Study of Distinguishing Academic Characteristics among Undergraduate Engineering Students: Successful Non-Traditional Students vs. Successful Traditional Students

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Abstract

Each year, thousands of students from groups which have not been traditionally identified with the majority of persons who study and enter engineering professions enroll in engineering programs. These non-traditional groups include under-represented minority (URM) students, women and transfer students (largely from community colleges), and a large proportion of students from these groups fail to graduate with an engineering degree. To help engineering programs and their host institutions in formulating strategies to improve the academic success rate for all students, including students from non-traditional groups, it may be useful to learn something about those URM, women and transfer students who do succeed in engineering which distinguishes them from historically traditional students who succeed. This study attempts to compare the academic performance and behavior of successful non-traditional students to successful traditional groups of engineering students to ascertain which characteristics that are identified by the literature as being associated with retention/graduation can distinguish between the groups. The study is conducted among undergraduates in the College of Engineering at Texas A&M University (TAMU), which is predominantly White, male, and comprised of non-transfer students. The results of this paper are based on the development of ANCOVA models, Bootstrap tests and nonparametric tests, as well as on descriptive analyses.

Introduction

Previous research has found that students' pre-college preparation, reflected by both standardized admission scores and high school rank, is highly associated with students' early college academic performance. Both GPA[12,16,18] and the credit hours[8,10] passed ratio are universal indicators of students' academic performance. Researchers have also found that college students' enrollment practices, such as course load, certainty of major, consecutive enrollment, and concurrent enrollment influence the likelihood that students

will persist and/or graduate[2,3,4,8,9,11]. A variety of research efforts have investigated these general findings by gender, race/ethnicity and among transfer students[4,7,8,11]; however, research has not been widely published that extends these particular findings specifically to these population subdivisions among engineering students. This study tries to compare the academic performance and behavior of successful non-traditional students to successful traditional groups of engineering students to ascertain which characteristics identified by the literature distinguish between those groups. The study compares and contrasts success characteristics across population subdivisions, defined by gender, ethnicity, transfer vs. native students, and students who engage in concurrent enrollment vs. those who do not. It examines the effects of attributes which are known to be associated with retention/graduation, including pre-college preparation (SAT scores and high school ranks), early collegiate academic performance (credit hours passed/credit hours registered and average GPA of first three semesters), and students' enrollment practices (average credit hours registered per semester, number of changes in majors, number of consecutive semesters in college, and concurrent enrollment in multiple institutions).

Theoretical Background

Previous research has found that several factors, such as pre-college preparation[2,5,7,10,11], early collegiate academic performance[3,4,8,20] and enrollment practices[3,8,9,10,11,16], influence academic performance and the likelihood that students will persist and/or graduate. Pre-college preparation include factors defining study and academic skills—high school GPA, and SAT/ACT scores. Early collegiate academic performance is commonly measured by early GPA as well as credit hours complete/credit hours registered (course completion rate). Enrollment practices are general enrollment behaviors like average credit hours, certainty of major, consecutive enrollment, and full-time versus part-time enrollment.

Enrollment practices have been studied by several researchers, and have been shown to have an impact on retention of college students, including those in engineering and science majors[2,3,4,7,8,9,10,11,16]. One study found three factors, collectively called study attitude, and referring to a gauge of commitment to succeeding academically, that influence persistence[3]. This study describes these factors as “non-normative course scheduling (taking both major and summer terms), midstream change in program curriculum, and strict sequential semester enrollment (no “stopping out”)”[3]. Other research has also found that both native and transfer student who dropped out were more likely to leave by the end of their third year in college[9]. According to several studies cited in one article, “students’ degree of academic certainty about their major was positively related to persistence in college”[2]. Brooks-Leonard also found that for male, African-American men attending community college, certainty of major could significantly predict retention[4]. There is so much research supporting the correlation between full-time enrollment and higher retention rates that after reviewing the literature, Brooks-Leonard concluded that for two year colleges, “virtually the only theme that repeats itself throughout the literature is that students who attend college on

a full-time basis return at a much higher rate than those who attend on a part-time basis"[4]. In fact, in Brooks-Leonard's study, about 43% of the part-time students returned, while 80% of the full-time students returned[4]. Both Boughan and Summers state that how many credit hours students take influences persistence, with students who take fewer hours at more risk for dropping out[3, 16]. Not only does the number of credit hours taken affect retention in the short term, but Gao, Hughes, O'Rear, and Fendley found transfer students to be more likely to graduate if they transfer 32 or more hours[8].

Course load has also been found to affect retention specifically among under-prepared students and African-American students. In 1993, Long & Amey even found that underprepared students at a community college could be divided into successful and unsuccessful groups based on the number of credit hours they took in their first semester, although the average credit hours of successful students (11.6) were only higher than those of the unsuccessful students (10.6) by one credit hour[11]. Like other students, African-American students who are enrolled full-time are more likely to persist, and "in terms of the delta-p statistic, for each credit hour dropped, the likelihood of non-retention increased by 29%"[7]. Lanni's 1997 study indicated that African-American community college students did not do as well as white students, but a higher percentage of the African-American students were part-time students[10]. When full-time/part-time status is considered, both African-American and Caucasian students were more likely to be successful if they were enrolled full-time[10].

Pre-college preparation also appears to have a significant impact on the success of students' college careers. Bean and Metzner located several studies supporting the connection between study skills/study habits and persistence[2]. Another component of pre-college preparation is high school performance. For college students in general, high school academic performance had a negative (-.17) correlation with dropping out [12]. Hagedorn et al. showed high school GPA to significantly predict retention during the first three semesters of community college among African-American students[7]. Civian & Schley found that female college students who left the fields of science and math had "lower high school grades in math and science, lower entrance examination math scores, and lower college grades in science and math," and also had "lower levels of interest in science and lower mathematical ability, and were less likely to have a parent with an advanced degree"[5]. In addition, Long and Amey found that high school GPA could predict success for under-prepared students in community college[11]. Besides high school GPA, actual skill levels of beginning college students were found to be important in Lanni's study[10]. Lanni found that 17.6% more African-American students than Caucasian students had "less than college-level capability"[10]. Not surprisingly, this meant that African-American students did not do as well overall, although there was no difference after controlling for parents' education levels[10]. Furthermore, of part-time African-American students who had college level math skills on a test, "47% were more frequently successful compared to students that scored below college-level math or did not take the math assessment test (19%)"[10]. In addition, full-time Caucasian students were more likely to succeed with college level math skills, and part-time Caucasian students were more likely to succeed with college level English skills[10]. Aptitude

measures such as the SAT and ACT, which can be assumed to reflect skill levels and are therefore related to academic preparedness, also predict persistence. Another study found that along with low high school GPA, low SAT and ACT scores predicted drop out[13]. Interestingly, Bean and Covert discovered that "academic aptitude measures [SAT verbal and math] discriminated between persisters and academic dismissals" for men and women, while "personality measures discriminated between persisters and withdrawals" for women only[1].

The beginning of a student's academic career may be the most important in predicting success, and studies have investigated several factors related to early college academic performance. Gao et al. state that "first-term academic performance is crucial for both native and transfer students in terms of their graduation and persistence"[8]. More specifically, Zhao concluded that the six factors which significantly predicted success for under-prepared community college students are "cumulative credit hours earned; good academic standing; cumulative grade point average; course load; the number of developmental courses taken; and race/ethnicity"[20]. Zhao also believes that Astin's 1991 Input-Environment-Outcome (IEO) model can be applied to prepared and under-prepared students since both groups are evaluated with the same measures and have to meet the same requirements in terms of GPA points and credit hours before they can move on from developmental courses to the courses that count towards their certificate or degree[20]. During the first three major semesters, there appears to be "a group of attendance and performance variables" that "instead of factoring in with other attendance and performance variables, coalesced into a separate factor measuring initial study survival and success (Early Term Performance)[3]. This suggests that the first year of study has its own dynamic which may be critical to ultimate success or failure"[3].

Concerning early academic performance in college, GPA seems to be one of the most important and most studied variables. Although Brooks-Leonard found that the only academic variable related to retention was first-term GPA[4], other researchers argue that cumulative GPA is important as well [2,11,20]. Metzner's 1989 study showed that of several contributing factors, GPA was the most strongly associated (-.41) with dropping out[12]. Tinto also feels that grades are the most important factor in a student's decision to drop out[18], and Spady agrees that grades, as well as intellectual development and other factors, affect retention[14]. Summers cites several studies that all found GPA to have a strong negative correlation with attrition[16]. While the studies Summers discusses say that GPA and persistence have a strong positive correlation among commuter students[16], Bean and Metzner's review of the literature indicates that although both cumulative and first-semester GPA strongly predict persistence at community colleges and universities, these variables may predict less well for older commuter students or those who attend part-time[2].

Just considering Science and Engineering students, those who graduated with lower undergraduate GPAs "were more likely to have attended community college than were graduates with higher" GPAs[19]. Another population studied specifically is under-prepared community college students. Zhao's "inspection of the literature on the

academic outcomes" of these students revealed that cumulative GPA best predicts success[20]. Similarly, Long and Amey's results showed that successful under-prepared community college students had both higher developmental GPAs and higher non-developmental GPAs[11].

Despite the abundance of evidence supporting the correlation between GPA and success, Sumers mentions that Grimes and Antworth believe that course completion rate, or the number of credit hours registered/number of credit hours passed, should be used as a measure of academic success as opposed to GPA because GPA can be misleading when dealing with students who frequently withdraw or retake courses[15]. In fact, Summers found that "a combination of number of course drops, course adds, when schedule changes were made, and when a student initially enrolled could predict 37.6% of the variation in semester GPA and 48.6% of the variation in semester course completion. Except for when changes were made to the schedule, these same behaviors could predict the odds of attrition"[15]. Additionally, after controlling for student characteristics, the combination "of number of course drops, course adds, when scheduling changes were made, and when a student initially enrolled could predict 33.9%" more of the variance in fall semester GPA than the 6.5% that a combination of five student characteristics could predict, and these factors, not including when schedule changes were made "could significantly predict the odds of attrition beyond what the student characteristics could predict"[15].

Methodology

Hypotheses

Hypotheses are developed to test whether significant academic behavioral differences exist between the traditional and non-traditional engineering student segments. The hypotheses serve to comparatively investigate academic behavior characteristics, which are associated with success, across a set of population subdivisions. The population is subdivided by gender, race/ethnicity, and admission status defined as native vs. transfer. Native students were admitted to a university as freshmen and remained there thenceforth, while transfer students have transferred from another institution--mostly from a community college. In addition, the study examines characteristics for a special subpopulation of URM students who are subdivided into those who practice concurrent enrollment and those who do not.

Across the different population subdivisions (i.e., women/men, URM/non-URM, transfer/native, and concurrently enrolled/not concurrently enrolled), five null hypotheses are posited for testing: Hypothesis 1—a uniform relationship between early college GPA and pre-college academic preparation; Hypothesis 2—no differences in course load per term; Hypothesis 3—no difference in "credit hours passed" ratio; Hypothesis 4—no difference in major certainty; and Hypothesis 5—no difference in consecutive enrollment.

Pre-college academic preparation here refers to high school rank and SAT scores. Course load per term refers to the average number of the credit hours taken per semester. Credit hour passed ratio is calculated from (the number of credits passed)/(the number of credits registered) for the first three semesters. Students' certainty of major is measured by the total number of majors ever attempted in an engineering college. Consecutive enrollment refers to students' uninterrupted attendance in college, and its value is given by the number of consecutive enrollment semesters in college. Concurrent enrollment refers to the situation where a college student concurrently enrolls in multiple institutions. Concurrent enrollment is measured by the number of semesters in which the student concurrently enrolled in more than one institution.

As indicated earlier, each null hypothesis is tested: (a) between men and women; (b) among different ethnicities; (c) between natives and transfers; and (d) between students who ever practiced concurrent enrolment and those who did not. For example, Hypothesis (H) #2 c posits that native students and transfer students take the same course load per term in university engineering programs. Due to the special parameters of the data set which provides evidence of concurrent enrollment, which is described in the Study Population discussion below, some hypotheses could not be tested on the subdivisions of subpopulation (d).

Study Population

A well known fact about the TAMU engineering college at the undergraduate level is that the majority of the students enrolled there are historically traditional engineering students, who are White men and were admitted to TAMU as freshmen. Records of 7,601 students were originally collected from the College of Engineering of the Texas A&M University at College Station. This population represents all the students admitted to TAMU engineering college between Fall, 1994 and Summer, 1998. Our study is based on 5,179 members of this population who successfully completed their BS engineering programs within six years of admission. The population data for this study intentionally ignored one underrepresented minority—Native American, because its population represents only 0.3% of the TAMU engineering data, compared with Hispanics' 12.4% and African Americans' 3.5%.

To measure student's concurrent enrollment, we introduced one variable to the TAMU engineering data from a very different data set describing URM engineering/science students and students who had been members of the Texas Alliance for Minority Participation (TX AMP). This data was obtained from the Texas Higher Education Coordination Board (THECB), and documents students' enrollment across almost every public higher education institution in Texas, thereby permitting us to observe the phenomenon of concurrent enrollment for each URM or AMP student who was enrolled in the TAMU College of Engineering between 1994 and 1998. Due to the fact that subpopulation "d" could only be defined among URM students, the testing of certain hypotheses was not possible due to insufficient data among subdivisions.

Procedures

For Hypothesis 1, analysis of covariance, or ANCOVA, was used to test the linear relationships across the studied groups. The critical assumption for ANCOVA model validity is that residuals are normally distributed with a constant variance. The ordinary t-test works well only under the strict conformance with the model assumption. Because the residual assumptions are not met in our data, we tested differences in slopes using bootstrap resampling technique to obtain unbiased answers.

Meanwhile, the distributions of the variables describing students' enrollment behavior typically deviate severely from normality. Therefore, for Hypothesis 2 through Hypothesis 5, nonparametric tests including Mann-Whitney-Wilcoxon test and Kruskal-Wallis test were performed to discern the general difference between groups.

Empirical Results

General Relationships

Table 1 presents Pearson's correlation between the academic behavior/performance characteristics of the entire population—the 5,179 engineering graduates from TAMU. Students' early college GPA is only weakly associated with enrollment behaviors, but is highly correlated with standardized admission scores and high school performance. The credit hours passed ratio is highly correlated with early college GPA because a course grade directly determines the pass/failure on that course. Therefore, we avoided using the credit hours passed ratio and the variables measuring enrollment behaviors as inputs to the development of the subsequent ANCOVA models.

	SAT Math	SAT Verbal	High School Percentile	Credit Hour Passed Ratio	Average Credit Hours Attempted per Term	Number of Major Switches	Number of Semesters in Consecutive Enrollment
Early College GPA	0.418	0.405	0.364	0.520	0.026	-0.117	-0.125

Table 1. Correlations between Measures of Academic Success, Admission Criteria, and Enrollment Behaviors

Testing Hypothesis 1—Results from ANCOVA and Bootstrapping Tests

Tables 2, 3 and 4 show the unstandardized coefficients of the ANCOVA models, which measure the relative importance of the inputs associated with student's first three

semester's GPA. * denotes that the boostrapping test indicated significant difference between the slopes across the groups at α= 0.05

		Intercept	SAT Math*	SAT Verb	HS Pct
H1a	Male	0.963	0.0012	0.0011	0.0078
	Female	0.393	0.0020	0.0012	0.0083

Table 2. ANCOVA Coefficients Developed between Genders

		Intercept	SAT Math	SAT Verb	HS Pct
H1b	White American	0.982	0.0011	0.0011	0.0088
	Hispanic American	0.539	0.0013	0.0015	0.0088
	African American	1.116	0.0011	0.0012	0.0043

Table 3. ANCOVA Coefficients Developed between Majority and URMs

		Intercept	SAT Math	SAT Verb*	HS Pct*
H1c	Natives	0.460	0.0014	0.0012	0.0112
	Transfers	1.509	0.0013	0.0007	0.0042

Table 4. ANCOVA Coefficients Developed between Native Students and Transfer Students

H1a and H1c are rejected according to the test results, while H1b is confirmed. Female engineering students' early collegiate GPA is more closely related to objective college admission score, especially to SAT math score. This is indicated by the statistical significance in the difference between the coefficients that are associated with the SAT Math score. Although there is no compelling test evidence to reject H1b, compared with that of Hispanic Americans, African Americans' early college GPA is less associated with students' admission scores and high school performance. Meanwhile, compared with natively enrolled students, transfer students' post-transfer university GPA performance is generally less associated with the students' SAT scores. Transfer students' post-transfer GPA is also less likely to be associated with students' high school percentile.

Testing Hypothesis 2 through Hypothesis 5—Results from Nonparametric Tests

Male vs. Female

Tests provide statistical evidence to reject H2a and H3a, while H4a and H5a are confirmed. Male students generally take more credit hours than female students do, but males' credit passed ratio is not as high as females'. Other than these two differences, males and females tend to behave identically in terms of the number of major switches and the number of consecutive semesters enrolled.

White Americans vs. African Americans vs. Hispanic Americans

Statistical evidence exists for H3b, H4b, and H5b to be rejected, while H2b is confirmed. The three ethnicities take the same course load in their engineering programs. African Americans and Hispanic Americans exhibit the same enrollment behaviors in terms of the credit hour passed ratio, the times of major switches, and the number of semesters of consecutive enrollment. However, Whites have a significantly higher credit hours passed ratio, fewer major switches, and shorter consecutive enrollment time.

Natives vs. Transfers

There is statistical evidence for rejecting H2c, H3c, H4c and H5c. When compared with transfer students, native students generally take more coursework every term, achieve a higher credit passed ratio, switch their majors more frequently, and have longer consecutive enrollment times.

Concurrent Enrolled vs. Non-Concurrent Enrolled students (among URMs only)

There is no statistical evidence that concurrently enrolled students have different academic performance characteristics or that they demonstrate different enrollment practices (beyond enrolling in other institutions). However, since this data is limited to URM engineering students only, this finding is correspondingly limited.

Discussion of Implications

Our study reveals that women's early collegiate GPA in engineering programs is far more sensitive to admission scores and high school ranks. SAT math score, in particular, is more strongly associated with women's GPA than with men's. This finding indicates that SAT math, which is often used in admissions and placement decisions, may not predict equally well for men and women. Meanwhile, females tend to take lighter course load every term, and their credit passed ratio is higher than males'. This finding is particularly outstanding against the general trend that more credit taken is associated with higher academic performance. This suggests that female students tend to either take the courses they are most sure of, work harder than their male counterparts, or both.

Compared with other ethnicities, Hispanic American engineering students' GPA is more

associated with student admission criteria. With regard to enrollment practices, compared with White engineering students, underrepresented minorities have lower credit hours passed ratios, switch majors more frequently and remain consecutively enrolled longer. These three behaviors may be interrelated with each other, suggesting that URMs tend to face more difficulties in studying engineering, but they tend to engage in a greater variety of enrollment behaviors in order to work their way through their programs.

This study found that college GPA is differently related for women vs. men and for different ethnicities to SAT scores and high school performance. This conforms to the past research indicating that measures used to evaluate students often predict outcomes differently for different groups. For example, Thomas discovered that high school grades are more correlated with college grades for African-American women than they are for African-American men[17]. This phenomenon also suggests that high school intervention programs, especially those set up in the mathematics area, could lead to comparatively more academic achievement in engineering for women and Hispanic Americans.

We also found that for transfer engineering students, high-school performance, measured by percentile, is significantly less associated with early college GPA than it is for native students. Transfer students tend to switch major less frequently, but also seem to take less coursework every term, and obtain lower credit hour passed ratios. These factors seem to indicate an academic difficulty with transfer students' post-transfer engineering studies. However, one fact must be taken cautiously into consideration when one tries to interpret the findings on transfers—most students transferred to TAMU in their junior year, as compared with native students who entered as first time freshmen; therefore, the differences described may also be attributable to the difference in the class levels at which students' enrollment behaviors are recorded.

We did not find evidence to show that the practice of concurrent enrollment at more than one institution is related to early college GPA. Nor is concurrent enrollment associated with any other student enrollment behaviors examined in this study. This observation is encouraging considering the high number of students who take classes at multiple schools simultaneously[6]. If future studies are extended to encompass the White engineering students and confirm that concurrent enrollment does not affect student performance for the general population, educators can feel comfortable recommending that students take courses not offered at one school through another institution. Students could then feel free to take each course at whichever school is most convenient for them without having to worry about any negative effects

Finally, there are two findings of this study that apply to the general population. First, despite studies showing that certainty of major is related to persistence[2,4], we found no compelling evidence that number of major switches is related to students' early collegiate GPA in engineering programs. One possible interpretation is that engineering programs feature a range of common core courses, which makes it easy for students to

attempt different majors within the engineering school, although future studies are needed to investigate this possibility further. Second, the number of semesters a student is consecutively enrolled tends to be negatively correlated with GPA. Initially, this seems incongruent with the research showing that full-time students are more likely to persist than part-time students[3,11,7,10,16], and that persistence is related to GPA[2,4,11,12,14,16,18,20]. However, most of the students in our study were enrolled full-time at a tier-1 research university, and full-time students who take on too many hours may be at a disadvantage because they can not devote as much time to each class as can full-time students who take fewer hours.

Conclusions

The present study examines variables related to engineering students' academic performance, and indicates that different factors are important in predicting performance for different groups of students and that admissions criteria and intervention programs could be improved by considering these factors. In addition, full-time engineering students may do better when they do not overextend themselves by enrolling in too many credit hours. However, switching majors or being concurrently enrolled in more than one institution does not appear to affect academic performance in engineering disciplines. More research is needed to verify and expand our findings, and hopefully future studies will focus on continuing to explore the variables that predict and influence engineering academic performance for various nontraditional groups and on implementing interventions that optimize learning and success for all engineering students.

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