AC 2007-1549: RETENTION AND PERSISTENCE OF UNDERGRADUATE ENGINEERING STUDENTS: "WHAT HAPPENS AFTER THE FIRST YEAR?"

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Retention and Persistence of Undergraduate Engineering Students
"What happens after the first year?"

Abstract

As presented in the Phase I report, *The Engineer of 2020: Visions of Engineering in the New Century*, the changing demographics within countries, including the United States, where the number of minorities will grow rapidly in comparison with traditional majority groups, has major implications for the future of engineering, a profession where minorities and women are underrepresented. Engineering programs must find better ways to attract and retain minority students if the United States is to remain a technological leader. In order to develop more effective tools to increase retention an understanding of what influences the success or failure of engineering students is needed. In an earlier study to determine which student entry characteristics best determined long-term retention and graduation, we found for transfer students that the number of credits in math and science and previous GPA (Grade Point Average) are the strongest predictors of retention and academic achievement. In the case of freshmen students their placement in calculus played a major role in their ultimate success. This paper describes what happens from year to year and how retention and ultimately graduation are predicted by not only student entry characteristics, but also their academic performance in the first two years.
Our findings show that attrition in the second and third years is at its highest, but that it stabilizes after four years.

1. Introduction

Engineering programs must find better ways to attract and retain minority students if the United States is to remain a technological leader. As presented in the Phase I report, *The Engineer of 2020: Visions of Engineering in the New Century*, the changing demographics within countries, including the United States, where the number of minorities will grow rapidly in comparison with traditional majority groups, has major implications for the future of engineering, a profession where minorities and women are underrepresented[1]. In order to develop more effective tools to increase retention an understanding of what influences the success or failure of engineering students is needed.

The first two lines of the mission statement of the City College of New York (CCNY) are as follows:

"City College's mission emphasizes access and excellence in undergraduate and graduate education and research. Requiring demonstrated potential for admission and a high level of accomplishment for graduation, the college provides a diverse student body with exceptional opportunities in creative intellectual pursuits."

With a mission that emphasizes access, excellence and diversity for undergraduates and graduate students the goals of CCNY and the Grove School of Engineering at CCNY are very much in line with the ideas and objectives stated in the Engineer of 2020 report. However, maintaining the balance between these three, sometimes competing, goals is a major challenge. CCNY has a long history of accessibility, providing quality education to a diverse student body that was usually poor. CCNY was tuition-free from 1847, when it was established, until 1976, the first year tuition was imposed. In 1970 access to the school increased even further with the institution of the revolutionary program of "open enrollment" that provided every graduate of a New York City high school admission. Open enrollment helped to increase the number of African American and Hispanic students at CCNY. It also was blamed for the decline in the college's prestige during the 1970s and 1980s. In 1999, under great political pressure, "open enrollment" at CCNY ended. While it was thought that the demise of "open enrollment" would lead to a drastic drop in the enrollment of minority students at CCNY, this turned out not to be the case. While access is very important to public institutions, it is imperative that the student be properly prepared in order to reap the full benefits of a quality education. This idea is reflected in the phrase "Requiring demonstrated potential for admission…" found in the CCNY mission statement. In other words access, excellence and diversity need not be mutually exclusive ideas when considering admission.

In our previous work we studied the entry characteristics of engineering students that best determined long-term retention and graduation rates. This paper describes what happens from year to year and how retention and ultimately graduation are predicted by not only student entry characteristics, but also institutional and departmental characteristics.

2. A New Admission Criterion

In an earlier publication[2] where we studied a cohort of engineering students who started in the fall of 1999, we found that retention of transfer students was best predicted by the entry characteristics "number of math and science credits transferred", grade point average at the previous school(s), and choice of major (Electrical Engineering students were retained most, Computer Science students least). Freshmen retention was best predicted by program major (Chemical Engineering students were retained more than other engineering students), the level of math they could start at in engineering, and gender (women were more retained than men). Based on the above and other data about student retention, the Grove School of Engineering decided in the fall of 2005 to change its admission criteria and to direct students who did not (yet) fulfill the admission criteria to a new program, the Gateway program, so they could postpone matriculation until they could go into Engineering or choose another major instead, without having the experience of having 'failed' in Engineering.

For entering freshmen, previously an admissions index that considered numerous academic parameters such as the student's College Admissions Average (CAA), SAT (Scholastics Aptitude Test) scores and when applicable TOEFL scores, were used to determine whether a student would be admitted to the school of engineering. If a student received an index number over a certain minimum score they were admitted. Students

were also required to take a placement examination for math but the examination had no bearing on the their admission. The new engineering admissions criteria for freshmen now requires, in addition to a minimum index score, placement in pre-calculus or higher. For transfer students the new criteria requires the completion of Calculus I with a C or higher, an overall GPA of 2.50 or higher and demonstrated proficiency in mathematics and science.

This raised some concerns about the accessibility of Engineering to minority (Black and Hispanic) students, since minority students were assumed to have had less educational opportunities in high school than White and Asian students. The fall 1999 cohort in the Grove School of Engineering consisted of 11% White students, 32% Black students, 29% Hispanic students, and 29% Asian students, out of a total of 291 students who had indicated their ethnicity. We found that ethnicity played no relevant role in predicting long term retention in the fall 1999 cohort. Section 3 explores what would have happened to the ethnic composition in the Grove School of Engineering, had the new admissions criteria of the fall of 2005 been in effect.

In general, if the fall 1999 cohort had been submitted to the new admissions criteria, 44% of the 123 admissible freshmen would have been retained (almost all graduated by fall 2006), versus 27% of the 70 not admissible (X^2=5.33, df=1, $p < .05$). Of the transfers, 64% of the 55 admissible students would have been retained (all graduated by fall 2006), versus 31% of those who would not have been admitted (X^2=14.97, df=1, $p < .001$). In addition, students who did not fulfill the admissions criteria, but who draduated after all, took on average much longer to graduate than the students who fulfilled the admissions criteria.

Table 1 and Table 2 show the year to year retention for transfers and freshmen. For both groups, attrition has stabilized after four years, with most of the attrition occurring during the second and third years. Attrition does not mean drop-out from academe. We were able to track almost half of the students who had left the School of Engineering.

Of the 201 students who were not graduated or still in Engineering by the fall of 2006, 115 (57%) had left the CUNY system altogether, but may have been accepted at a non-CUNY school, e.g., in the SUNY (State University of New York) system or a private school. Thirty students (17)% had graduated from, or were still in another City College program, twenty-six (13%) were accepted at a CUNY community college, twenty-four (12%) were accepted at a CUNY 4-year school other than CCNY, 5 students had applied to a non-specified CUNY school and 1 student had graduated from a non-CUNY school. Among the leavers, Economics and other business-oriented programs were very popular.

Since freshmen retention after the first year turned out to be very high, it made no sense to try and predict it using entry characteristics. The only thing that correlates significantly with retention after one year is the number of credits that were obtained in the first year. The few freshmen who did not come back in the second year passed significantly less credits (on average 14.3) than the students who stayed on after one year (on average 20.8) (*Eta squared*=.05, *df*=1, *F*=10.6, *p*=.001).

	Freshmen (N=193)			Transfers (N=143)		
by:	Left	in SOE	Graduated	Left	in SOE	Graduated
Fall 2000	8	92		18	82	
Fall 2001	31	69		38	59	3
Fall 2002	48	52		48	38	15
Fall 2003	58	39	3	54	18	29
Fall 2004	60	22	19	52	14	34
Fall 2005	62	6	33	55	8	37
Fall 2006	62	2	36	57	3	41

Table 1. Year to year retention of freshmen and transfers cohort fall 1999.

	Freshmen (N=123)			Transfers (N=55)		
by:	Left	in SOE	Graduated	Left	in SOE	Graduated
Fall 2000	8	92		16	84	
Fall 2001	28	72		20	75	6
Fall 2002	42	59		31	36	33
Fall 2003	53	42	5	36	7	56
Fall 2004	54	19	28	33	7	60
Fall 2005	56	2	42	35	2	64
Fall 2006	56	1	43	36		64

Table 2. Year to year retention of freshmen and transfers cohort fall 1999 for students who would have fulfilled the 2004 admissions criteria.

More can be said about retention after the second year, for the students who were retained after the first year. Retention for this group was predicted again by the total number of credits obtained (by successfully completing courses) in the first two years and in addition by the grade in the first math course they took, irrespective of the level of the course. These two variables together explained 31% of variance in a discriminant analysis with retention after two years as the criterion. The entry characteristics that were found earlier to predict long-term retention (gender, math entry level and major) had no significant direct correlations with retention after two years.

It appears that “previous study progress” (the accumulation of credits for courses successfully completed) and math achievement are important predictors for early retention. Further analyses will be directed at more precise measures of math achievement than the simple measure of the first grade in math while in the School of Engineering. For now, the data seems to support the idea that early intervention for freshmen, that improves “previous study progress” and math achievement in the first and second years, can strengthen retention. It is commonly understood that early intervention is always a good thing. However, knowing what type of intervention to employ is not always obvious. A study of predictors for early retention for transfers is in progress and we hope to be able to say more about transfers at the conference.

3. Ethnicity and Math Preparedness

As was stated earlier in this report, when the admissions criterion for the Grove School of Engineering was changed and made more selective, considerable concern was expressed by the college community over the impact this would have on the enrollment of underrepresented groups. Many felt that underrepresented groups, particularly Black and Hispanic students, would be at a disadvantage and the demographics of the school would change considerably. To address this valid concern the question was asked:

Would minority students be more disadvantaged than non-minority students with a more selective admissions criterion? The answer to this question is, that it depends on how you develop and implement the criterion and how you define disadvantaged.

The new Grove School of Engineering admissions criterion for freshmen requires that entering freshmen be able to start in Pre-Calculus (Math 19500).

Of the 193 freshmen in cohort fall 1999, 170 indicated their ethnicity. Of these 170, 112 could start in Pre-calculus or higher, and 72 in Calculus 1 or higher.

The ethnic composition of the freshmen cohort for all freshmen (n=170) was:
White 6%, Black 34%, Hispanic 28%, Asian 32%.
Among those who could start at math 195 or higher (n=112), the composition was:
White 6%, Black 32%, Hispanic 21%, Asian 40%.
Among those who could start at math 201 or higher (n=72), the composition was:
White 6%, Black 28%, Hispanic 21%, Asian 46%.

Among freshmen, we can see that from the fall 1999 cohort, the percentage of Asians increased, and the percentage of Black and Hispanic students dropped with increasing selectivity. The new admissions criterion would not have meant a large drop (2%) in the percentage of Black students, from 34 to 32 percent.

The new engineering admissions criteria for transfer students require they start in Calculus II (Math 20200) or higher, have a GPA of at least 2.50, and are proficient in science (interpreted for this study as having at least three transfer credits in a science discipline).

Of the 143 transfers in cohort fall 1999, 60 indicated their ethnicity and were previously in a 2-year college. Of these 60 students, 51 could start in Calculus I or higher, 43 in Calculus II or higher, and 25 fulfilled the present admission criteria for transfer students.

The ethnic composition of the transfer cohort for all transfers from 2-year colleges was:
White 13%, Black 27%, Hispanic 35%, Asian 25%.
Among those who could start at math 201 or higher (n=51), the composition was:
White 14%, Black 31%, Hispanic 29%, Asian 26%.
Among those who could start at math 202 or higher (n=43), the composition was:
White 12%, Black 33%, Hispanic 28%, Asian 28%.

Among those who fulfilled the present transfer admission criteria (n=25), the composition was:

White 12%, Black 36%, Hispanic 24%, Asian 28%.

Among transfers from 2-year colleges, we can see that the percentage of Black students would have increased, and the percentage of Hispanic students decreased, under the present admission criteria. For Whites and Asians, there would have been no difference.

4. Satisfaction with the Program, Achievement and Retention.

From data that was collected among senior students in three departments, we have departmental level measures of the student ratings of the relationship between faculty and students, academic facilities (such as labs, computers and classrooms), and the strength of the education received by the senior year. The data was collected over the period of January 2001 to December 2004, in which we can assume that most of the students in the fall 1999 cohort were in the School of Engineering and participated in engineering courses. All indicators were measured on a scale for 1=poor to 5=excellent, with 3=adequate. In addition, the students provided an answer to the question, if they would recommend their department to family and friends. Table 3 shows the results for the three departments (Civil Engineering, Chemical Engineering, and Mechanical Engineering).

Table 3. Senior Student Satisfaction Indicators in the Period January 2001 to December 2004					
Department	Recommend Department	Student –Faculty Relationship	Academic Facilities	Strength of Education	Number of Students
Civil	74%	3.15	2.61	3.57	74
Chemical	66%	3.26	3.34	3.87	38
Mechanical	91%	4.10	3.29	4.00	90
Scale: 1 = poor to 5 = excellent, with 3 = =adequate					

Table 3. Senior student satisfaction indicators in the period of January 2001 to December 2004

We see from Table 3 that there are differences between departments, especially between Mechanical Engineering and the two other departments, with Mechanical Engineering scoring significantly higher than the other two departments on student recommendation of the department and quality of the student-faculty relationship. In addition, in the period under consideration Civil Engineering scored relatively low on the quality of academic facilities.

Only students who have completed discipline specific courses can be expected to have been exposed to departmental characteristics to some extent. This also means that departmental characteristics start to "work" only after students have already made it into engineering courses, which requires the completion of at least Calculus I. The departmental retention rates of the fall 1999 cohorts, once students had completed at least 3 engineering credits in Civil, Chemical or Mechanical Engineering, did not differ very

much: 56% for Civil, 61% for Chemical, and 55% for Mechanical Engineering (Note: students who changed departments, and were retained for Engineering, were not considered retained in the departmental retention rate, hence the relatively low percentages).
The major cumulative grade point average (MGPA) in Civil Engineering courses (2.20) was about half a point lower than the grade point average in Mechanical (2.61) and Chemical Engineering (2.78) courses. The general grade point average (GPA) is less relevant here, since it is calculated over many courses that are not offered in Engineering (e.g., liberal arts, science and math courses).

Since there was little variation between departments in retention rates, possible correlations between retention and institutional variables could not be explored. There was some variation in academic achievement between departments in MGPA, to the effect that the department with the lowest scores on academic facilities and strength of education also had the lowest scores on academic achievement in terms of MGPA. We need more data from more departments however, to be able to say more about the nature of the relationship between achievement in engineering courses and departmental characteristics. For instance, a relatively low MGPA could also be related to the grading practice in a particular department, which is also a departmental characteristic, but at present we have no reliable data about grading practices in each department. It would have been very helpful if we had been able to connect individual students' perceptions of departmental characteristics to their retention, not only for seniors, but all engineering students, as well as those who left the school.

5. Conclusion

It is imperative that the engineering schools and industries of this country balance the three-legged stool of access, excellence and diversity if the United States is to remain technologically competitive in the world arena. While at one time diversity in engineering may have been a secondary concern, but with the shift in the world population where majority groups are decreasing and minority groups are increasing, it has become a critical issue. Universities are compelled to be more aggressive in producing engineers from underrepresented groups (Black, Hispanics, Native Americans, Women). Recruiting, retaining and ultimately graduating students from underrepresented groups requires an understanding of the characteristics that best determines or predicts their success.

In this report, we have demonstrated the importance of data driven changes in admissions policy and procedures and the role data analysis can play in understanding and improving the retention and graduation rates of engineering students from diverse backgrounds. We considered several scenarios where the admissions criterion for the school of engineering became more and more selective. As one would think as the requirements for admission became more competitive (tougher), retention and graduation rates improved. Also somewhat predictable is that mathematics and science preparation is a good predictor of academic success. However, we also observed in the case of freshmen students, that a more selective admissions criterion (placement into pre-calculus freshmen year) had little

impact on the demographics of the engineering freshmen population, causing a small drop of two percent in the number of Black students. This outcome was not obvious. In a similar fashion we observed that as the admissions criterion for transfer students became more selective (requiring more advanced mathematics at each level) that in one scenario (the current transfer admission criterion) the percentage of Black students admitted (36%) was greater than that for White students (12%). Unfortunately, there was a significant drop of 11% in the number of Hispanic students (24%), reminding us of the importance of paying close attention to the impact of subtle changes in policy and criterion.

To study the nature of the relationship between achievement in engineering courses and departmental characteristics (e.g., academic facilities, strength of education, student faculty relationship) requires more departmental data. Even though we observed some variation in "academic achievement" (MGPA) between departments- to the effect that departments with the lowest scores on "academic facilities" and "strength of education" also had the lowest "academic achievement" scores- the connection was not conclusive. For example, a low MGPA score could be the result of the grading practices in a particular department and have little to do with the other departmental characteristics.

In future works, we plan to examine the impact of the departmental characteristics on the retention and academic achievement of engineering students as well as continue to study the predictors of retention, graduation and academic achievement. We will also explore the challenges in implementing new policies, gaining buy-in from the college community and the importance of good communication both in and outside of the college campus.

Bibliography

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