calculus (AB)	**37.6**	25.4	***
Took AP calculus (BC)	**10.9**	5.7	***
Ethnicity—"Hispanic" student	3.6	**6.0**	**
Race—"Black" student	**7.4**	5.1	*
Encouragement to take science classes from mother	27.9	**32.2**	*
Encouragement to take science classes from school counselor	**26.4**	21.4	**
Encouragement to take science classes from science teacher	21.9	**28.6**	***
Science involved in one parents' job.	**34.6**	29.2	**
Family attitude: science is for a better career	20.6	**23.8**	*
Family attitude: science is a diversion or hobby	15.2	**18.9**	*
Family attitude: science is a series of classes to pass	**20**	15.6	***
High school did not offer science fair	**34.8**	29.1	**
Test questions typically required the memorization of terms or facts	68.8	**79.8**	***
Lab preparation: read directions while doing lab	**40.8**	36.1	*
Lab preparation: read directions immediately before starting	**33.1**	28.7	*
Lab preparation: read directions the night before	21.5	**24.0**	***

Before examining these results in detail, one methodological concern needs to be addressed. There is a possibility of selection effects stemming from the way in which the three versions of the survey were administered. Recall that if a student was surveyed in a college biology class, then they were asked primarily to report on their classroom experiences in their last high school biology course (in addition to all of the subject-nonspecific questions); if a student was surveyed in a college physics class, then they were only asked about their classroom experiences in their last high school physics course. As might be expected, engineering students were more likely to be enrolled in college physics courses than science students (43.8% of the individuals in our analysis as opposed to 21.9%) and less likely to be enrolled in college biology

(9.4% vs. 36.6%). This raises a real possibility that any difference in responses for classroom-specific questions might stem simply from the relatively different proportion of high school courses, rather than genuine differences in the experiences of engineering and science students. In order to investigate this possibility, a set of much more sophisticated tests were run for each of the variables appearing in Tables 1 and 2.

For the linearized variables (Table 1), a set of ANCOVA tests were performed, in order to determine if differences in the high school subject could explain the reported differences. In fact, even when controlling for any differences stemming from the high school subject area, *all* of the differences reported in Table 1 continued to be significant. In the majority of cases, the subject area was not a significant predictor of the responses and in only one case, that of the variable "Frequency of labs that addressed real-world belief", was the significance level lower than the t-test results (declining to $p<0.05$ from $p<0.001$). Similarly, for the dichotomous variables (Table 2), a set of logistic regressions were performed, in order to control for the survey subject area. Again, for *all* of the variables appearing in Table 2, even when controlling for high school subject area, the differences continued to be significant, and in only three cases was the significance level lower in these tests (declining to the $p<0.05$ level for the variables "Ethnicity—Hispanic student", "Science is involved in one parents' job", and "Test questions typically required the memorization of terms or facts"). Thus the results in Tables 1 and 2 are robust in the more sophisticated analysis and cannot be explained away by this alternative hypothesis.

In order to begin to understand the results appearing in Tables 1 and 2, this discussion will treat tests for thematically-related variables together, regardless of which type of test was appropriate. For each result, the level of significance will be quoted in parentheses (ie. $p<0.01$). Firstly, consider the academic background variables that were significantly different for engineering and science students. Of the two groups, engineering students earned SAT Math scores that are 30 points higher, on average ($p<0.001$)—note, however, that both science and engineering students had higher SAT Math scores than other groups. Similarly, they are 7.8% more likely to report that they have taken some calculus during high school ($p<0.001$), 12.2% more likely to report that they took the AB section of AP calculus ($p<0.001$), and 5.2% more likely to have taken the BC section of AP calculus ($p<0.001$). They are also 9.5% less likely to have taken Algebra I in high school, likely indicating that they more frequently took this course before high school ($p<0.001$). On the other hand, they scored 20 points lower on the SAT Verbal ($p<0.001$) and had a lower GPA in their last high school English course ($p<0.001$).

Secondly, consider the demographic and affective variables that appear in Tables 1 and 2. Engineering students were 2.3% more likely to report their race as "black" ($p<0.05$) and were 2.4% less likely to report their ethnicity as "Hispanic" ($p<0.01$). They were 5.7% more likely to indicate that their high school did not offer science fair ($p<0.01$). The parents of engineering students were reported to have lower levels of education, on average ($p<0.05$), although engineering students were 5.4% more likely to report that science was involved in one of their parents' jobs ($p<0.01$). They were 3.2% less likely to report that their family's attitude towards science was that "science is for a better career"($p<0.05$), 3.7% less likely to report that this attitude was that "science is a diversion or hobby"($p<0.05$), yet were 5.3% more likely to report that their family's attitude was that "science is a series of classes to pass" ($p<0.001$). Most interestingly in this category, engineering students reported that their home environment was less supportive of science ($p<0.001$), were 4.3% less likely to report that they were encouraged to take science by their mothers ($p<0.05$), were 6.7% less likely to report that they were encouraged to take science by their science teacher ($p<0.001$), but were 5.0% more likely to report that they were encouraged to take science from their school counselors ($p<0.01$).

Finally, consider the classroom and laboratory experiences that were reported differently by engineering and science students. Engineering students reported spending shorter times each day reading the textbook (both in class and as homework, $p<0.001$). They also reported that they spent less time each day working on or studying the subject out of class ($p<0.001$). Engineering students reported longer pre- and post-demonstration discussions (both $p<0.05$) in their classes. They were 9.0% less likely to report that their tests typically required the memorization of terms or facts ($p<0.001$). Several indicators of students' laboratory experiences were significant. Engineering students were 4.7% more likely to report that they prepared for laboratories by “reading the directions while doing the lab” ($p<0.05$), 4.4% more likely to report that they prepared by “reading the directions immediately before starting”($p<0.05$), and were 3.5% less likely to report that they prepared by “reading the directions the night before”($p<0.001$). Lastly, engineering students reported a greater frequency of laboratories that addressed their real-world beliefs ($p<0.001$), and they indicated that they had, on average, greater freedom in the conducting/designing of laboratories ($p<0.01$).

A number of variables are notable by their absence from the preceding results. That is, on a number of questions, engineering and science students did not respond significantly differently. Notably, the variables accounting for various specialized high school science courses (year taken, level of course, final grade) were not significant in this study. It seems reasonable that such courses (e.g. pre-engineering) could have some impact on the likelihood of a student choosing engineering as a college major; however, in the current analysis, this was not seen. This is most likely due to the fact that the number of students in each sample who had taken specialized courses was too small to measure any significant differences. In addition, a number of variables related to students' high school science course length, class sizes and frequency of meeting were reported to be the same by both engineering and science students. Similarly, students were questioned about the impact of several out-of-school science-related activities such as hobbies, exposure to science-related media and after-school/summer employment, but no significant differences were found. Also, students were asked to rate their high school science teachers on a number of domains, but no differences were found. These results suggest that, while such factors may have a significant impact on the recruitment of students into STEM majors, no differential effects could be seen between engineering and science students.

Discussion

Broadly speaking, our results on the academic background indicators of engineering and science students are consistent with earlier work[8-12], despite our focus on career intentions as an outcome rather than college success or persistence. As pointed out by Ohlund et al, “there is already considerable discourse on persistence [in engineering programs] ... more research focus is needed on the pathways into engineering, including pathways from other majors.(p. 259)”[17]

Engineering students had particularly high SAT math scores and comprehensive mathematics preparation (e.g. rates of completion of various calculus courses), although science students were more well-rounded in their pre-college academic preparation (e.g. high school English grades and SAT verbal scores) and reported spending longer times studying outside of class and preparing for their laboratories. Engineering students' high math preparation is consistent with earlier work that suggested such indicators are crucially important to college engineering success[8-15]. Possibly, this is because students (and/or their parents, teachers, and counselors) have come to understand that strong high school mathematics preparation has a significant impact on success in undergraduate engineering programs and, consequently, have organized their high school studies appropriately. Alternatively, it may be that engineering students are simply more intrinsically drawn to mathematics, resulting in their relatively higher performance. Similarly, the results on science students' study habits suggests that they may have come to understand the importance of such skills for their success in college[12], or that they are fundamentally oriented towards these skills, leading to their increased all-around performance.

Engineering students tended to report greater freedom in designing/conducting their laboratories, and reported more frequent labs that addressed their "real-world" beliefs. This result is consistent with the picture of engineers as being interested in the creative and pragmatic application of science to the real world[6,7]. It is tempting to think that these results mean that such high school experiences encourage individuals to choose engineering as a career path. However, since all of our results are correlational in nature (not causal), the reverse explanation might also be true: students who are *already* oriented towards the engineering mindset might more frequently identify laboratories as relating to something in their daily experience or recall better the opportunities that they had to freely design/conduct laboratories. Nonetheless, these results do suggest that further investigation of the impacts of such laboratory experiences on students' choice of college major is warranted.

Our findings on family support and encouragement are interesting. Engineering students had lower socioeconomic statuses (as measured by the highest level of their parents' education; also, indirectly, by the fact that they were more likely to report that their high schools did not offer science fair) and were more likely to be encouraged by their school guidance counselor. Science students were more likely to be encouraged by their mothers and their high school science teachers. The families of engineers were reported to be less supportive of science overall and were more likely to see science as "a series of classes to pass" rather than being "for a better career" or being "a diversion or hobby". These results are suggestive of the following picture of the differences between the individuals in our sample: students with strong mathematics skills who have somewhat lower socioeconomic status are more frequently encouraged by their guidance counselors to make a pragmatic career choice—engineering, which is perceived as being highly-paying and having a high degree of stability, whereas more well-rounded students with relatively higher socioeconomic status more frequently get encouragement towards pure science from their families.

A general conclusion to be drawn from this work is that there are, indeed, measurable differences in the backgrounds of future engineering and science majors. While not entirely surprising, our results do suggest that there are certain domains that should be investigated further, in order to understand how to more effectively encourage high school students to make a lasting choice of college major. Particular domains that seem to be rich are: students' family support towards the sciences (both the nature and level of this support), the structure and context of classroom laboratories, and factors that lead to the development of good mathematics and/or study skills. As Adelman has suggested[7], it may be that some students who choose to enter freshman engineering programs have based their decisions on certain experiences, impressions or affective factors which later lead to students leaving engineering majors. On the other hand, there may be many students who would thrive in college engineering who choose *not* to enter such programs because of their experiences, impressions, and attitudes. Another interesting avenue to explore in the future would be the impact of certain types of specialized high school courses, such as those designed for pre-engineering. These courses might have a significant impact on the career choices of engineering students, and it would be valuable to evaluate and assess these effects.

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