AC 2009-454: AN INITIAL ANALYSIS OF FRESHMAN-TO-SOPHOMORE RETENTION IN A NEW FIRST-YEAR ENGINEERING PROGRAM

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Initial Analysis of Freshman-to-Sophomore Retention in a New First-Year Engineering Program

Abstract

During the 2007-2008 academic year, the University of Arkansas (UofA) implemented the Freshman Engineering Program (FEP),a new first-year experience program for engineering students. The FEP was originally proposed to the UofA engineering faculty as an effort to improve the retention of new engineering students from their freshman to their sophomore years. As a result, the activities of the Academic and Student Services Sub-Programs executed by the faculty and staff of the FEP are all intended to improve students' likelihood of academic success and/or to increase students' desire to pursue an engineering degree. Since improving freshman-to-sophomore retention was a primary goal of the FEP, a significant amount of data has been collected on each of the 343 students enrolled in the first FEP cohort. This data includes demographic information, ACT (or similar) scores, high school GPA, Advances Placement (or similar) scores, scholarship data, fall 2007 class schedule and grades, spring 2008 enrollment data, spring 2008 class schedule and grades, fall 2008 enrollment data, and information related to the process used by students in selecting their engineering major for the sophomore year. Our primary objective in constructing this data set is to facilitate the completion of an exploratory data analysis to examine the interrelationships among the variables in hopes of identifying more effective methods for predicting student success in engineering. The long-term goal is to use the information and models obtained from this analysis to identify intervention programs that will promote increased retention rates for these students. In this paper, we present what we view to be the most interesting results of our initial analysis of this data. These results will range from tabulated counts from selected categories of the data to statistical models of relationships between these categories. We also present a brief synopsis of the activities associated with the executing of the Academic and Student Services Sub-Programs of the FEP.

Review of the Literature

A plethora of research has been generated regarding the prediction of success in college (Young and Korbin[11]; Burton and Ramist[4]; Ting[8]; Pennock-Roman[7]; Wilson[10]; Bamforth et al.[1]). However, a growing concern among researchers is the ability to retain students in the quantitative fields like math, science, and engineering. Retention of students is defined as either graduation or concurrent enrolment in a specific academic field. Without retention of students in math- and science-based fields, national and local economies suffer due to the increased demand for such research and development professionals (NARSET Report[6]). Retaining students is a growing concern in many university departments, especially in the field of engineering. According to the National Access and Retention in Science, Engineering and Technology (NARSET) Report[6], two factors determine the success of economic development in a country: 1) the amount and quality of human resources available, and 2) the extent of the research and development capacity. Without a retention and attraction program in place, the supply of graduates from the fields of science, engineering, and technology is unlikely to significantly grow. Identification and targeting of factors which influence retention is critical to the future growth of university engineering programs. Through the identification of prediction factors, specific programs and models can be created which aid in the development of retention and success programs for current students. Predictive modeling can also aid in the identification, attraction, and support for future students.

Research has shown that many factors such as gender, high school GPA, math and verbal SAT scores, and ethnicity contribute to college success of students and retention in science-based academic programs (Zhang et al.[12], Bamforth et al.[1], Budny et al.[3], NARSET Report[6], Pennock-Roman[7], Wilson[10]). Other associated factors known to influence the completion of a program include psychological, social, and cultural factors. Due to many associated factors, collecting and maintaining longitudinal tracking systems is often a complicated and expensive endeavor (Brainard and Carlin[2]). According to the National Research Council in 1998, the inadequacies and inconsistencies of collection and maintenance of evaluation and retention data are major hindrances to projecting future manpower needs and identifying problems in the sciences field. Without access to consistent data which predicts success, engineering programs lack the ability to pinpoint deficiencies within their academic program and keep talented students. In addition to increasing attrition rates within engineering majors, another problem faced by departments is attracting talented high school applicants. Felder et al.[5] in their study on longitudinal engineering performance and retention found that both the increasing difficulty of attracting high school students into engineering and high attrition rates of enrolled engineering students have lead to the major decline in the graduation rates. With the need for math-based degrees on the rise, low graduation and attraction rates serve as a major detriment to local economies. Because of this fact, all prediction factors for college success, academic and non-academic, must be evaluated at the college as well as high school levels.

Some common tools utilized by colleges in the admissions process are standardized test scores such as the SAT and ACT as well as high school performance in academic and community endeavors. For most colleges and universities, high school GPA and math SAT scores are positively correlated with graduation rates (Zhang et al.[12]). However, the most frequently used criterion to assess the predictive validity of admissions based upon test scores is the freshman GPA (Wilson[10]).However due to the rigors associated with the degrees, grades of students in the math and science fields of college tend to be lower than scores received in high school. These lower grades can lead to a lowered math confidence and increased risk of failure. Because the distribution of grades for physical science and engineering majors tend to more frequently be in the range of C or below (Pennock-Roman[7]), students may be more inclined to seek a degree in the fields of arts and humanities where grade distributions are higher. Willingham's[9] study with engineering students' attrition rates found that students tended to migrate to majors where grading standards best fit their levels of preparation and lead to feelings of greater success. He found that the best-prepared students tend to major in more stringent disciplines whereas least-prepared students focus on more lenient disciplines. A more lenient degree where higher grades are possible could be viewed as appealing to an engineering student struggling in math.

In preparation for college, many potential pre-engineering students engage in harder science and math classes in college as well as high school. However, many students find that for the field of engineering that they have gaps in their mathematical knowledge: gaps often due to the diversity of mathematical curricula taught in high schools. In most higher education institutions, a growing awareness exists in regards to the lack of mathematical preparedness exemplified in freshman students for harder math and science courses (Bamforth et al.[1]). This lack of knowledge of needed math skills and low levels of success can lead students to develop low self confidence in their ability to obtain a math-based degree during their freshman year; and unfortunately, research has shown that the freshman year can be critical to predicting the future success of an engineering student (Zhang et al.[12]). Because of this mathematical diversity of the student intake, the Engineering Council in 2000 recommended that students embarking on a mathematics-based degree should have a diagnostic test before beginning the program and intervening support be provided immediately (Bamforth et al.[1]). Through the provision of support to pre-engineering students lacking certain skills, mathematical competency can be reinforced and strengthened. This type of individualized support leads to the development of basic needed skills needed for the profession as well as increased student confidence in mathematics.

Demographic factors which affect engineering students are gender and minority status. Due to the major decline in graduation rates, most engineering schools have undertaken major recruitment efforts directed at women and minorities (Felder et al.[5]). Typically, more males than females major in engineering and physical sciences whereas more females major in the social sciences and humanities (Pennock-Roman[7]). Many non-cognitive variables are associated with attraction and retention rates of women and minorities in the engineering field. In a study by Brainard and Carlin[2], the most frequent non-cognitive barriers associated with women students in engineering are fear of losing interest, intimidation, lack of self-confidence, and poor advising. The researchers also found that young women who changed their major had experienced a loss of self-confidence prior to loss of performance in math and science classes; thus showing it was not a lack of ability that prompted the change. However, the successful establishment and accomplishment of women in many university engineering programs is an acknowledgement of the theory that given support and opportunity women can survive and thrive in a male-dominated field (Brainard and Carlin[2]). The same theory could apply to minority students.

Over the past several years, the retention of underrepresented groups has been a growing concern in the fields of science and engineering (Brainard and Carlin[2]); therefore, universities have increased their recruitment efforts to target more women and minorities. According to Young and Kobrin[11], racial and ethnic differences in success rates in college involve: 1) psycho-social differences, 2) differences in pre-college academic preparation (as compared to the majority white students), 3) institutional factors, and 4) statistical research and design artifacts inherent in the manner that the studies were conducted. In research on minority students and college success, adjustment to college and university life in predominantly white institutions is considered to be more difficult (Younhg and Korbin[11]; Ting[8]). However, the analysis of the differential validity and prediction results becomes a challenge to predict because none of the minority groups share the same patterns in their findings (Young and Korbin[11]). Although many different variables exist between different minority engineering students, some of the shared non-cognitive variables associated with retention and support are psychological, social, and cultural factors like coping with racism and retaining a positive self-concept (Ting[8]).

The Freshman Engineering Program at the University of Arkansas

During the 2007-2008 academic year, the University of Arkansas (UofA) implemented the Freshman Engineering Program (FEP), a new first-year experience program for College of Engineering (CoE) students at the UofA. The objective of the FEP is to support the achievement of the retention and graduation rate goals established by the CoE, with particular emphasis on the retention of new freshmen to their sophomore year. Meeting this objective requires establishing the foundation for the academic and professional success of new freshmen entering the CoE by:

- delivering appropriate educational content to FEP students so that they are academically and technically prepared to move on to a discipline-specific CoE undergraduate program;
- providing FEP students having Advanced Placement (AP) or transfer credit with opportunities to pursue more advanced coursework aligned with their academic interests;
- introducing FEP students to the various CoE disciplines so that they appreciate and understand the multi-disciplinary nature of the engineering and computer science professions;
- assisting FEP students who are undecided about their intended major with choosing a major appropriate for their skills and interests (the eight majors available to CoE students are Biological Engineering, Chemical Engineering, Civil Engineering, Computer Engineering, Computer Science, Electrical Engineering, Industrial Engineering, and Mechanical Engineering);
- providing FEP students with academic, career, and personal advising in a proactive manner;
- fostering a sense of community among FEP students, other CoE students, the CoE faculty, and the balance of the UofA community.

The FEP is executed via two sub-programs – the Freshman Engineering Academic Program (FEAP) and the Freshman Engineering Student Services Program (FESSP). These sub-programs are executed by a faculty Director, two full-time professional staff members, one full-time instructor, volunteer CoE faculty (who teach in the program), and seven graduate teaching assistants (one from each CoE academic department – note that the Computer Engineering and Computer Science degrees are offered by a single department, Computer Science and Computer Engineering).

The Freshman Engineering Academic Program

The FEAP is a two-semester, thirty-credit-hour program. The required courses in the Fall Semester are:

GNEG 1111	Introduction to Engineering I
MATH 2554	Calculus I
CHEM 1103	University Chemistry I
PHYS 2054	University Physics I
ENGL 1013	Composition I

Note that the scheme used at the UofA to number courses is such that the fourth digit in a course number corresponds to the number of semester credit hours for the course.

The required courses in the Spring Semester are:

GNEG 1121	Introduction to Engineering II
MATH 2564	Calculus II
ENGL 1023	Composition II
	Freshman Engineering Science Elective (4 credit hours)
	University Core Elective (3 credit hours)

For the Freshman Engineering Science Elective, FEP students choose between CHEM 1123/1121L University Chemistry II (with laboratory) and PHYS 2074 University Physics II. This selection has no impact on the students' selected CoE major at the conclusion of their first year.

The University Core Elective can be any course that satisfies one of the requirements of the UofA core curriculum in the social sciences, humanities, and fine arts.

Like similar students at many of our peer institutions, a significant number of FEP students do not have the mathematics ACT score (26 or greater) required to enroll in MATH 2554 as a new freshman. Most of these students qualify to take MATH 1285 Precalculus Mathematics. Successful completion of MATH 1285 qualifies students to take MATH 2554. A few of our students must begin their mathematics courses in MATH 1203 College Algebra (two semesters behind MATH 2554), and a very small number must begin in MATH 0003 Beginning and Intermediate Algebra (three semesters behind MATH 2554). Note that FEP students who are not calculus-ready are also not eligible to enroll in PHYS 2054. For FEP students who take MATH 1285 in the Fall Semester, the MATH 2554 and PHYS 2054 requirements shift to the Spring Semester, the Freshman Engineering Science Elective must be CHEM 1123/1121L, and the University Core Elective shifts to the Fall Semester. These students are then one MATH class behind at the end of the Spring Semester.

Honors sections of MATH 2554, MATH 2564, CHEM 1123/1121L, PHYS 2054, PHYS 2074, ENGL 1013 and ENGL 1023 were available to qualified FEP students during the 2007-2008 academic year. Enrollment in the Honors College at the UofA requires a composite ACT score of at least 28 and a high-school GPA of at least 3.5.

In implementing the FEAP, extensive interaction with the UofA Fulbright College of Arts and Sciences is required. Most importantly, the FEP staff works closely with the Fulbright College to implement block scheduling for the Fall Semester. In the block scheduling system, each FEP student is assigned to a block consisting of 22 students. All students in a given block have identical class schedules.

The Freshman Engineering Student Services Program

The FESSP provides proactive support to FEP students through summer orientation, academic skills and personal wellness workshops, academic advising, peer mentoring, supplemental instruction and tutoring, and extracurricular activities. The FESSP is housed in the 5500 sq ft Freshman Engineering Center. The Freshman Engineering Center includes faculty and staff offices, a peer mentoring center, a tutoring room, a project room, a 60-seat computer lab, and a large study lounge. The peer mentoring program is staffed by approximately 25 CoE sophomores, juniors, and seniors. Participation in the peer mentoring program is required as part of GNEG 1111 and GNEG 1121. The supplemental instruction and tutoring activities are offered via the UofA Enhanced Learning Center (ELC). Because of the historical struggles of first-year CoE students at the UofA, ELC activities are primarily focused on MATH courses.

The Introduction to Engineering Course Sequence

A key element of both the FEAP and the FESSP is the Introduction to Engineering course sequence (GNEG 1111 and GNEG 1121). The goal of these courses is to prepare FEP students for their transition into a discipline-specific CoE undergraduate program. In both courses, a variety of engineering topics (statics, DC circuits, statistics, engineering economics, mass balance, etc.) are used to train the students on applying a disciplined approach to completing engineering homework assignments. These topics are also used to facilitate the development of FEP students' abilities in spreadsheet modeling (using Microsoft Excel) and computer programming (using Visual Basic for Applications behind Microsoft Excel). Throughout the courses, the primary emphasis relative to grading is placed on submitting complete, correct, and neat homework in a timely fashion. Most FEP students find that achieving a high grade in GNEG 1111 and GNEG 1121 is a result of beginning assignments in a timely fashion, diligently following directions, and taking advantage of resources available for assistance. As such, the FEP faculty and staff consider the grades in GNEG 1111 and GNEG 1121 to be accurate measures of the students' work ethic.

The Introduction to Engineering course sequence also provides a forum for many activities related to CoE major selection, career development (resumes, interview skills, job search strategies, coops and internships, etc.), academic skills development (note taking, test preparation strategies, etc.), and personal wellness. Relative to major selection, several GNEG 1111 and GNEG 1121 class meetings are dedicated to departmental information and recruiting sessions. These sessions culminate with Decision Day, a class meeting in March during which students announce their CoE major, and a project in GNEG 1121 associated with their selected major.

The Fall 2007 Freshman Engineering Program Cohort

The Fall 2007 FEP (FY07) cohort includes 343 students. Under the UofA definition, the students in the FY07 cohort include all students who were new to the UofA in the Fall Semester of 2007, entered the UofA with 24 or fewer transfer credits, and were enrolled in the CoE on the 11th day of class in the Fall Semester of 2007. Cohorts of this type are used to track retention and graduation statistics at the UofA.

Cohort Demographics

Of the 343 students in the FY07 cohort, 290 (85%) are male, 276 (81%) are Caucasian, 22 (6%) are Asian-American, 16 (5%) are African-American, 11 (3%) are Hispanic-American, 9 (3%) are Native American, 334 (97%) are from the United States, and 240 (70%) are from Arkansas.

Cohort Academic Preparation

Table 1 includes summary statistics regarding the 323 students in the FY07 cohort who entered the UofA with verified ACT scores. Table 2 contains summary statistics regarding the 341 students in the FY07 cohort who entered the UofA with a verified high-school GPA. Table 3 contains summary statistics on the AP credit obtained by students in the FY07 cohort for courses that are required in the FEAP. These statistics reported in Tables 1-3 are consistent with what is typical for first-year UofA CoE students in the past decade.

	ACT Composite	ACT English	ACT Mathematics	ACT Reading	ACT Scientific Reasoning
average	27.3	27.4	28.1	27.8	27.6
median	27	28	28	28	27
% scoring 30 or more	30%	34%	39%	39%	33%

Table 1. ACT Score Statistics of the FY07 Cohort

average	3.74
median	3.84
% of students scoring at least 4	30%

Table 2. High-School GPA Statistics for the FY07 Cohort

Course	% of students having AP credit
MATH 2554	23%
MATH 2564	4%
CHEM 1103	4%
PHYS 2054	1%
ENGL 1013	10%
ENGL 1023	2%

Table 3. AP Credit Statistics for the FY07 Cohort

Fall Semester Academic Performance

Table 4 includes the Fall Semester 2007 distribution of grades (including withdrawals) received by students in the FY07 cohort in a set of key courses that are closely monitored by FEP faculty and staff. Because of the observed differences between MATH 2554H Honors Calculus I and

MATH 2554, MATH 2554H is separated from MATH 2554 in Table 4. The grades from every other honors course are included with the grades from the non-honors course having the same number. Table 4 also includes the percentage of students who passed each course, and the average grade point achieved in each course. Note that a grade of C or better is required to advance to the next MATH course at the UofA, and withdrawals are not included in grade point averages.

	A	B	C	D	F	W	Total	% Passing	Average Grade Point
GNEG 1111	194	56	31	14	21	19	335	88%	3.2
MATH 1203	0	1	5	1	4	5	16	38%	1.3
MATH 1285	15	20	13	10	9	5	72	67%	2.3
MATH 2554	12	34	32	18	19	31	146	53%	2.0
MATH 2554H	13	10	9	3	4	8	47	68%	2.6
MATH 2564	13	15	10	2	1	6	47	81%	2.9
MATH 2574	3	2	2	0	1	0	8	88%	2.8
CHEM 1103	64	65	67	34	43	34	307	75%	2.3
PHYS 2054	65	69	19	5	2	4	164	96%	3.2

Table 4. Fall Semester 2007 Academic Performance of the FY07 Cohort

As mentioned previously, the FEP faculty and staff believe that the grade in GNEG 1111 is an accurate measures of a student's work ethic. Specifically, they feel that a grade of A generally reflects an adequate work ethic, a grade of B generally reflects a marginal work ethic, and a grade of C or lower (including most withdrawals) generally reflects a poor work ethic. Therefore, we use the GNEG 1111 grade as a descriptor of work ethic in the remainder of this paper.

Anecdotal data suggests that grades in the first-semester MATH class are of great concern to all faculty and staff members (across all colleges and universities with engineering programs) who work with first-year engineering students. Such concern is shared by the FEP faculty and staff. In the Fall Semester of 2007, only 58% of the students in the FY07 cohort who attempted MATH 1203, MATH 1285, MATH 2554, or MATH 2554H received a passing grade. Therefore, performance in these problematic MATH classes is our first topic for additional analysis.

Table 5 breaks down by GNEG 1111 grade the Fall Semester 2007 grade distribution of students in the FY07 cohort across all of MATH 1203, MATH 1285, MATH 2554, and MATH 2554H. The purpose of this breakdown is to assess grade distribution in the problematic MATH courses using the surrogate measure of student work ethic. If we accept the measure of work ethic as defined by the FEP faculty and staff, then the statistics in Table 5 indicate that, in these problematic MATH courses, the vast majority of the students with an acceptable work ethic pass, about half of the students with a marginal work ethic pass, and the vast majority of students with a poor work ethic fail or withdraw.

Table 6 breaks down by mathematics ACT score the Fall Semester 2007 grade distribution of students in the FY07 cohort attempting MATH 2554. The purpose of this breakdown is to assess grade distribution in the entry-level calculus course using an accepted measure of preparation for college-level mathematics. The statistics in Table 6 indicate that students just above the ACT threshold for entry in to MATH 2554 pass at a very low rate.

		Distribution of MATH Grade								
		A	B	C	D	F	W	Total	% Passing	Average Grade Point
GNEG 1111 Grade	A	36	49	32	10	6	13	146	80%	2.7
	B	2	12	14	11	2	11	52	52%	2.0
	C or worse	1	4	13	12	29	23	82	22%	0.9

Table 5. Fall Semester 2007 MATH Performance by GNEG 1111 Grade
(including only MATH 1203, MATH 1285, MATH 2554, MATH 2554H)

		Distribution of MATH 2554 Grade								
		A	B	C	D	F	W	Total	% Passing	Average Grade Point
ACT Math. Score	26 or less	1	4	4	7	7	10	33	27%	1.3
	27	1	1	4	4	1	9	20	30%	1.7
	28	0	3	4	1	3	3	14	50%	1.6
	29	1	3	7	2	1	3	17	65%	2.1
	30	0	6	6	1	2	5	20	60%	2.1
	31 or 32	4	8	4	1	2	1	20	80%	2.6
	33 or more	4	6	3	1	1	0	15	87%	2.7

Table 6. Fall Semester 2007 MATH 2554 Performance by ACT Mathematics Score

Table 7 breaks down by mathematics ACT score the Fall Semester 2007 grade distribution of students in the FY07 cohort attempting MATH 2554H. The purpose of this breakdown is to assess grade distribution in the honors entry-level calculus course using an accepted measure of preparation for college-level mathematics. The statistics in Table 7 indicate that students just with an ACT mathematics score of less than 30 pass MATH 2554H at an unacceptable rate for an honors course.

Another area of historical concern in the UofA CoE is first-semester engineering student performance in chemistry. In the Fall Semester of 2007, 75% of the students in the FY07 cohort who attempted CHEM 1103 passed, but only 64% received a grade of A, B, or C. Therefore, performance in CHEM 1103 is our second topic for additional analysis.

Table 8 breaks down by GNEG 1111 grade the Fall Semester 2007 grade distribution of students in the FY07 cohort attempting CHEM 1103. The purpose of this breakdown is to assess grade distribution in the CHEM 1103 using the surrogate measure of student work ethic. The statistics in Table 8 indicate that, in CHEM 1103, almost all students with an acceptable work ethic pass, the majority of the students with a marginal work ethic pass, and the majority of students with a poor work ethic fail or withdraw.

		Distribution of MATH 2554H Grade								
		A	B	C	D	F	W	Total	% Passing	Average Grade Point
ACT Math. Score	29 or less	2	3	2	3	2	2	14	50%	2.0
	30 or 31	3	4	2	0	0	3	12	75%	3.1
	32 or 33	2	2	2	0	2	0	8	75%	2.3
	34 or more	5	1	2	0	0	3	11	73%	3.4

Table 7. Fall Semester 2007 MATH 2554H Performance by ACT Mathematics Score

		Distribution of CHEM 1103 Grade								
		A	B	C	D	F	W	Total	% Passing	Average Grade Point
GNEG 1111 Grade	A	63	53	36	13	0	8	173	95%	3.0
	B	1	8	19	8	9	8	53	68%	1.6
	C or worse	0	4	11	13	34	17	79	35%	0.8

Table 8. Fall Semester 2007 CHEM 1103 Performance by GNEG 1111 Grade

Table 9 breaks down by attempted MATH class the Fall Semester 2007 grade distribution of students in the FY07 cohort attempting CHEM 1103. The purpose of this breakdown is to assess grade distribution in CHEM 1103 based on MATH placement. The statistics in Table 9 indicate that students who are not calculus-ready struggle with CHEM 1103 much more than their calculus-ready peers.

		Distribution of CHEM 1103 Grade								
		A	B	C	D	F	W	Total	% Passing	Average Grade Point
MATH Course	1203 or 1285	3	7	19	13	17	19	78	54%	1.4
	2554	19	41	33	15	23	10	141	77%	2.1
	2554H 2564 or 2574	42	17	14	5	2	4	84	93%	3.2

Table 9. Fall Semester 2007 CHEM 1103 Performance by MATH Course

Interventions Based on Fall Semester Academic Performance

Based on our analysis of the Fall Semester 2007 academic performance of the FY07 cohort, the FEP faculty and staff took several actions for subsequent academic years.

- Based in part on the statistics in Tables 5 and 8, more emphasis is being placed on developing a strong work ethic in the early weeks of GNEG 1111.
- Based in part on the statistics in Table 6, the FEP supported the proposal of the Department of Mathematics to raise to 27 the ACT mathematics threshold for entry into MATH 2554. A proposal to raise the threshold further are under consideration.
- Based in part on the statistics in Table 7, the FEP faculty and staff are more cautious in advising students to enroll in MATH 2554H.
- In consideration of the statistics in Table 9, the FEP faculty and staff are considering a redesign of the FEAP for students who are not calculus-ready.

Fall-to-Spring Retention

In the Spring Semester of 2008, 75% of the FY07 cohort (257 students) returned to the CoE, 17% (60 students) returned to the UofA but not the CoE, and 8% (26 students) did not return to the UofA. These percentages were very similar across both genders and across the home state of students. With regard to ethnicity, 83% of underrepresented minorities (African-American, Hispanic-American, and Native American) returned to the CoE for the Spring Semester of 2008. We refer to the students in the FY07 cohort who returned to the CoE for the Spring Semester of 2008 as *spring-returning students*.

Poor academic performance is often a symptom of students who are not retained in engineering programs. For the FY07 cohort, spring-returning students had an average Fall Semester 2007 GPA of 2.8; students who returned to the UofA but not the CoE had an average fall GPA of 2.3; students who did not return to the UofA had an average fall GPA of 1.0.

Anecdotal data suggests that student performance in their first mathematics class is an excellent predictor of continued success in engineering study. Table 10 breaks down by Fall Semester 2007 MATH grade the Spring Semester 2008 enrollment status of the FY07 cohort. The statistics in Table 10 make it clear that fall-to-spring retention was a critical issue for students who failed or withdrew from their fall MATH class. However, note that students who withdrew from their MATH class were retained at a much higher rate than students who failed their MATH class.

Spring Semester MATH Performance

Table 11 includes the Spring Semester 2008 distribution of grades (including withdrawals) received by spring-returning students in a set of MATH courses that are closely monitored by FEP faculty and staff. Because of the observed differences between MATH 2564H Honors Calculus II and MATH 2564, MATH 2564H is separated from MATH 2564 in Table 11. The grades from every other honors course are included with the grades from the non-honors course having the same number. The statistics in Table 11 indicate that the performance of FEP students in MATH 1285 and MATH 2554 was worse in the Spring Semester of 2008 than in the Fall Semester of 2007. This degradation in performance can be attributed in part to the fact that spring-returning students in these classes either have lower ACT mathematics scores upon entry to the UofA and/or they failed to pass these courses in the Fall Semester of 2007.

			Spring 2008 Enrollment Status		
		% returning to CoE	% returning to UofA	% returning to UofA but not CoE	% not returning to UofA
Fall Semester 2007 MATH Grade	A	95%	all	5%	none
	B	77%	96%	19%	4%
	C	85%	99%	14%	1%
	D	89%	all	11%	none
	F	43%	70%	28%	30%
	W	56%	82%	25%	18%

Table 10. Spring Semester 2008 Enrollment Status by Fall Semester 2007 MATH Grade

	A	B	C	D	F	W	Total	% Passing	Average Grade Point
MATH 1285	0	3	3	1	4	0	11	55%	1.5
MATH 2554	8	13	20	11	17	8	77	53%	1.8
MATH 2564	7	24	22	5	8	16	82	65%	2.3
MATH 2564H	9	6	4	2	2	1	24	79%	2.8
MATH 2574	16	11	4	1	0	0	32	97%	3.3

Table 11. Spring Semester 2008 MATH Performance of Spring-Returning Students

Interventions Based on Spring Semester Academic Performance

Based on our analysis of the Spring Semester 2008 academic performance of spring-returning students, the FEP faculty and staff took one key action for subsequent academic years.

- Based in part on the statistics in Tables 4 and 11, the MATH 2554 tutoring programs in the Freshman Engineering Center were significantly expanded.

Fall-to-Fall Retention

In the Fall Semester of 2008, 62% of the FY07 cohort (214 students) returned to the CoE, 19% (64 students) returned to the UofA but not the CoE, and 19% (65 students) did not return to the UofA. The fall-to-fall CoE retention rates were higher for all underrepresented groups (70% of females, 75% of African-Americans, 64% of Hispanic-Americans, 67% of Native Americans).

As mentioned previously, poor academic performance is often a symptom of students who are not retained in engineering program. The spring-returning students who did not return to the CoE for the Fall Semester of 2008 had an average Spring 2008 cumulative GPA of 1.2.

As mentioned previously, anecdotal data suggests that student performance in their first mathematics class is an excellent predictor of continued success in engineering study. Table 12 breaks down by Fall Semester 2007 MATH grade the Fall Semester 2008 enrollment status of the FY07 cohort. The statistics in Table 12 make it clear that fall-to-fall retention was a critical issue for students who failed to pass their fall MATH class. However, note that students who withdrew from or earned a D in their MATH class were retained at a much higher rate than students who failed their MATH class.

			Fall 2008 Enrollment Status		
		% returning to CoE	% returning to UofA	% returning to UofA but not CoE	% not returning to UofA
Fall Semester 2007 MATH Grade	A	91%	96%	5%	4%
	B	71%	94%	23%	6%
	C	76%	93%	17%	7%
	D	49%	74%	25%	26%
	F	15%	35%	20%	65%
	W	47%	67%	20%	33%

Table 12. Fall Semester 2008 Enrollment Status by Fall Semester 2007 MATH Grade

Interventions Based on Fall-to-Fall Retention

Based on our analysis of the fall-to-fall retention statistics for the FY07 cohort, the FEP faculty and staff took one key action for subsequent academic years.

- Based in part on the statistics in Tables 10 and 12, the FEP faculty and staff emphasize the option of withdrawing from classes if students failing a class do not think they have a very good chance of improving their performance and earning a passing grade.

Generating K-12 Data for the FY07 Cohort

A unique student identifier for each student in the FY07 cohort was used to merge their UofA performance data with academic data from their K-12 experience. The K-12 academic data was provided by the National Office for Research on Measurement and Evaluation Models (NORMES) at the University of Arkansas. NORMES is a research office that works with the Arkansas Department of Education in managing the Arkansas K-12 longitudinal data system, constructing educational research models on student achievement, and providing educational reports on the school systems in Arkansas.

The FY07 cohort academic information was merged with Stanford Achievement Test, Version - 9 (SAT-9) math and reading standardized test scores from 1999, which represents when most of the FY07 cohort would have been in 5th grade. In addition to the 5th grade SAT-9 test data, the following data sets were merged.

- 2001 (7th grade) SAT-9 math and reading test scores
- 2002 Arkansas Comprehensive Testing Assessment and Accountability Program (ACTAAP) 8th grade achievement math and literacy scores
- end-of-course ACTAAP algebra test scores
- end-of-course ACTAAP geometry test scores
- ACTAAP 11th grade literacy end-of-course exam

The goal for using academic history data is to better understand if there is pattern in the K-12 performance that will help identify those students who are most likely to be successful as engineering students. The early academic records may also provide information on which students currently in the K-12 system have academic achievement consistent with students currently in the system.

Prediction Models of Success in Engineering

The initial goal of the statistical modeling phase of our study was to develop a predictive model of academic success in the FEP using the following variables as predictors of success:

- High School GPA (HSGPA)
- ACT Math
- ACT English
- Fall Semester 2007 MATH grade (FMG)
- Fall Semester 2007 GNEG 1111 Grade (FEG).

Academic success was measured using the Spring Semester 2008 cumulative grade point average (CGPA).

The regression model produced an $F(5,251) = 116.07$ ($p < .0001$) with 69.81% of variance explained, which suggests a very effective model. A review of the contribution of the five predictors revealed that both ACT Math and ACT English were not significant predictors of CGPA, whereas HSGPA, FMG and FEG were very significant predictors of Freshman GPA. However, further review of the model revealed significant problems with multicollinearity which could be attributed to ACT English scores.

A second model was completed using HSGPA, ACT Math, FMG and FEG and produced an $F(4,252) = 144.14$ ($p < .0001$) with 69.59% of variance explained in the model. In this second model, FMG and FEG were the strongest predictors of overall student success. The second model also addresses a consistent theory among many that the use of ACT Math and ACT English scores are not as useful in predicting freshman success as HSGPA. However, due to the clear multicollinearity problems it was revealed in fact that ACT English was contributing to this issue and a more effective model can be obtained using ACT Math and HSGPA.

The second goal of the statistical modeling phase of our study was to determine which elements of the students' K-12 data are the best predictors of success as measured by FMG and FEG. The predictors used include:

- 5th grade SAT-9 math and reading scores

- 7th grade SAT-9 math and reading scores
- 8th grade ACTAAP math and literacy scores
- end-of-course (EOC) algebra, geometry, and literacy Scores.

The first model completed examined the success of students in FMG and FEG using the SAT-9 at grades 5 and 7, ACTAAP at grade 8, and EOC algebra and geometry scores. These models produced an $F(6,117) = 1.98$ and $F(6,117) = 0.94$, both with $p > .05$, indicating there is limited support for a “math track” of evidence to support success in FMG or FEG. Several of the variables, including the SAT-9 scores, did not contribute much to the models and were set aside.

Additional analysis revealed that using EOC algebra and ACT Math generated $F(2,118) = 6.85$ ($p < .05$) and $F(2,118) = 2.12$ ($p > .05$), respectively. Further, ACT Math appeared to be the least important of the two variables, so one additional analysis was completed predicting FMG from EOC algebra and produced $F(1,165) = 7.77$ ($p < .05$) and variance explained of 4.5%. The result was statistically significant, but the amount of variance explained is slightly above random chance suggesting the statistical significance is not meaningful or a type I error.

The use of the literacy or reading variables produced a similar pattern with no real evidence that long-term academic history produced any better information in terms of identifying those students most likely to be successful in engineering programs. One explanation for this finding may be the various standardized exams employed by the Arkansas Department of Education may not be discriminating between those students more proficient in mathematics. This needs to be examined more carefully and further examination of academic history studied to gain a better understanding of how this information can be more useful in identifying potential engineering students.

The impact of the FEP is pretty clear with a student’s progress in GNEG 1111 being a strong indicator of future success. More needs to be understood about the specific benefits and impact of this course in identifying successful engineering students. A post analysis, perhaps qualitative in nature, is warranted to understand the perceptions of the professors about what makes Student A versus Student B more likely to be successful. The academic indicators do not appear to improve the overall predictive modeling of success, which may be due to a ceiling effect with all students having relatively high entry scores.

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