Freshman Engineering Student Success Indicators II

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Abstract:

Every year, up to 1300 freshman engineering students from around the world arrive at Virginia Tech's[1] College of Engineering with varying backgrounds, experiences, and degrees of academic expertise. Many fail to meet first year engineering expectations even though college entrance requirements have increased. The question is why and how can the college improve retention?

This paper provides results of a study of first year engineering students at Virginia Tech. The purpose of the study is to attempt to discern student success predictors so that appropriate interventions / corrective actions can be taken to increase retention in the program. The study includes the analysis of student Scholastic Aptitude Test (SAT) scores and performance on a baseline math test. This data is then compared with student first semester engineering course grades. Last year, the correlation between final course grades and student SAT scores were presented. This year, the correlation between final course grades and student performance on the baseline math test are addressed. Overall student performance in the initial freshman-engineering course is analyzed in addition to female, Afro-American, and Hispanic subgroups. The goal of the study is to better accommodate student needs by identifying how to allocate existing resources more effectively.

I. Introduction

Significant numbers of freshman engineering students at Virginia Tech do not perform at a satisfactory level in their first semester engineering course. The questions are, "Why?" and "How can the college increase retention of the students without decreasing performance standards?" To help answer these questions, the Engineering Fundamentals Division (EF) performed an analysis of freshman-engineering student performance during their first engineering course and on two tests. The tests are the national SAT test and in-house developed mathematics pre & post tests. The objective is to identify trends and/or indicators of poor student performance that can facilitate the development of programs to increase student performance and subsequent retention.

An analysis of Virginia Tech student SAT scores versus first engineering course performance is presented in "Freshman Engineering Student Success Indicators".[2] The study shows that a student's total SAT score is not a reliable predictor of their introductory freshman engineering course performance. This conclusion supports Gilbert's 1960 report that " . . . scores on the SAT-V, SAT-M, and the Advanced Mathematics Test and scores on a science test (Physics and Chemistry) do not seem to provide a very sound basis for predicting whether students will graduate from the school of engineering at Princeton University."[3] The study also showed that:

- Students with a "Total SAT" score higher than 1300 have a high probability of **PASSING** their first introductory engineering course.

- Students with a "Total SAT" score less than 1000 have a high probability of **NOT PASSING** their first introductory engineering course.

- Female freshman engineering student performance mirrors the overall student norm. The female group follows the same trends associated with peer students and no group specific indicators of varying performance have been identified.

- Afro-American freshman engineering students parallel the overall student performance at a lower total SAT level. The lower group average SAT scores are reflected in the group grade performance. However, it appears that "pockets" of these students respond well to targeted support programs that attempt to ameliorate the academic and social struggles common to all students.

- Hispanic freshman engineering students tend to follow overall student norms but display large variations in performance. This is attributed to the limited number of Hispanic students used in the study. As a result, no general tendencies could be extrapolated.

- The establishment of a "C- Rule" for Virginia Tech's freshman-engineering student's first course did greatly affect grade distribution.

- Support programs benefit students. Based upon the Afro-American group data, overall student retention would be increased by providing the same support services to all students. This same conclusion is supported by Prather's 1996 study.[3]

In this paper, an analysis of the correlation between student pre & post math test scores and their first engineering course final class grade is presented. During the analysis, freshman-engineering students that have recorded mathematics test scores in addition to first semester introductory engineering course grades will be looked at as a whole and in selected demographic groupings. The purpose is to identify across the board pass/fail indicators along with abnormalities between group performance as compared with the norm. In doing so, programs may be developed that more closely align themselves with the student population. Additionally, the paper will present and analyze data related to the new "C- Rule" policy initiated by EF to improve student performance. The rule requires that each student must earn a "C-" or higher in their first two introductory freshman-engineering courses before being eligible to take required follow-on engineering courses.

II. Overview

The study's mathematics pre & post test database includes Virginia Tech's freshman-engineering first semester "Introduction to Engineering" (EF1015) course students during the Fall '97/Spr '98 and Fall '98/Spr '99 semesters. There are 730 students in the Fall '97/Spr '98 database. There are 979 students in the Fall '98/Spr '99 database.

The EF1015 course teaches general engineering material required by most engineering fields. It is a one semester, two credit, lecture oriented course. The course objectives are that the student, having successfully completed the course, will be able to:

- apply engineering ethics to real life situations,
- apply the engineering method to problem solving,
- apply basic physical and mathematical concepts to introductory engineering problems,
- translate "word" problems into the mathematical statements that describe the physical situations presented; i.e., read, or listen to, problems and understand them,
- graph numeric data and develop simple empirical functions,
- develop algorithms and apply decision and repetition structures to basic problem solving, and
- use selected computer software.

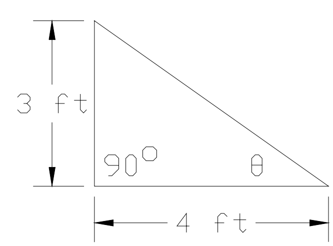
The Math Pre and Post tests are the same. The tests were given to students on their first and last EF1015 course lessons. The twenty-minute test is multiple choice and includes twenty questions. The questions cover basic algebra (5 each), geometry (10 each), and trigonometry (5 each) in both a short answer (17 each) and word problem (3 each) format. Several example questions are provided below.

Example 1: If $\pi^5 = 306$, $\log_{\pi} 306 =$ ________ .

(a) 12 (b) 4 (c) π (d) 5 (e) None of these.

Example 2: The value of sine θ is ________ .

(a) 0.6
(b) 0.75
(c) 0.8
(d) 3
(e) None of these.



Example 3: A circle having a radius of 10” is inscribed inside an equilateral triangle. The approximate area of the triangle is ________ in^2.

(a) 32 (b) 520 (c) 200π (d) 700 (e) None of these.

Example 4: Using a base of “b”, the logarithm of “x” in the expression $x = b^y$ is ________ .

(a) y (b) x + y (c) x^b (d) y – x (e) None of these.

The semester databases do not reflect the average 1300 freshman-engineering student numbers entering Virginia Tech. Only students who have both mathematics test scores and an EF1015 grade are entered in the database. There are several reasons for the difference in initial student class numbers and the study's database entries. The primary factors are that a student:

- took some other standardized test,
- is a transfer student,
- changed majors, and/or
- dropped EF1015 before a grade was recorded.

The study also analyzes and compares three subgroups to the group norm, in addition to the overall freshman-engineering class analysis. The three subgroups are the female, Afro-American, and Hispanic groups. For each group, the same student data was extracted and viewed. The number of students in each subgroup is provided in Table 1.

	Female	**Afro-American**	**Hispanic**
Fall '97/Spr ‘98	180	48	24
Fall '98/Spr ‘99	165	23	21

Table1. Study Database Subgroup Student Numbers.

Each group's database is presented in a topographic format. In this format, a group's

'97 All (Fall EF1015 / Pre-Test)

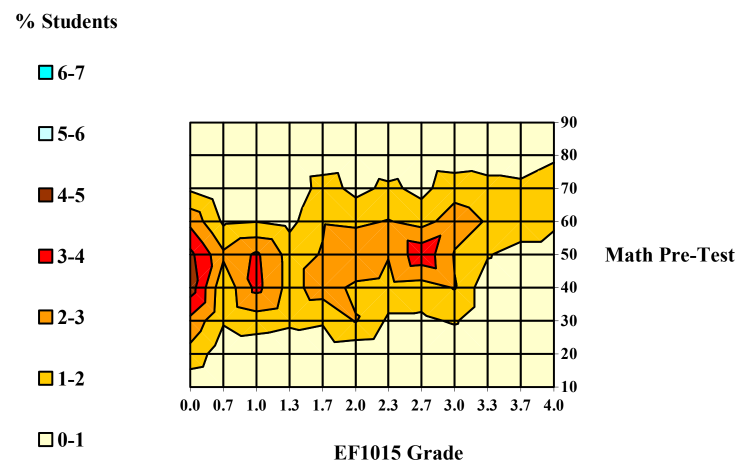


Figure 1. Fall '97 Overall Freshman-Engineering Student Performance.

EF1015 grades (X axis) and mathematics pre-test scores (Y axis) are provided in terms of the percentage of student (Z axis) reflected in the displayed database. For example, the overall Fall '97 freshman-engineering group data is displayed in Figure 1, where 1 % is equivalent to 7.3 students. The "EF1015 Grade" axis reflects a "0.0" to "4.0" numerical grade scale where "0.0" is equivalent to an "F" and "4.0" an "A" letter grades, respectively. The "Math Pre-Test" axis reflects a student's mathematics pre-test score.

In using the Figure 1 format, the EF1015 grade performance of students who have a mathematics pre-test score of 50 may be displayed as Figure 2. This figure is derived by taking a horizontal slice of Figure 1 when the "Math Pre-Test" score is "50".

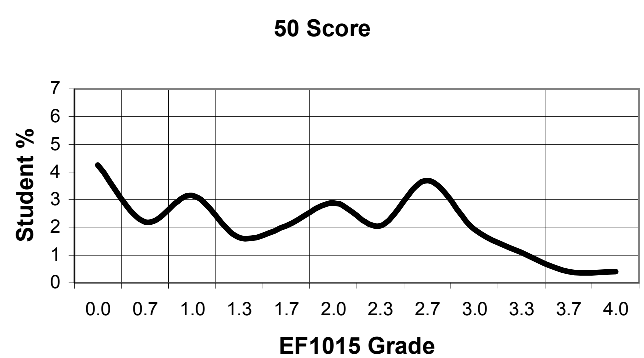


Figure 2. Fall '97 Overall "50%" Math Pre-Test Score Freshman-Engineering Student Performance.

Similarly, a display of all students receiving a "C" grade (2.0 score) in EF1015 versus their mathematics pre-test score can be derived from Figure 1 and is displayed as Figure 3. This figure is derived by taking a vertical slice of Figure 1 when the "EF1015 Grade" score is "2.0".

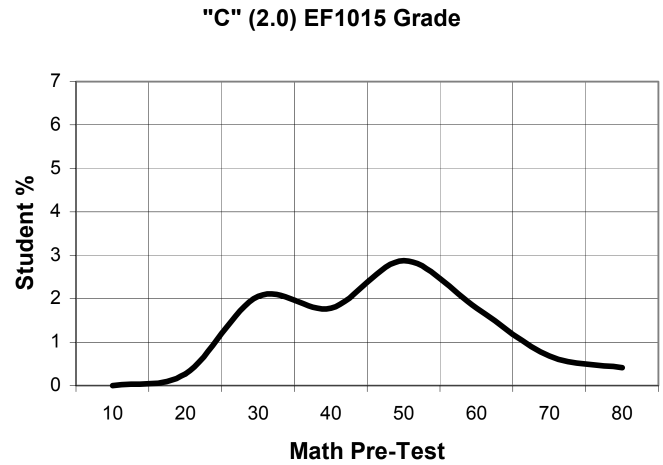


Figure 3. Fall '97 Overall "C" grade Freshman-Engineering Student Performance.

A display of all Fall '97 students grades in EF1015 versus their respective mathematics pre-test scores is displayed in Figure 4 and provided from Figure 1. The figure is derived by taking vertical slices of Figure 1 when the "EF1015 Grade"s are "0.0" ("F"), "1.0" ("D"), "1.7" ("C-"), "2.0" ("C"), "3.0" ("B"), and "4.0" ("A").

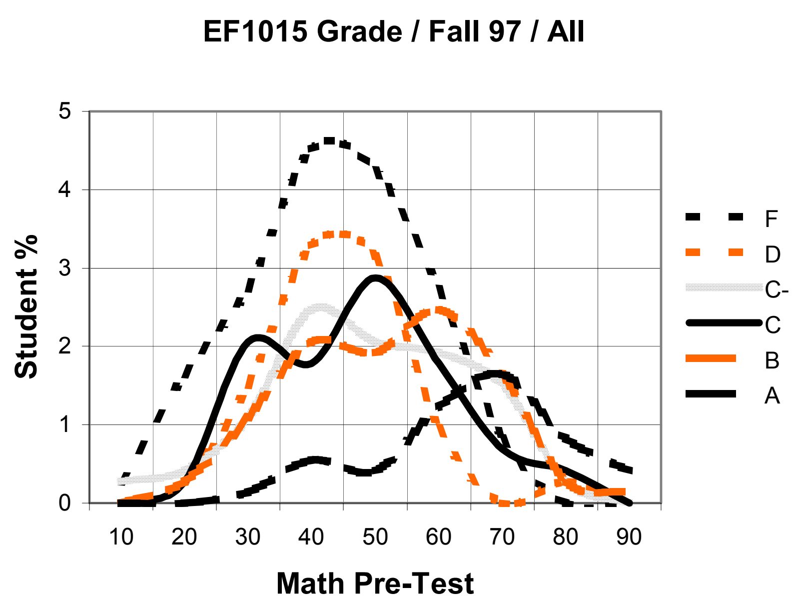


Figure 4. Fall '97 Overall Freshman-Engineering Grade Student Performance.

III. Analysis

Both Figures 1 and 4 for Fall '97 show that more students receive an "F" ("0.0" score) than any other specific grade. In Fall '97, 124 students received an "F" or 17.0% of the course students. The next most received grades were evenly distributed to "D"s, "C-"s, "C"s, and "B"s, where 10.0% of the class earned each grade. The "F" percentage can be extrapolated from Figure 1 by performing the following operation:

Math Pre-Test	**Percentage w/ "0.0" EF1015 Grade**
10	0.0
20	1.5
30	3.0
40	4.5
50	4.0
60	3.0
70	1.0
80	0.0
90	0.0
	Total = 17.0

Although not the focus of this document, it is the authors' opinion that the high failure rate is not primarily attributed to a student's capability or a student's ability to become an engineer. It is the authors' opinion that the failure rate is mainly attributed to some combination of those factors and:

- course difficulty,
- social transition from high school to college,
- poor study skills,
- poor organizational skills,
- lack of self discipline (procrastination), and
- desire to be an engineer versus another profession.

Figure 3 shows that 10.0% of the Fall'97 EF1015 students made a "C" grade. Of this group, more students had a "50" mathematics pre-test score than any other score. In the referenced example, 21 out of 72 students who received a "C" grade had a "50" mathematics pre-test score.

Math Pre-Test	**Percentage w/ "C" EF1015 Grade**
10	0.0
20	0.0
30	2.0
40	2.0
50	3.0
60	2.0
70	0.5
80	0.5
90	0.0
	Total = 10.0

As shown in Figure 5, a “best fit” line that follows the highest percentage of students in each grade level and the left to right upward topographic shift has a small slope. This

'97 All (Fall EF1015 / Pre-Test)

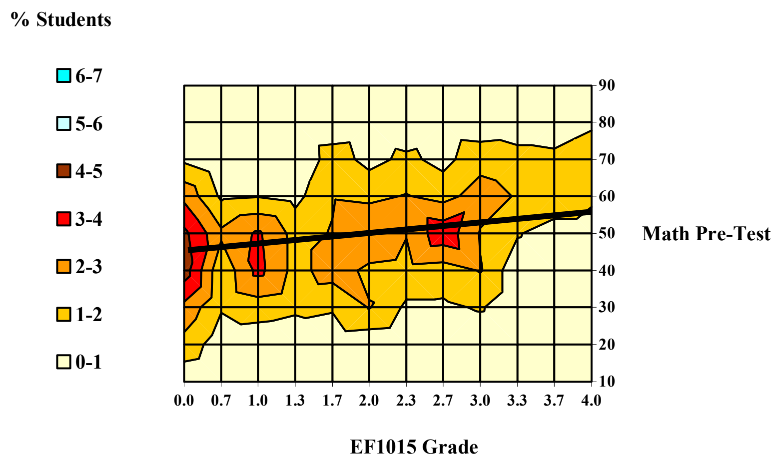


Figure 5. Fall '97 Pre-Test Overall Freshman-Engineering Student Performance with best fit peek line.

indicates that a student's grade does increase in relation to increased mathematics pre-test scores. The correlation is approximately 2.5 mathematics pre-test points (one half of one test problem) to every 1.0 increase in EF1015 grade. The shift does not, however, reflect a substantial indicator of student performance. Figure 5 shows that numerous students will fall within the 0.0 to 3.0 grade range regardless of their mathematics pre-test score.

'97 All (Fall EF1015 / Pre-Test)

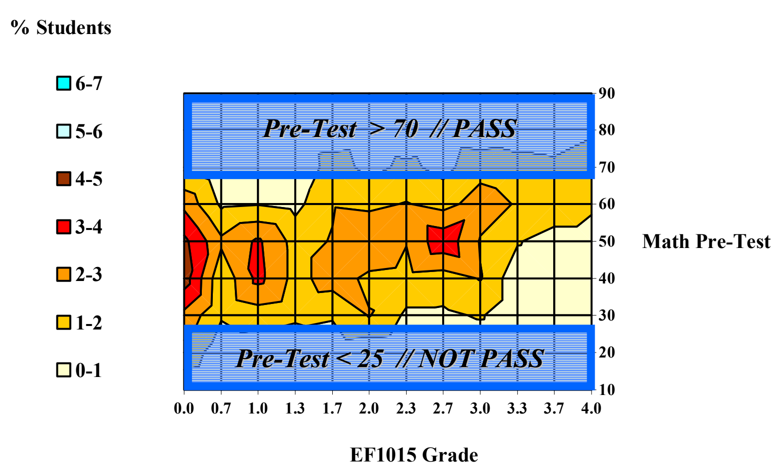


Figure 6. Fall '97 Overall Freshman-Engineering Student Performance with limited predictors.

Two additional limited predictions can be made and are displayed in Figure 6. They are: A student has a good probability of passing their first engineering course if they have greater than a "70" mathematics pre-test score. A student has a poor probability of passing their first engineering course if they have less than a "25" mathematics pre-test score.

Figures 7 and 8 display Spring '98 and '99 student performance versus mathematics pre-test score database information in a topographic format, respectively.

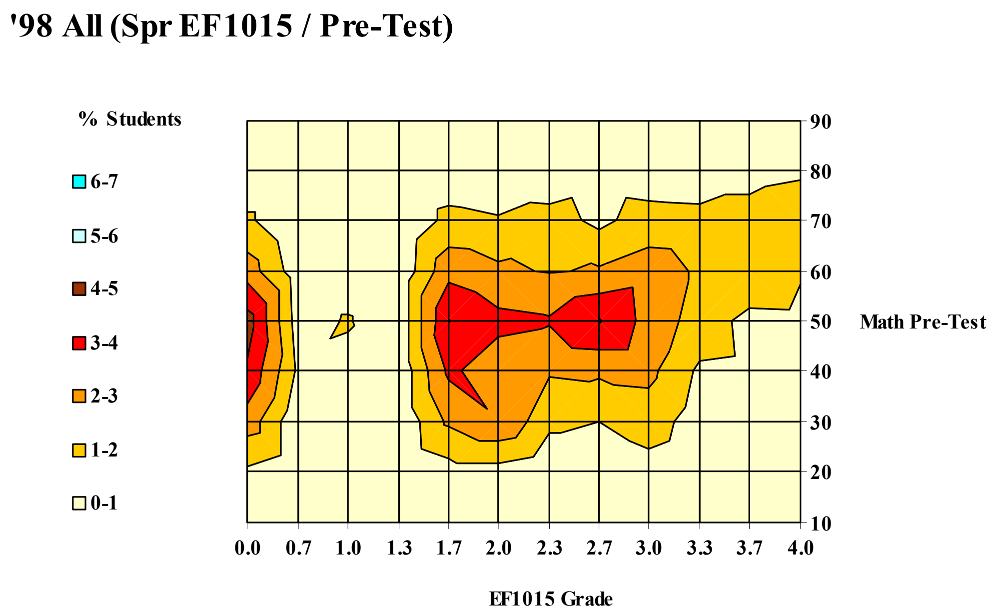


Figure 7. Spring '98 Overall Freshman-Engineering Student Performance.

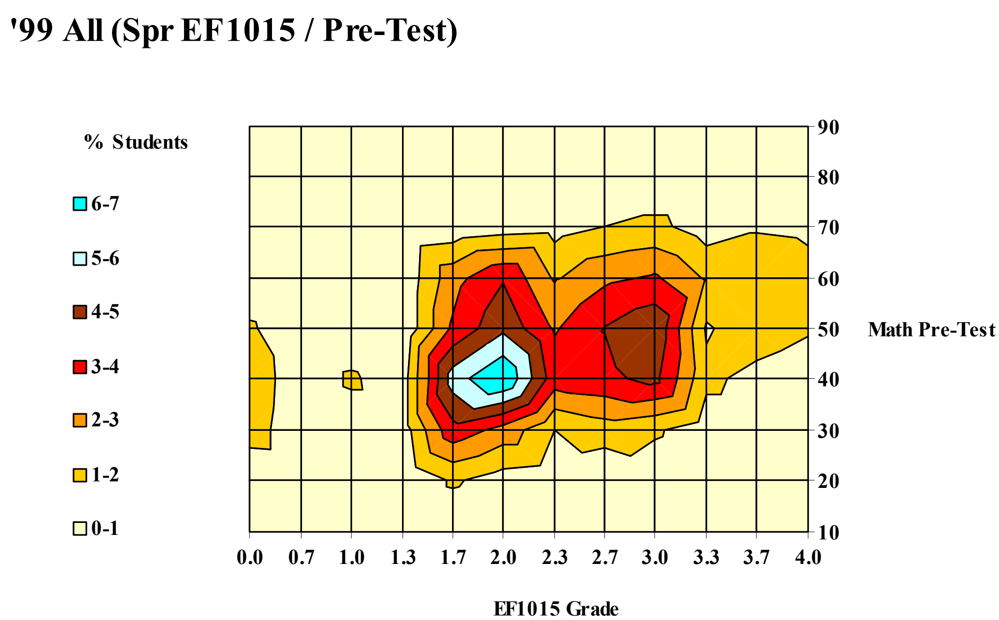


Figure 8. Spring '99 Overall Freshman-Engineering Student Performance.

Note the "hole" that appears in the 0.0 to 1.3 range of figures 7 and 8. There is a noticeable shift in student percentages from the 1.3 and below range to 1.7 and above. This shift can only be attributed to the EF Divisions instigation of a "C- Rule" for EF1015 classes beginning Fall 1997. As stated before, the rule stipulates that, "A student must receive a "C-" or higher in their first two introductory engineering courses to be eligible to take required follow-on engineering courses." The result has been a dramatic change in grade distribution. The authors' believe there are several possible cause and effect manifestations of the policy. These include:

- student performance has increased to meet the higher standards and expectations,
- more students dropped the course before grades were assigned, and/or
- the policy may foster some grade inflation.

Figure 9 is derived by taking horizontal slices of Figures 7 and 8 at the "50" mathematics pre-test score and consolidating the information into one figure. Again, notice the leftward shift in grades as the "C-" rule began to take effect.

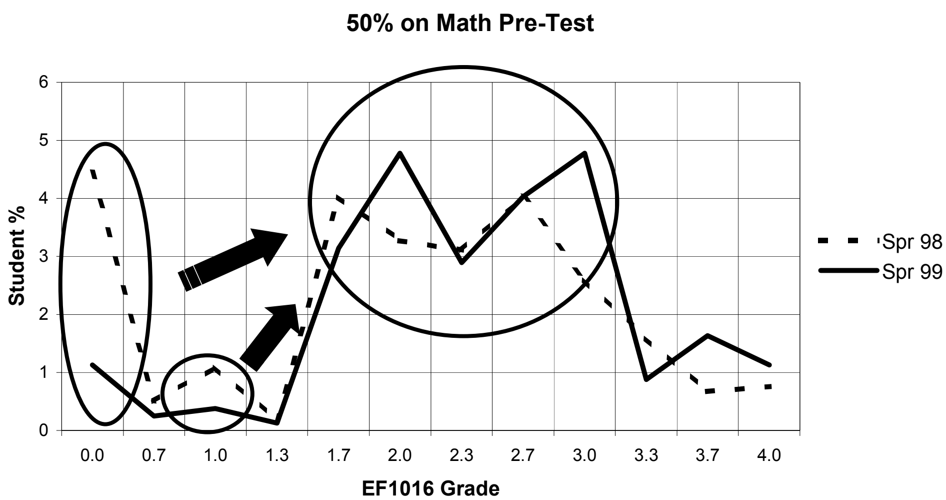


Figure 9. "50%" Mathematics Pre-Test Score vs Freshman-Engineering Student Performance showing "C-"Rule grade shift.

Figures 5 and 10 display student mathematics test improvement from the beginning to end of EF1015. Figure 5 shows EF1015 pre-test performance, while Figure 10 shows post-test results from student scores at the conclusion of EF1015. The data reflects a similar slope and improvement of ten to twenty points on the same mathematics test. This is the equivalent to correctly answering an additional two to four questions on the mathematics test. The reasons for this improvement may be:

- More knowledgeable (EF1015 course learning)
- Increased student self-assurance
- Less threatening environment

'97 All (Fall EF1015 / Post-Test)

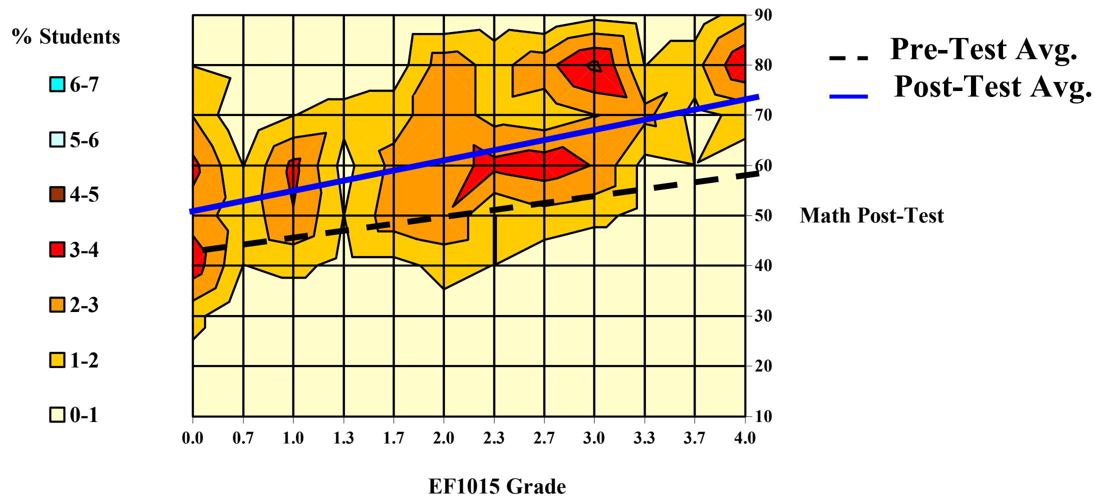


Figure 10. Fall '97 Post-Test Overall Freshman-Engineering Student Performance with best fit peek line.

Figures 8 and 11 display the same student improvements between pre-test and post-test student mathematics scores for the following year. Again, the slopes are similar and reflect a general ten to fifteen point increase in scores (two to three more correct answers on the mathematics test).

'99 All (Spr EF1015 / Post-Test)

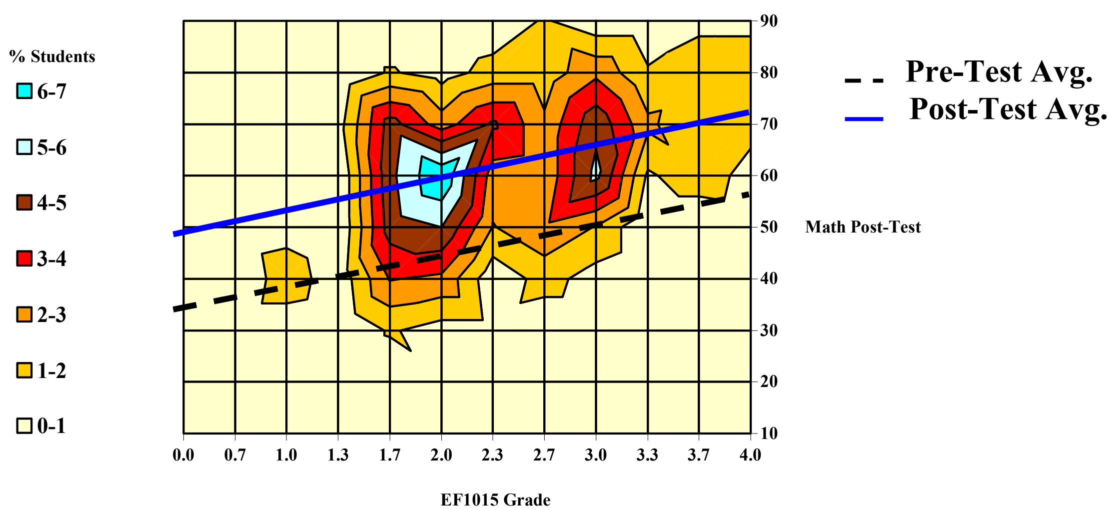


Figure 11. Spring '99 Post-Test Overall Freshman-Engineering Student Performance with best fit peek line.

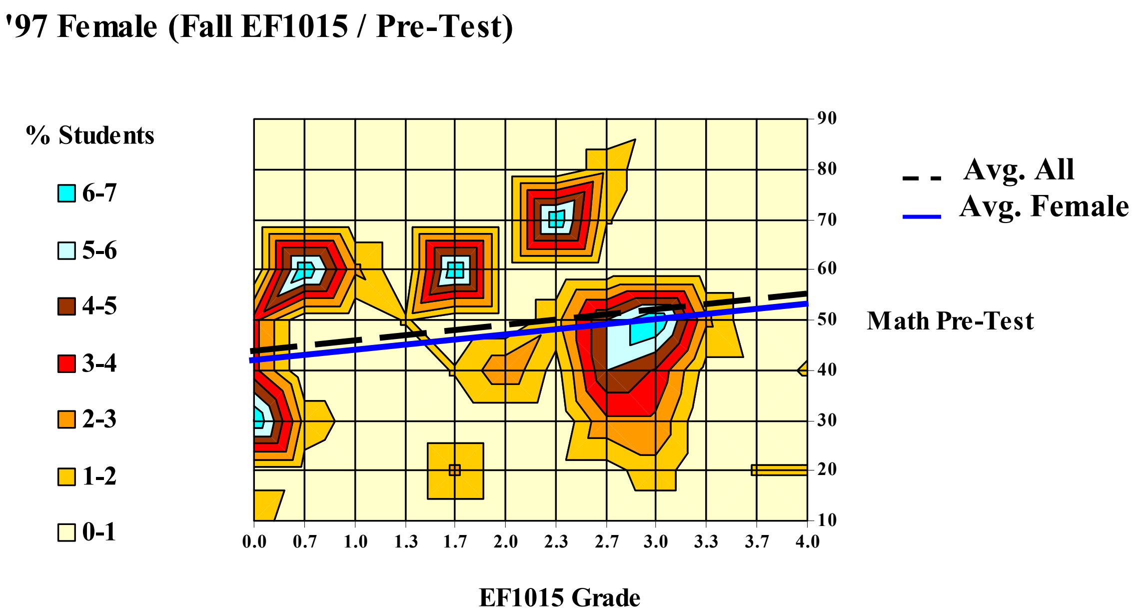


Figure 12. Fall '97 Female Freshman-Engineering Student Performance.

The Fall '97 female group data is displayed in Figure 12 with the best fit line for both the female group (46.06 average) and total student (49.30 average) best fit lines superimposed. The data indicates a three point or less than one correct mathematics question difference in student performance based upon gender. 18.3% of the female students received an "F" versus the 17.0% overall student average.

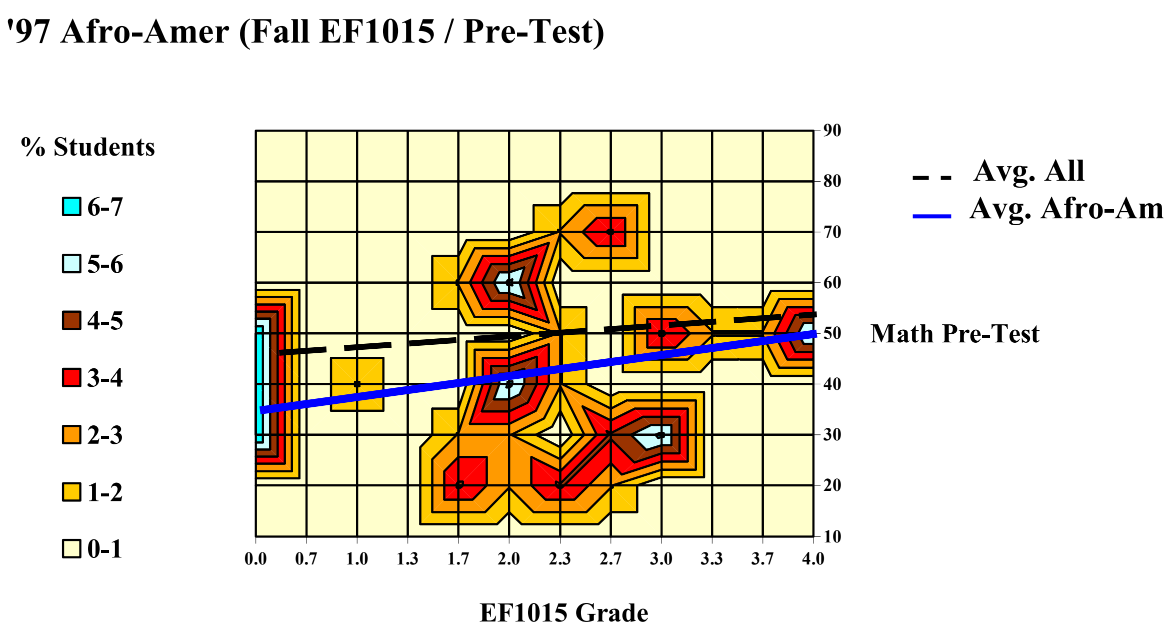


Figure 13. Fall '97 Afro-American Freshman-Engineering Student Performance.

Figure 13 displays the Fall ’97 Afro-American group data (41.46 average) with the best fit lines for the group’s performance in comparison to all freshman engineering students. The results show a similar relationship between increased mathematics pre-test scores and EF1015 grades but also displays an eight point or less than two correct mathematics test question difference between the groups. A major concern is the indicated 31.3% first semester Afro-American group failure rate versus the 17.0% overall average. However, the figure also shows that many Afro-American students with a lower mathematics pre-test score are earning the same grades as their peers with higher mathematics scores. This effect is attributed to Afro-American student support programs.

'97 Hispanic (Fall EF1015 / Pre-Test)

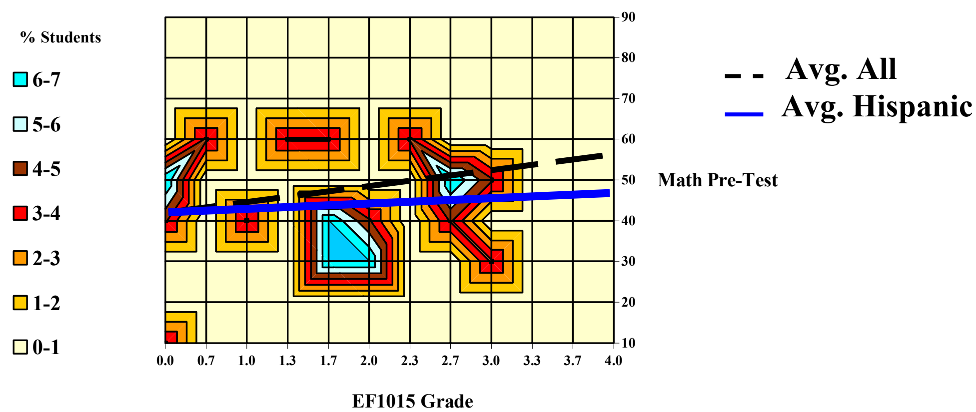


Figure 14. Fall '97 Hispanic Freshman-Engineering Student Performance.

Hispanic group data (43.3 average) for Fall ’97 along with best fit lines are displayed in Figure 14. The data shows the same trends as other groups and a six point or a little more than one correct mathematics question difference in student performance compared to the overall class. The Hispanic group failure rate is 20.8%, below the 17.0% class average.

'99 Female (Spr EF1015 / Pre-Test)

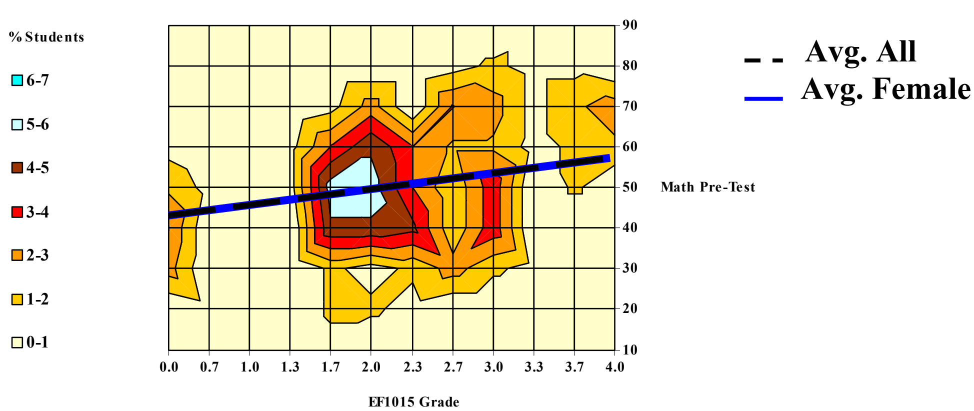


Figure 15. Spring '99 Female Freshman-Engineering Student Performance.

Figure 15 displays the Spring ’99 female mathematics pre-test scores (50.84 average) versus EF1015 course grade relationship and the best fit lines of the female group in comparison to the overall student (52.18 average) database. Again, the data indicates little difference in student performance based upon gender. The variations can be attributed to the student population change, not group trends or differences. The female group did make up 1.4% of the total failures in the course, or a group 8.5% overall “F”s versus a 4.3% overall group norm.

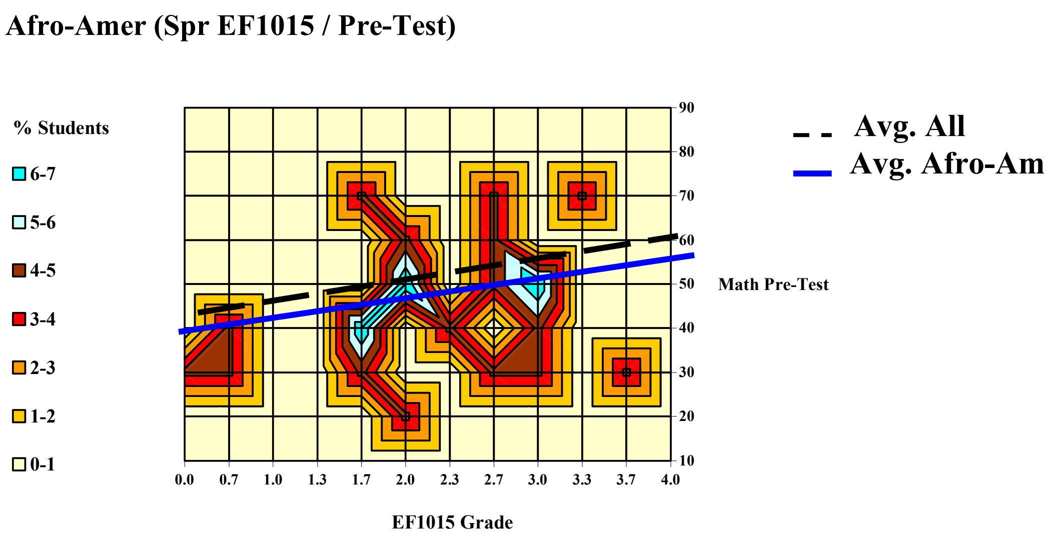


Figure 16. Spring '99 Afro-American Freshman-Engineering Student Performance.

Figure 16 shows the same correlation between Afro-American mathematics pre-test scores (44.35 average) and EF1015 grades as previously displayed. The group had the same 4.3% “F”s as the overall student norm and displays the same trends. There is, however, a continuing average eight point difference or almost two correct mathematics question difference in student performance compared to the overall class.

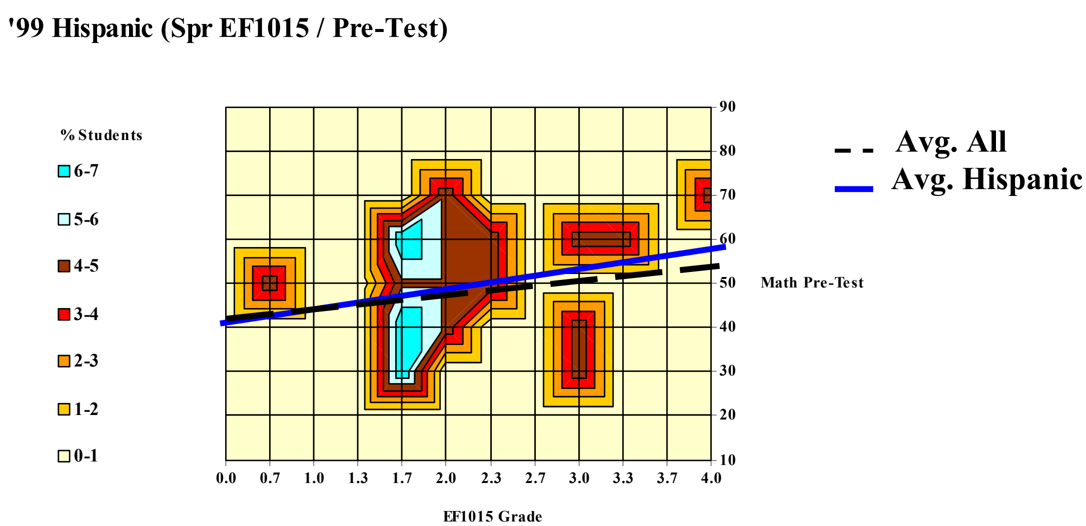


Figure 17. Spring '99 Hispanic Freshman-Engineering Student Performance.

Figure 17 displays the same best line fit for the Spring '99 Hispanic (48.57 average) and overall student group (52.18 average). As in all cases, there is a migration of grades from the 1.0 to 1.3 range. The most noteworthy observation is 0% failures. Of the 21 Hispanic students, each student who remained in engineering earned above an "F" before the end of their freshman year. Only one student didn't meet the "C-" rule requirement. This is a 20.8% decrease in Hispanic group failures and the improvements are attributed to targeted support programs.

III. Conclusions

The presented information is drawn from data derived by a study addressing freshman engineering student performance. As previously stated, the purpose is to identify trends and provide a factual basis for the allocation of limited resources to improve overall student retention and performance.

The following generalizations can be stated at this time.

- A student's mathematics pre-test scores is **NOT** a reliable predictor of their introductory freshman engineering course performance. Although there is a consistent "Mathematics Pre-Test" score and "EF1015 Grade" correlation, the relationship is negligible and significantly clouded by other factors as proposed during the data analysis.

- Students with a "Mathematics Pre-Test" score higher than 70 points have a high probability of **PASSING** their first introductory engineering course.

- Students with a "Mathematics Pre-Test" score less than 25 points have a high probability of **NOT PASSING** their first introductory engineering course.

- Female engineering student performance mirrors the overall student norm. The female group follows the same trends associated with peer students and no group specific indicators of varying performance have been identified.

- Afro-American engineering students parallel the overall student performance at a slightly lower level. The lower group average mathematics pre-test scores are reflected in the group grade performance. However, it appears that "pockets" of these students respond well to targeted support programs that attempt to ameliorate the academic and social struggles common to all students.

- Hispanic engineering students tend to follow overall student norms but display large variations in performance. This is attributed to the limited number of Hispanic students used in the study. As a result, no general tendencies can be extrapolated.

- The establishment of a “C- Rule” did greatly affect EF1015 grade distribution. Grades within the 0.7 to 1.3 range have decreased dramatically. Also, there is a decrease in the failure rate.

- A student’s “Mathematics Pre-Test” score provides little indication that a student will pass or fail their first engineering introductory course. Although students with low “Mathematics Pre-Test” scores are more likely to fail, many students with high scores will also fail. There are factors other than academic capability that influence a student’s success rate.

- Support programs benefit students. Based upon the Afro-American group data, overall student retention would be increased by providing the same support services to all students. This same conclusion is supported by Prather’s 1996 study. [4]

IV. Recommendations

The following recommendations are provided.

- A “Mathematics Pre-Test” should not be used as a predictor of student performance.

- Support services foster better student performance in relation to “Mathematics Pre-Test” scores and should be made available to all students.

- Continue to monitor and study the “C- Rule” to ensure positive objectives are met.

- This analysis should be expanded to study other factors such as student study skills and performance in high school science courses.

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