

EFFECT OF A FRESHMAN ENGINEERING PROGRAM ON RETENTION AND ACADEMIC PERFORMANCE

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Abstract—*Longitudinal studies using seven years of student record data were recently performed on the students participating in a freshman-engineering program (called TIDE) and on students in a comparison group. The results show that: 1) a statistically significant larger percentage of TIDE students graduated in engineering than students from the comparison group; and 2) there was no significant difference in academic performance (as measured by final GPA) between TIDE and traditional students. TIDE students entering the university ready for calculus had a 14% better graduation rate (significance level of $\alpha = 0.001$), students entering ready for pre-calculus had a 16% better graduation rate ($\alpha = 0.10$), women entering ready for calculus had a 23% better graduation rate ($\alpha = 0.001$) and women entering ready for pre-calculus had a 26% better graduation rate ($\alpha = 0.05$). The paper briefly describes the TIDE program, presents the data, and discusses the results.*

Index Terms — *freshman engineering program, retention, under-represented groups*

OVERVIEW OF THE TIDE PROGRAM

The UA freshman-engineering program, now called TIDE, grew out of a prototype program developed as part of the NSF-supported Foundation Coalition. The Foundation Coalition (FC), composed of seven partner schools, emphasized four areas for improving undergraduate engineering education: curriculum integration, teamwork and collaborative learning, technology in the classroom, and continuous assessment and evaluation.

UA faculty from the departments of chemistry, mathematics, mechanical engineering and physics developed the curriculum for the prototype program during the 1993-1994 academic year. The primary goal of the faculty developing the curriculum was to improve student learning. Toward this end,

- Course topics were substantially rearranged to achieve better integration between chemistry, mathematics and physics,
- Students worked in four-person teams in the new math, physics, chemistry and engineering courses, and
- All courses (except labs) were taught in new computer-equipped classrooms.

Because the topics in the new FC courses were rearranged to achieve better integration, students could not take a first-semester FC course and a second-semester traditional course. Although exceptions were made on a case-by-case basis, the majority of students took *all* of the FC courses. Students therefore went to their chemistry, mathematics, physics and engineering courses with the same group of students. Furthermore, they sat with the same team of four students in each lecture and worked with the same team for the chemistry lab, mathematics recitation, physics lab and engineering design projects.

The chemistry and physics courses assigned team lab reports and the engineering course assigned team design projects. The reports and projects required the four-person teams to meet several times per week outside of class. This had two results. First, the students usually met in the new computer-equipped classrooms and soon got in the habit of going to the classrooms in the evenings to study. Second, the students quickly made friends and study partners with their classmates. The long-term result was the students formed a support network, a community of fellow engineering students. The authors believe this community was the most significant result of the FC freshman-engineering program.

The first prototype freshman curriculum was offered to 36 student volunteers, ready for calculus, in the Fall of 1994. Two sections of calculus-ready students were taught in the Fall of 1995. A pre-calculus section was offered in the Fall of 1996. Electrical engineering faculty required the new freshman curriculum for all its students beginning in Fall 1999 and in Fall 2000 the aerospace engineering, civil engineering and mechanical engineering departments required the new curriculum (now called TIDE). The other engineering departments (chemical, industrial and metallurgical engineering) and computer science allow the curriculum as an option.

LITERATURE REVIEW

We reviewed peer-reviewed articles on freshman engineering courses or programs that included statistics on retention and/or GPA. Only two of the programs (E⁴ at Drexel University and IMPEC at North Carolina State University) accounted for the volunteer effect by selecting both participants and a comparison group from students volunteering for the new program. Drexel reported improved retention for participants but North Carolina State

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reported no difference in retention between participants and the comparison group. The freshman engineering courses or programs are summarized below in the order in which they were implemented.

Drexel University has an innovative freshman engineering program [1, 2] in which “engineering is up-front” and “topics of mathematics, physics, chemistry and are presented from an application and engineering perspective.” Beginning in 1989, 100 students were “randomly selected [for the pilot program] from volunteers having generally similar levels of academic preparation and achievement as non E⁴ cohorts.” The size of the pilot program was doubled in 1992, and in 1995 “the Faculty Senate unanimously approved the new Drexel Engineering Curriculum” for all entering students.

Assessment of the E⁴ program showed that students in the prototype program “had, in general, higher grade point averages, improved progress rates, and higher retention rates.” For students in the initial prototype E⁴ program of 1989, 23% more E⁴ students were retained in engineering after eight semesters than for the control group. Also, the freshman class of 1992 had 12% better retention after eight semesters than its control group.

Rose-Hulman Institute of Technology ran an Integrated, First-Year Curriculum in Science, Engineering and Mathematics (IFYCSEM) beginning in 1990 [1]. Math, physics, chemistry and engineering topics were delivered during a common time block. The extremely integrated nature of IFYCSEM necessitated giving one grade to the students for the entire curriculum. Students volunteer to participate in IFYCSEM. Students who completed IFYCSEM “did significantly better both in persistence at Rose-Hulman and grade-point average in upper level courses.

“As upper class students, [IFYCSEM] students were rated more highly by faculty in the areas of communication skills, ability to integrate the use of technology for problem solving, ability to integrate their ideas to appropriate conclusions, and ability to integrate previous knowledge into their current work.” Retention data indicates that 17% more IFYCSEM students graduated in engineering compared to the comparison groups (freshman classes of 1990 through 1993). Average senior GPAs for these students was 3.26 for IFYCSEM and 2.95 for the comparison groups.

The Freshman Engineering Department at Purdue University has run a Counselor-Tutorial (CT) program [3] since 1971 for “beginning students whose high school academic backgrounds indicate high learning potential, but whose academic profiles predict a high probability of difficulty in completing the freshman engineering curriculum.” For freshmen entering between 1971 and 1990, only 34% of the CT students graduated from an engineering program compared to 57% for non-CT students, a 23% difference. The CT program was modified in 1990 to include a more extensive tutoring system and expanded to

include more students. The new program increased the number of CT students retained from 34% to 51%.

Ohio State has offered an integrated first-year curriculum [1] involving mathematics, physics and engineering to honor student volunteers since 1993. “Retention is 10% higher than matched comparison groups if students complete one quarter, more than 20% higher if they complete the year.” Also, overall GPA is higher by the junior year and participation in the coop program is higher.

Faculty at University of Florida developed a discipline-based, one-credit freshman-engineering course [4] in which students participated in hands-on exercises and watched demonstrations at each of eleven engineering departments. Retention data was collected for students who opted for the new course over the traditional lecture-style course between Spring 1993 and Spring 1994. Students taking the new course had 17% better retention (measured at the beginning of the junior year) as compared to students taking the traditional “sleep 101” freshman-engineering course. The authors comment that, “These substantial improvements seem too great to be effected by a single course.” Entering freshmen volunteered for the new course, making it possible that “the laboratory enrollment was filled with students with a greater commitment to engineering at the outset.” The authors discard the “volunteer effect” as a cause for the improved retention based on student survey results from the new and the traditional courses.

Faculty at Purdue University developed an orientation course [5] that supplemented the existing required one-credit freshman-engineering course. The existing course introduced students to the various engineering disciplines and the new course provided student development information such as study skills, time management and registration information. The new course was offered in the Fall of 94 and the Fall of 95 to the first students who requested it. Survey results indicate that students in the new course were significantly more satisfied with academic counseling and had a more positive impression of the university than students in a control group. However regarding retention, “There were no significant differences between the control group and the orientation class after three or four semesters.”

North Carolina State University has an integrated first-year engineering curriculum called IMPEC (Integrated Math, Physics, Engineering and Chemistry Curriculum) [6]. Participants were selected randomly from students expressing an interest in the new program. A control group with similar pre-college performance measures was then formed from the remaining volunteers (students who volunteered for IMPEC but could not participate due to space limitations). Grade and retention data for the 1995-1996 freshmen indicate the IMPEC students had a 17% higher pass rate than the control group. Retention at the beginning of the 1996 Fall semester was equal for the two groups at 80% (although fewer IMPEC students were in academic difficulty). In the latest version of the program,

the math and science courses teach traditional topics using innovative pedagogy and the engineering course provides the links to math and science topics [7]. The physics course has 1/2 the failure rate of the traditional course, (and failure rates of 1/3 and 1/4 the traditional for women and minorities, respectively).

At Texas A&M University, freshman students elect to enroll in cohort sections of engineering, mathematics, physics, chemistry and English [1]. Students sit in teams of four at computer-equipped desks and participate in collaborative learning exercises. Curriculum integration was strong for the prototype program and included integrated exams developed by math, physics, chemistry, and engineering faculty. Topical integration occurs primarily through the engineering courses in the institutionalized-version of the freshman program.

“Students in the pilot curriculum are retained at a higher rate than the rate for those in the traditional program. This is especially true of students from underrepresented groups: women, Hispanic and African-American engineering students.” For freshmen entering in 1995 and 1996, 16% more women, 14% more Hispanic and 20% more African-American students in the pilot curriculum were retained than in the traditional curriculum (measured at the beginning of the sophomore year). Although grade point averages for students in the pilot curriculum were essentially the same as for students in the traditional program, more students in the pilot curriculum successfully completed the freshman courses than students in the traditional curriculum.

University of Massachusetts Dartmouth began an integrated freshman engineering program (called IMPULSE) [8] in Fall 1998 that included calculus, physics, chemistry, English and engineering. All courses were taught in a computer-equipped classroom seating 12 teams of four students. Most courses were taught in the studio format (integrated lecture and lab). IMPULSE students performed better than comparison group students on common exam questions and successfully completed calculus and physics on schedule in much higher numbers. “The most dramatic effect of the IMPULSE project was improved retention in the engineering major.” 83% of the IMPULSE students returned as engineering majors for their third semester, compared with only 62% for 1991 through 1997.

METHODOLOGY

Based on results reported in the literature, students engaged in a freshman year program infused with active learning, group work, and community building should be retained better and have higher levels of achievement than those in a traditional program. Additionally, these effects should remain consistent over time in order to be assured that any effect is not due to aberrant group differences.

To test these hypotheses, engineering student data was compiled from the University’s student information system for students classified as incoming freshmen in the fall

semesters of 1994 through 1999. These data were subdivided into two distinct groups; those students who were part of the TIDE program and those that were engaged in the traditional freshman year program. The traditional students did not take part in group building activities, teamwork based projects, or classes infused with cooperative learning techniques during their first two semesters in the college of engineering.

Since the TIDE program stayed consistent over time in regard to classes taken and group/cooperative learning elements, the freshman classes were combined into a single database. Variables were created for 7 years of fall and spring semesters into which were placed a 1 or 0 designation depending on the retention status at a particular semester. Any student who remained enrolled in engineering during a semester or had graduated from engineering would be designated as retained. Similarly, any student who had transferred to another program besides engineering, graduated from another program besides engineering, or left the University all together were classified as not retained. By looking at the aggregated database of student retention information, we increased the sample size for analysis and decreased any effect due to a single aberrant class.

The overall sample contained 1522 students, 73% male and 27% female (Table I). The ethnic breakdown for the sample was 77% white, 18% African-American, and 5% from other racial/ethnic categories.

TABLE I
DEMOGRAPHIC BREAKDOWN OF THE SAMPLE.

		TIDE		Non-TIDE	
		#	%	#	%
<i>Gender</i>	Male	320	73%	794	73%
	Female	116	27%	292	27%
	Total	436	100%	1086	100%
<i>Ethnicity</i>	White	349	80%	827	76%
	African-American	71	16%	196	18%
	Hispanic	3	1%	5	0.5%
	Other	13	3%	58	5.5%
	Total	436	100%	1086	100%

The sample was well balanced in regard to gender and ethnicity. A *t*-test computed between TIDE and non-TIDE students does show a significant difference in overall math achievement as measured by the math placement test scores ($t = -5.659$, $df = 885.98$, $p < .001$). The mean TIDE math placement score was 44.82 ($SD = 6.27$) and the mean non-TIDE math placement test score was 42.75 ($SD = 6.97$). Although this mean difference of 2.08 is statistically significant, the effect size of the difference computed using Cohen’s *d* is 0.31, a small effect size [9]. Using a 95% confidence interval for the effect size ($SE = 0.06$), the computed effect size range is between 0.2 and 0.42.

The sample was subdivided into three groups based on math placement as a function of the math placement score. Those students who scored in the range of 31 to 37 were

placed in a rudimentary algebra math class we called pre-pre calculus, students with scores in the range of 38 to 43 were placed in an advanced algebra and trigonometry class we called pre-calculus, and students who had a score of 44 or above on the test were placed into a calculus class (Table II).

TABLE II
MATH CLASS PLACEMENT BY TRACK.

	TIDE	Non-TIDE
Pre-Pre Calculus	67 (15.4%)	304 (28.0%)
Pre-Calculus	97 (22.2%)	267 (24.6%)
Calculus	272 (62.4%)	515 (47.4%)
Total	436 (100%)	1086 (100%)

Research Questions

The questions that were explored using the historical student information database were:

Do TIDE and traditional students have significantly different retention rates over semesters in engineering school? Do calculus ready TIDE students have significantly different retention rates than calculus ready traditional students? Are there significant differences in retention rates between groups for historically underrepresented populations?

Do TIDE and traditional students have significantly different end of semester GPAs over time? Are any GPA differences observed between TIDE and traditional students when taking math aptitude groups into account? Are there differences in GPA between groups for historically underrepresented-groups?

RESULTS

Each student was given a dichotomous code of 1 or 0 for each semester he or she was retained in the College of Engineering or graduated with a degree. Summers were not included in analysis due to a large number of students who did not attend classes during summer months. A chi-square statistic was computed on each 4 by 4 retention matrix – TIDE retained, TIDE not retained, traditional retained, and traditional not retained. When looking at each potential semester that a student could have attended, TIDE students have significantly higher retention rates through 14 semesters or 7 years of schooling. Retention rates by semester for calculus-ready students, TIDE vs. traditional are compared in Figure 1.

Overall retention/graduation percentages for students in the TIDE program and traditional program were

significantly different than would be expected by chance alone for the calculus ready students ($X^2 = 17.77$, $df = 1$, $p < .001$), pre-calculus students ($X^2 = 7.37$, $df = 1$, $p = .007$), calculus ready female students ($X^2 = 10.42$, $df = 1$, $p = .001$), and pre-calculus female students ($X^2 = 5.53$, $df = 1$, $p = .02$). Non-white calculus ready students, however, did not display differences in retention/graduation rates ($X^2 = 0.178$, $df = 1$, $p = .673$) (Table 3).

A 2X2X2 factorial ANOVA was employed to determine the effect of program (TIDE vs. traditional), gender and ethnicity on cumulative grade point average. Only students in the 1994 to 1999 entering freshmen group who graduated or were retained in engineering were entered in the analysis. The last cumulative grade point average on record in the Spring of 2001 was used as the cumulative GPA. A .05 criterion of statistical significance was employed for all tests.

The main effects of program [$F(1, 481) = 0.291$, $p = .590$] and gender [$F(1, 481) = 0.606$, $p = .487$] were not statistically significant, however the main effect of ethnicity [$F(1, 481) = 15.162$, $p < .001$] was statistically significant. Where the cumulative GPA between TIDE and traditional students, as well as that of men and women students were not statistically significant, the cumulative GPA of white students was significantly higher than that of non-white students. The interaction of program and gender [$F(1, 481) = 0.013$, $p = .909$], and that of program and ethnicity [$F(1, 481) = 0.073$, $p = .787$] were not statistically significant.

CONCLUSION

Students participating in the TIDE program, compared to traditional students with similar pre-college performance measures, graduated from engineering in significantly higher percentages but with similar GPAs. White females participating in the TIDE program had especially higher graduation rates compared to their counterparts, while non-white students participating in TIDE had slightly poorer (though not statistically significant) graduation rates.

The following questions arise regarding the retention data.

1. Was the TIDE program responsible for the improved retention rates?
2. Why did white females seem to benefit more than other groups from TIDE?
3. And why did non-white students not benefit from TIDE?

Possible answers to these questions are posed in the following paragraphs. These answers need to be verified by qualitative research.

**Retention 1994-1999
Calculus Ready Students**

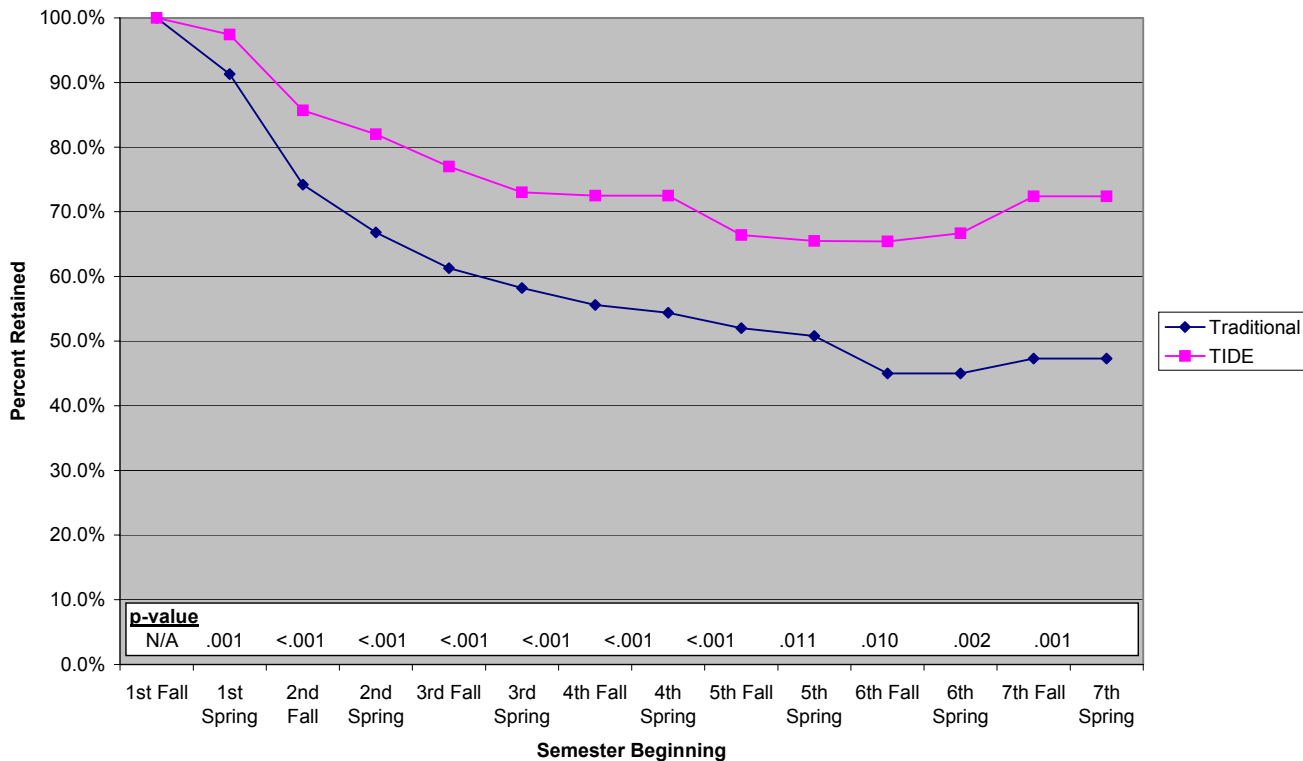


FIGURE 1
RETENTION RATES OF TIDE AND TRADITIONAL CALCULUS READY STUDENTS.

TABLE IV
OVERALL RETENTION/GRADUATION PERCENTAGES FOR TIDE AND TRADITIONAL STUDENTS: 1994 TO 1999.

Population	Traditional Retained/Graduated (N)	TIDE Retained/Graduated (N)	Chi-Square Value
All Calculus Ready	55.9% (288)	71.3% (194)	17.787***
All Pre-Calc	39.7% (106)	55.7% (54)	7.366**
Calculus Ready Female	52.3% (79)	75.0% (54)	10.420***
Pre-Calc Female	31.3% (21)	57.1% (16)	5.530*
Calculus Ready Non-White	65.7% (67)	62.3% (33)	0.178

***p = .001, **p = .01, *p = .05

1) Was the TIDE program responsible for the improved retention rates? Clearly TIDE students graduated at higher rates than matched students in the traditional curriculum. But, did the TIDE program produce better retention, or did the TIDE program attract students more likely to graduate in engineering? Only two freshman programs described in the literature review controlled for the volunteer effect (Drexel and North Carolina State). The volunteers placed in Drexel's E⁴

program had a higher graduation rate than the volunteers placed in the control group. At North Carolina State, the volunteers in IMPEC had no better retention rate than the volunteers in the control group.

Retention rates for programs that did not control for the volunteer effect were approximately 14%, 17%, 15%, 17%, 16%, and 15% for Rose-Hulman, Purdue's CT program, Ohio State, University of Florida, Texas A&M, and University of Alabama, respectively. These retention rates are remarkably similar for programs as different as

Rose Hulman's pioneering IFYCSEM program and University of Florida's one-credit lab-based freshman course. One explanation is that students willing to try a new program are more likely (on average) to graduate in engineering. This would mean that our TIDE program is not so much a "retention factory" but a recruiting tool, used to attract high school students with the attributes needed to successfully complete the engineering program.

2 & 3) Why did white females seem to benefit more than other groups from TIDE and why did non-white students not benefit from TIDE? We put these two questions together because, in our minds, they share a common explanation. The explanation, which needs to be verified by qualitative research, is based on personal experience teaching five semesters of the freshman-engineering course. As stated earlier in the paper, we believe the dominant effect of the TIDE program was the sense of community that developed among the students as they worked on the many team assignments. As the students became familiar with each other, they began to socialize; and as they socialized they reverted to familiar social norms. The white female students thrived on social interactions guided by these norms; the minority students became estranged. Here's an example.

During their second week of classes, the freshman students started coming to the classrooms in the evenings to work together on team assignments. Their demeanor was professional and almost all of the students attended. By the fifth week of class, the students had pizza delivered to the classrooms in the evenings, sat on top of the desks and played a radio. Their demeanor was social and the non-white students were absent.

Another possible reason non-white students did not benefit from TIDE as much as other groups is that many of the non-white students with good potential to graduate did not volunteer for TIDE (a reverse volunteer effect). The TIDE program, with its block scheduling, is more restrictive than the traditional curriculum with regard to dropping a difficult class. During a discussion with the entire class on the "excessive workload" of the TIDE program, the author was explaining that the heavy workload was difficult compared to high school, but was good preparation for the engineering curriculum to come. A young black man stood up immediately and responded emphatically, "Dr. Richardson, you don't understand. If I don't keep my GPA above a 3.0, I lose my scholarship and I go home." On average, African-American engineering students take an additional 1.5 years to graduate than white students (Table V).

In conclusion, the TIDE program had a positive effect recruiting and/or retaining engineering students. TIDE students develop a sense of community which provides a support structure. Development of this community can be facilitated simply by cohort scheduling and giving team assignments. Development of a

community which includes students from all backgrounds, however, will require some guidance.

TABLE V
GRADUATION RATES AND SEMESTERS TO GRADUATE FOR AFRICAN-AMERICAN AND WHITE STUDENTS

Yr Entered	African-American			White		
	Number Students	% Grad	Number Semesters	Number Students	% Grad	Number Semesters
1990	22	50%	10.2	127	49%	9.7
1991	19	42%	10.9	132	52%	9.2
1992	8	25%	13.3	101	51%	9.8
1993	16	38%	9.9	121	50%	9.9
1994	20	55%	11.6	114	52%	10.1
1995	18	44%	12.9	91	52%	9.8
1996	5	60%	10.0	81	59%	10.0
Average		43%	11.2		51%	9.7

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