Freshman Engineering Student Success Indicators

Patrick E. Devens, Thomas D. Walker
Virginia Polytechnic Institute & State University

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 at the two-year-point of an ongoing 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 a baseline math test. This data is then compared with their first semester engineering course grade. This paper only addresses correlations between final course grades and student SAT scores. 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.

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) continues to perform 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.

Other authors have attempted to analyze correlations between student SAT scores and academic performance. Most of these studies are, however, comparatively old and few are targeted at success in engineering education. For example, Gilbert reported in 1960 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

Copyright O 2001, American Society for Engineering Education

predicting whether students will graduate from the school of engineering at Princeton University." [2] Johnson looked for a correlation in 1955, [3] Shell in 1982. [4] Van Mater's[5] research is more current, 1990, but deals with engineering technology education as does Colwell[6] and Devi[7].

In this paper, an analysis of the correlation between student SAT scores and their first engineering course final class grade is presented. The analysis of student performance on the in-house mathematics' tests and their first engineering course grade will be presented in another paper. During the analysis, freshman-engineering students that have recorded SAT 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 a new policy initiated by EF to improve student performance.

II. Overview

The study's present database includes Virginia Tech's freshman-engineering first semester "Introduction to Engineering" (EF1015) course students during the Fall '97, Spring '98, and Spring '99 semesters. There are 758 students in the Fall '97 database. There are 1305 students in the Spring '98 database and 1024 students in the Spring '99 database. Both the Spring '98 and Spring '99 databases include study students for the whole '98 and '99 academic years, respectively.

The EF1015 course teaches general engineering material required by most engineering fields. 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 semester databases do not reflect the average 1300 freshman-engineering student numbers entering Virginia Tech. Only students who have both a recorded SAT score and an EF1015 grade are entered in the database. There are several reasons for the difference

Copyright O 2001, American Society for Engineering Education

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	142	31	15
Spr '98	217	69	26
Spr '99	166	30	21

Table1. Study Database Subgroup Student Numbers.

There are several reasons attributed to the increase in numbers of students between Fall ’97 and Spring ’98. The primary reasons are that:

- the database was more complete, and
- students took the course during their second semester after completing course prerequisites.

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

'97 All (Fall EF1015)

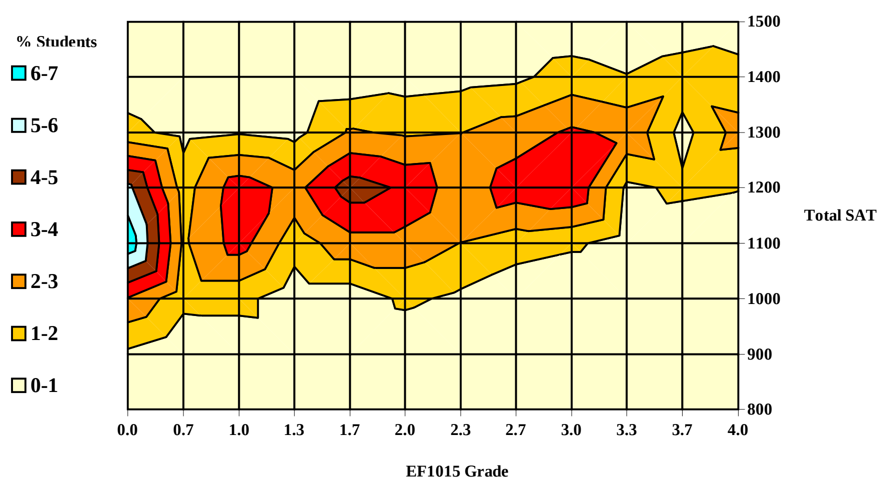

Figure 1. Fall '97 Overall Freshman-Engineering Student Performance.

Copyright O 2001, American Society for Engineering Education

EF1015 grades (X axis) and SAT score (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 7.6 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 "Total SAT" axis reflects a student's total SAT score or the student's cumulative math and verbal SAT scores.

In using the Figure 1 format, the EF1015 grade performance of students who have a combined SAT score of 1200 may be displayed as Figure 2. This figure is derived by taking a horizontal slice of Figure 1 when the "Total SAT" score is "1200".

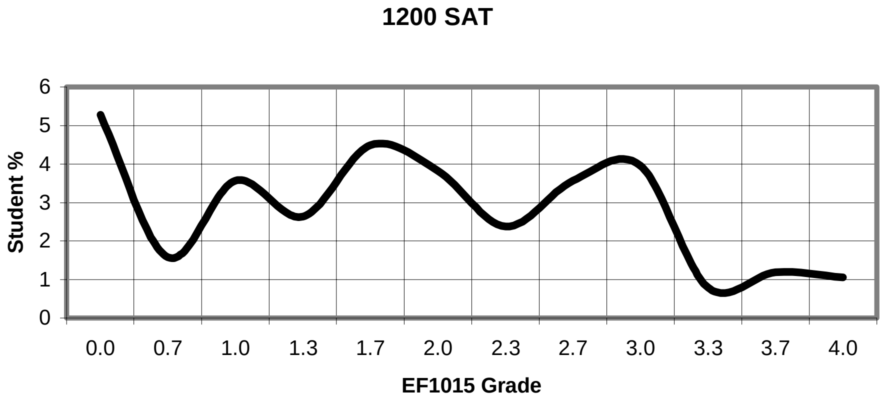

Figure 2. Fall '97 Overall 1200 SAT Score Freshman-Engineering Student Performance.

Similarly, a display of all students receiving a "C' grade (2.0 score) in EF1015 versus their SAT 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".

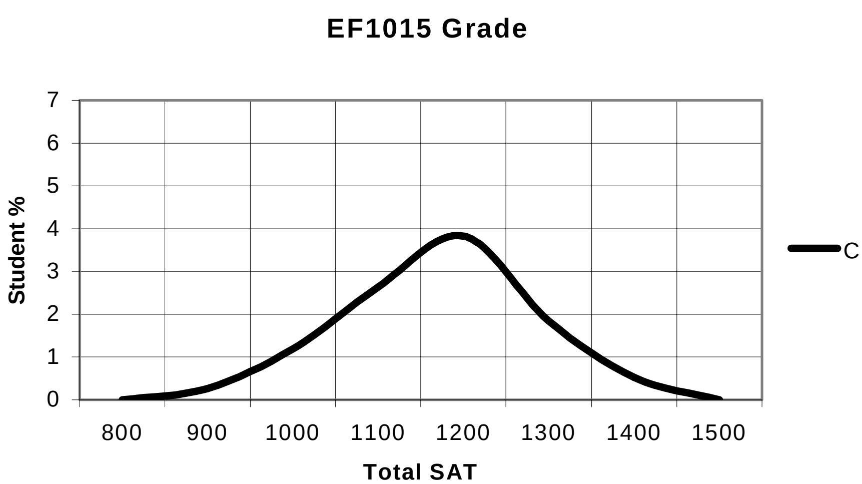

Figure 3. Fall '97 Overall "C" grade Freshman-Engineering Student Performance.

Copyright O 2001, American Society for Engineering Education

A display of all Fall '97 students grades in EF1015 versus their respective SAT 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”).

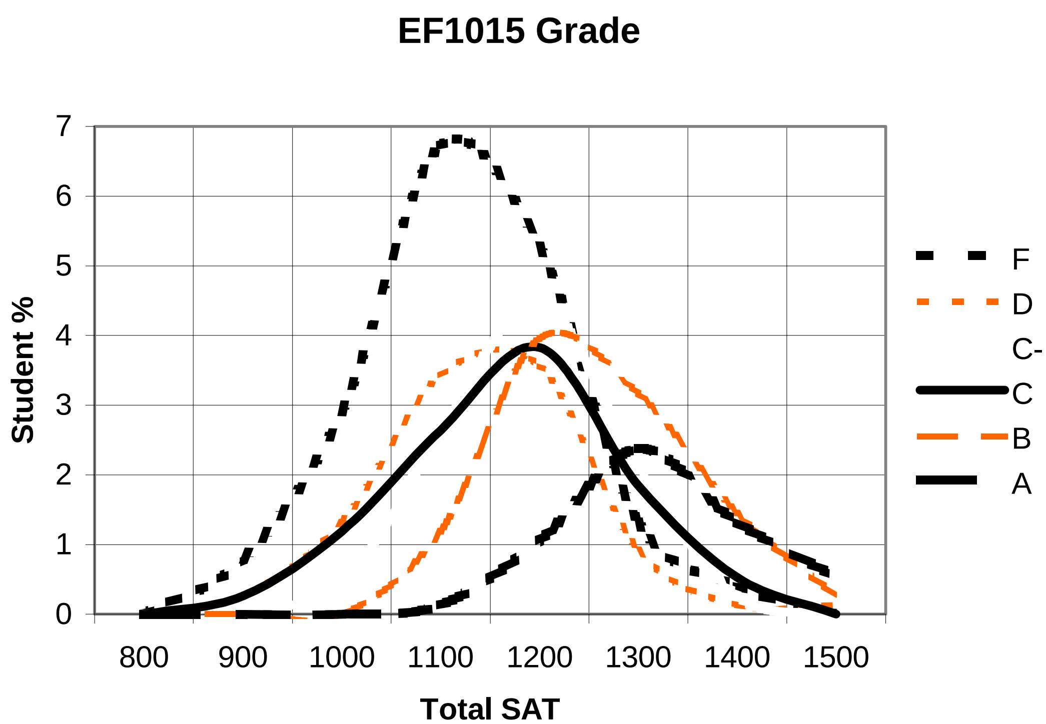

Figure 4. Fall '97 Overall Freshman-Engineering Grade Student Performance.

Copyright O 2001, American Society for Engineering Education

III. Analysis

Both Figures 1 and 4 for Fall ’97 along with subsequent year figures, to be displayed later, show that more students receive an “F” (“0.0” score) than any other specific grade. In Fall ’97, 132 students received an “F” or 17.5% of the course students. The percentage can be extrapolated from Figure 1 by performing the following operation:

Total SAT	Percentage w/ “0.0” EF1015 Grade
800	0.0
900	1.0
1000	3.0
1100	7.0
1200	5.0
1300	1.0
1400	0.5
1500	0.0
	Total = 17.5

Although this observation and a detailed analysis of reasons for this occurrence is not the focus of this document, it is the authors’ opinion that the 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 10.5% of the Fall’97 EF1015 students made a “C” grade. Of this group, more students had a 1200 total SAT score than any other SAT score. In the referenced example, 29 out of 78 students who received a “C” grade had 1200 total SAT scores.

Total SAT	Percentage w/ “C” EF1015 Grade
800	0.0
900	0.5
1000	1.0
1100	2.5
1200	4.0
1300	2.0
1400	0.5
1500	0.0
	Total = 10.5

Copyright O 2001, American Society for Engineering Education

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

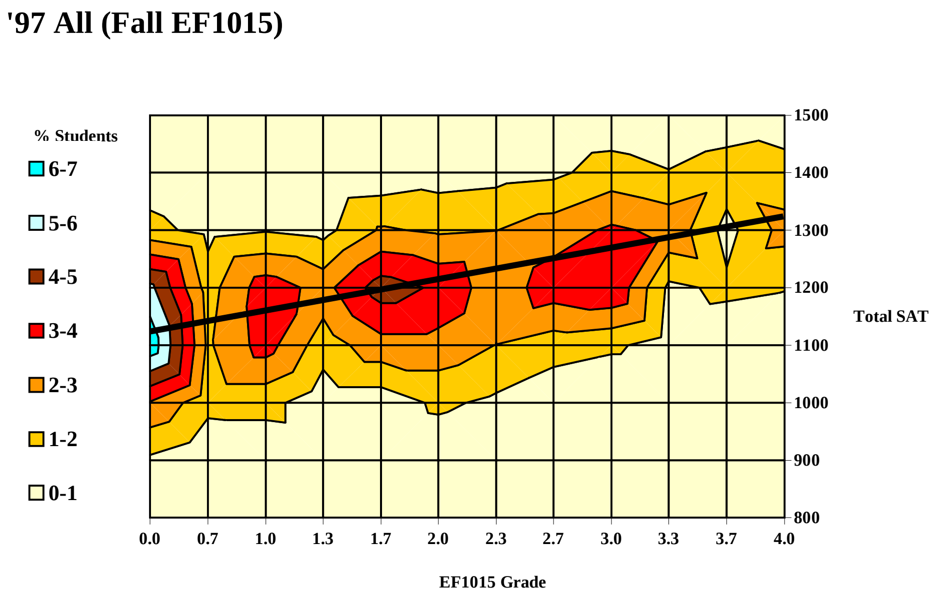

Figure 5. Fall '97 Overall Freshman-Engineering Student Performance with best fit peek line.

indicates that a student's grade does increase in relation to increased SAT scores. The correlation is approximately 50 SAT points 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 2.7 grade range regardless of their SAT score.

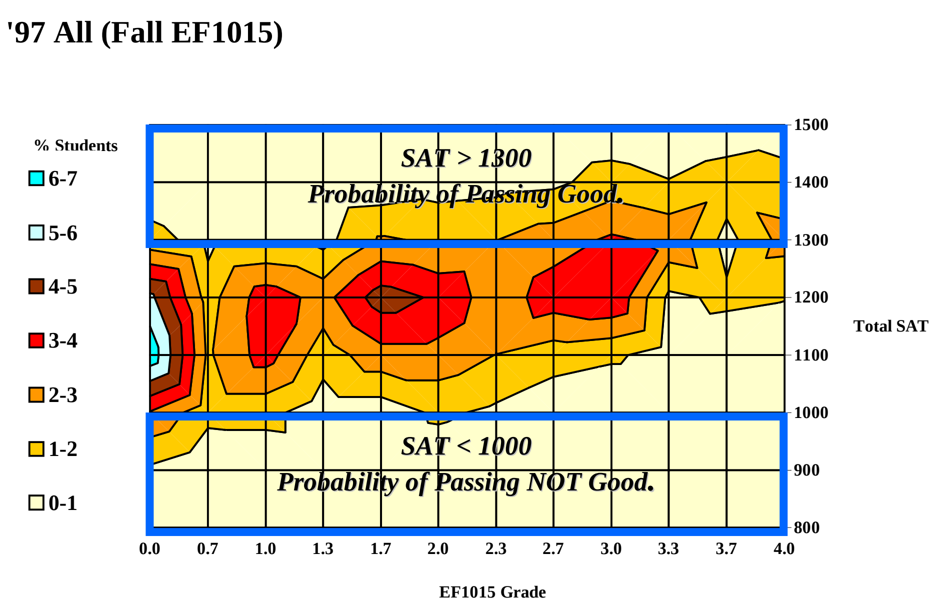

Figure 6. Fall '97 Overall Freshman-Engineering Student Performance with limited predictors.

Copyright O 2001, American Society for Engineering Education

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 1300 SAT score. A student has a poor probability of passing their first engineering course if they have less than a 1000 SAT score.

Figures 5, 7, and 8 display Fall 1997, Spring 1998, and Spring 1999 student performance versus SAT score database information in a topographic format, respectively.

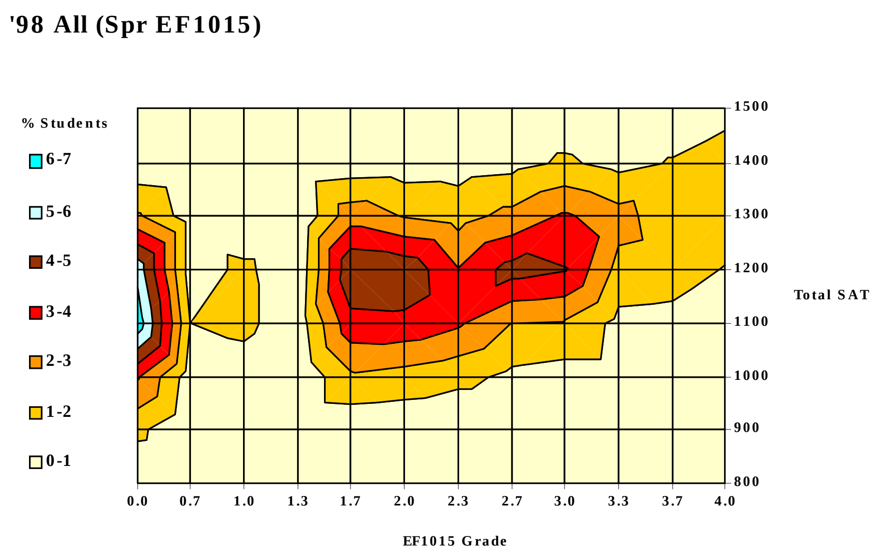

Figure 7. Spring '98 Overall Freshman-Engineering Student Performance.

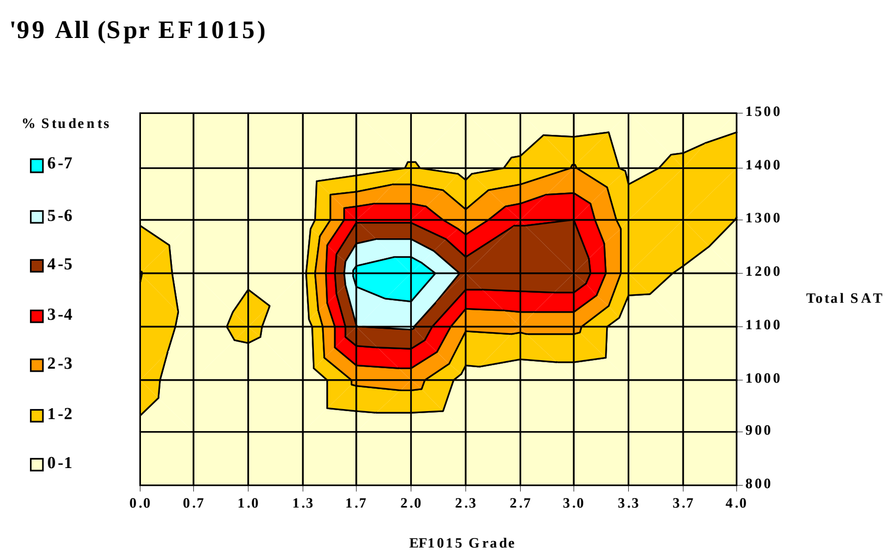

Figure 8. Spring '99 Overall Freshman-Engineering Student Performance.

Note the "hole" that appears in the 0.7 to 1.7 range of figures 7 and 8. There is a noticeable shift in student percentages from the 1.7 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. The rule stipulates that, "A student must receive a

Copyright O 2001, American Society for Engineering Education

"C-" or higher to be eligible to take 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 5, 7, and 8 at the 1200 SAT score and consolidating the information into one figure. Again, notice the leftward shift in grades as the "C-" rule began to take effect.

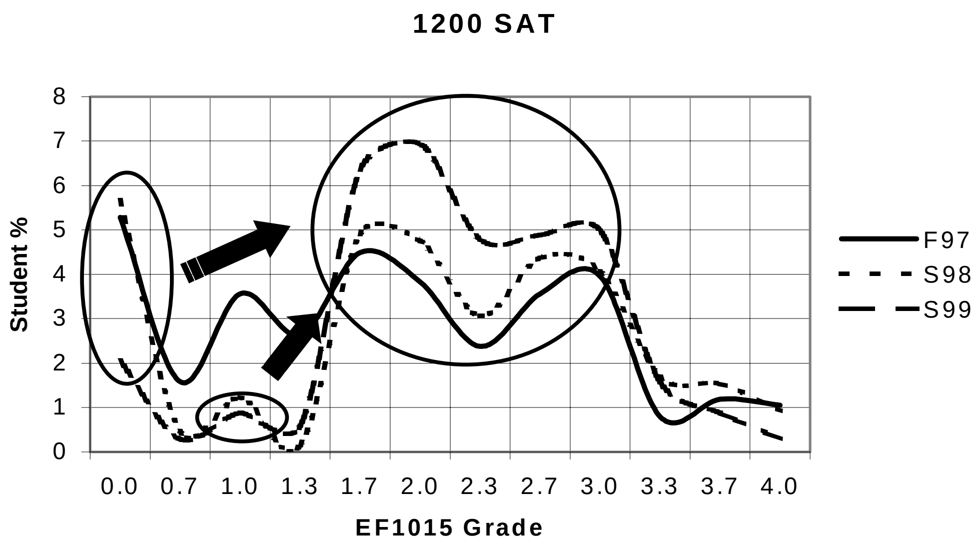

Figure 9. Overall 1200 SAT Score Freshman-Engineering Student Performance.

Copyright O 2001, American Society for Engineering Education

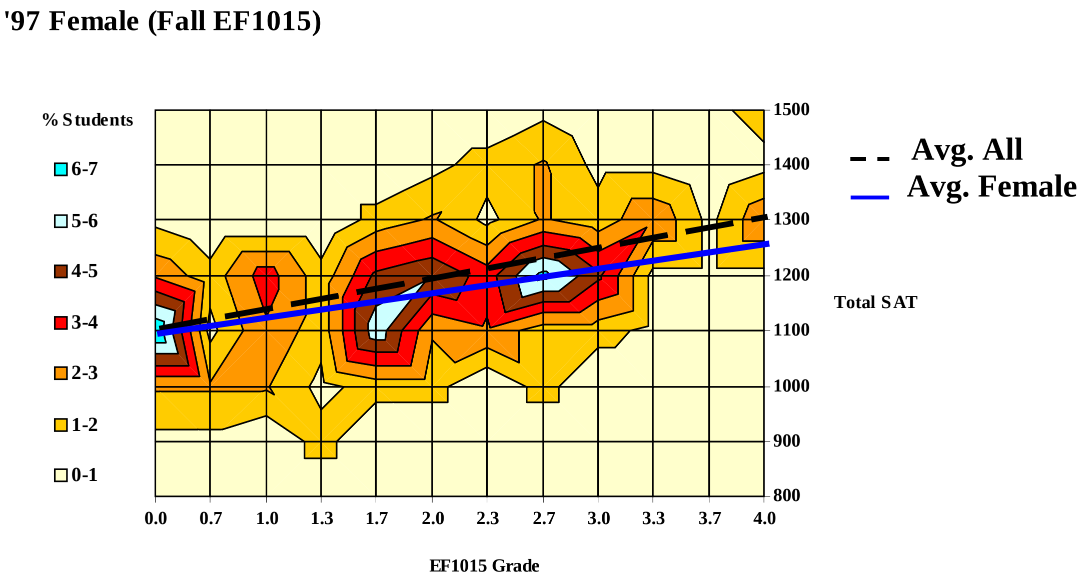

Figure 10. Fall '97 Female Freshman-Engineering Student Performance.

The Fall ’97 female group data is displayed in Figure 10 with the best fit line for both the female group and total student best fit lines superimposed. The data indicates little difference in student performance based upon gender. Only 14% of the female students received an “F” versus the 17.5% overall student average.

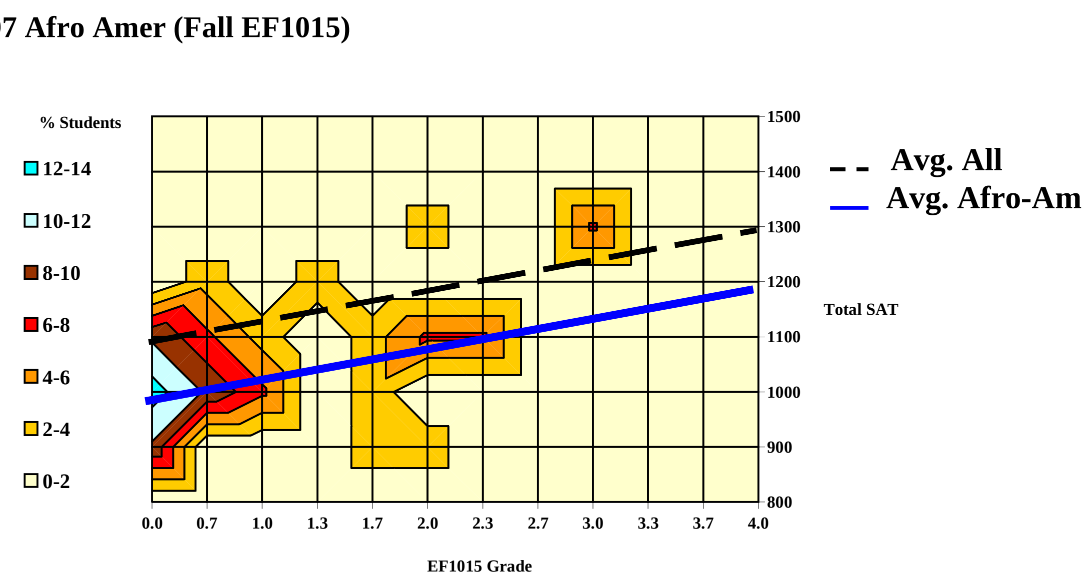

Figure 11. Fall '97 Afro-American Freshman-Engineering Student Performance.

The same conclusion is not valid when comparing the Afro-American group and the total student best fit lines. Figure 11 displays the Fall ’97 Afro-American group data 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 SAT score and EF1015 grade but also display a 1000 point decrease in “Total SAT” versus “EF1015 Grade”. A major concern is the indicated 32% first semester Afro-American group

Copyright O 2001, American Society for Engineering Education

failure rate versus the 17.5% overall average. However, the figure also shows that many Afro-American students with a lower SAT total are earning the same grades as their peers with higher SAT scores. This effect is attributed to Afro-American student support programs.

'97 Hispanic (Fall EF1015)

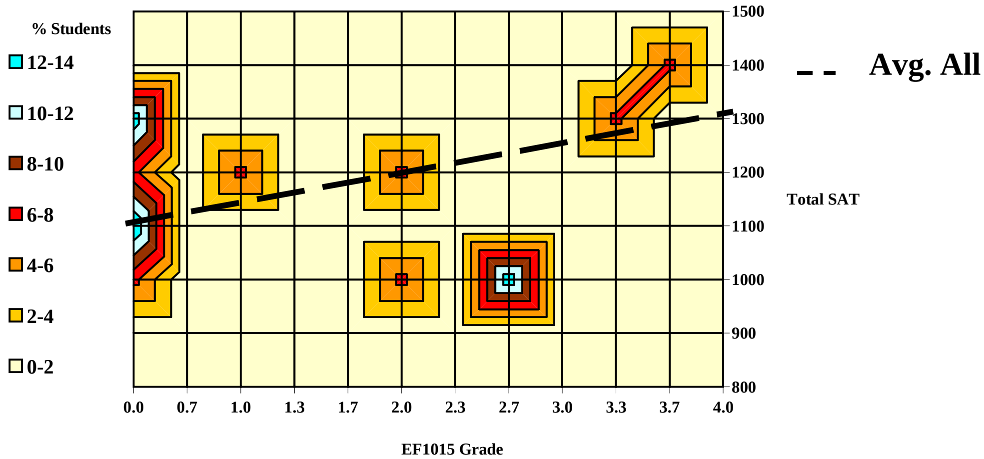

Figure 12. Fall '97 Hispanic Freshman-Engineering Student Performance.

Figure 12 shows the Fall '97 Hispanic group data and, again, the best fit total student line. Due to the limited number of students in the Hispanic group, no trends or a best fit line are apparent. The 53% failure rate is, however, substantially higher than the other groups.

'98 All (Spr EF1015)

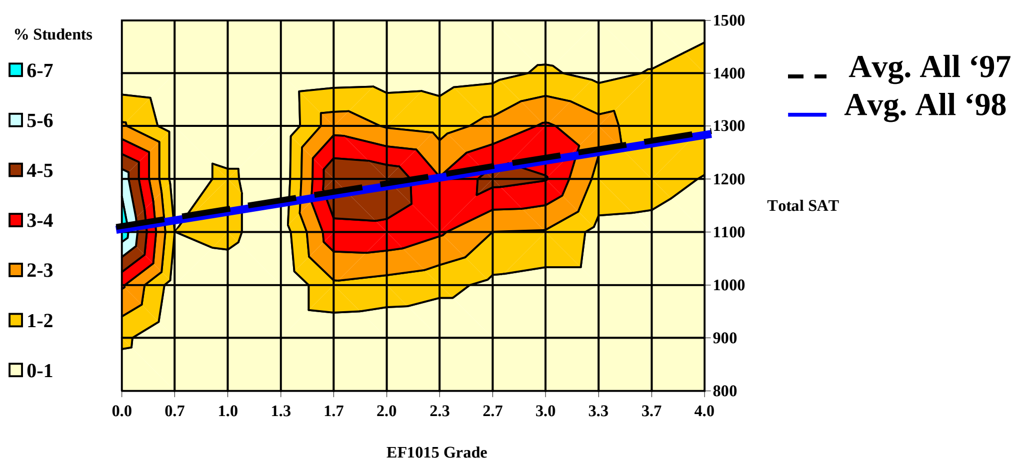

Figure 13. Spring '98 Overall Freshman-Engineering Student Performance.

Figure 13 displays Spring '98 overall freshman-engineering student grade relationships to

Copyright O 2001, American Society for Engineering Education

their SAT scores along with the Fall ’97 and Spring ’98 best fit lines. Both best fit lines are almost identical. The percentage of students within the 0.7 to 1.3 grade range has substantially decreased. This is attributed to the previously mentioned “C-” rule and students who retook EF1015 after doing poorly in the Fall ’97 semester. The percentage of “F”s increased from 17.5% to 19%.

'98 Female (Spr EF1015)

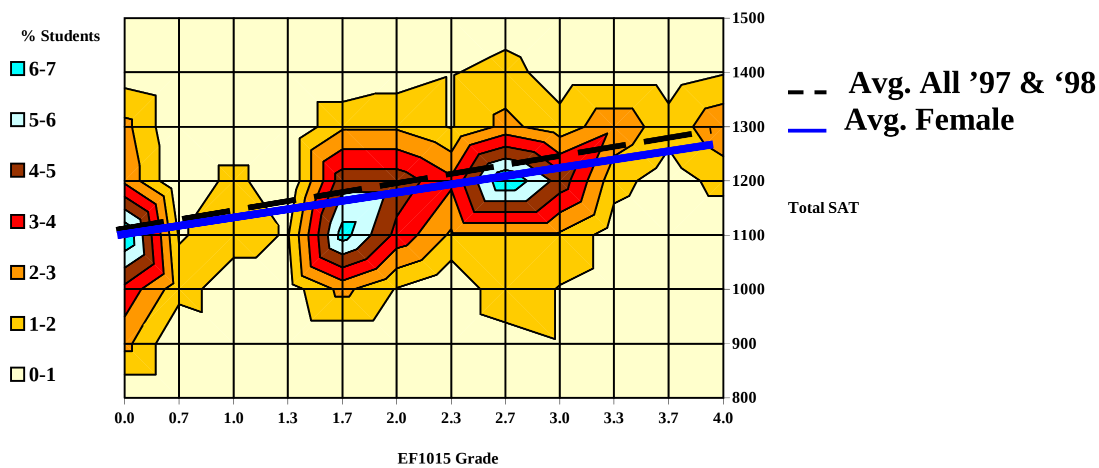

Figure 14. Spring '98 Female Freshman-Engineering Student Performance.

Figure 14 displays the female group data in conjunction with comparison best fit lines. The display shows no noticeable change in projections. The data is very similar to Figure 10, Fall ‘97s data, but there is a decrease in student percentages between the 0.7 to 1.3 range. The percentage of “F”s increased from 14% to 18%.

'98 Afro Amer (Spr EF1015)

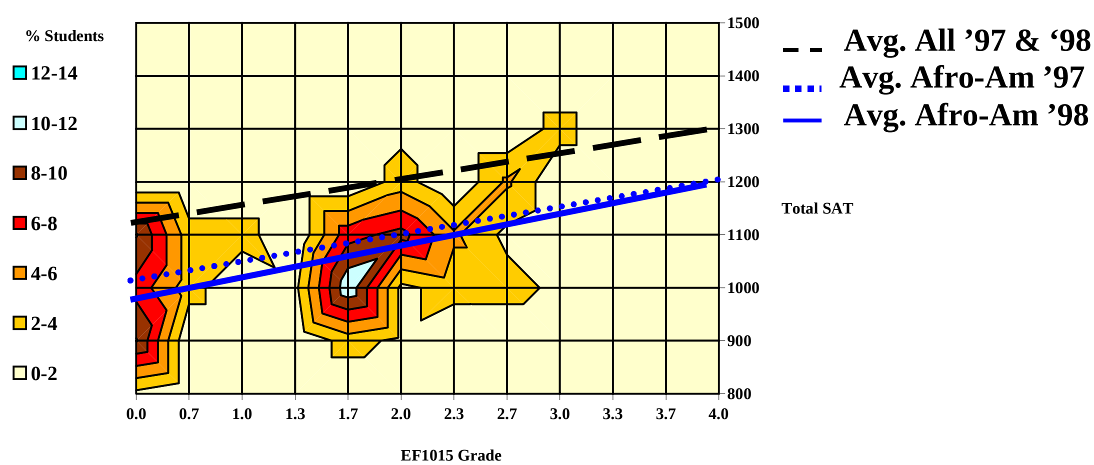

Figure 15. Spring '98 Afro-American Freshman-Engineering Student Performance.

Copyright O 2001, American Society for Engineering Education

Figure 15 shows the Spring ’98 Afro-American group data that reflects the same trends present in other groups. There is minimal shift in the best fit line and a decrease in the 0.7 to 1.3 grade range. The most notable movement was the decrease in percentage of “F”s. The percentage dropped from 32% to 29% while most groups increased by 2%. This improvement is attributed to targeted student support programs.

'98 Hispanic (Spr EF1015)

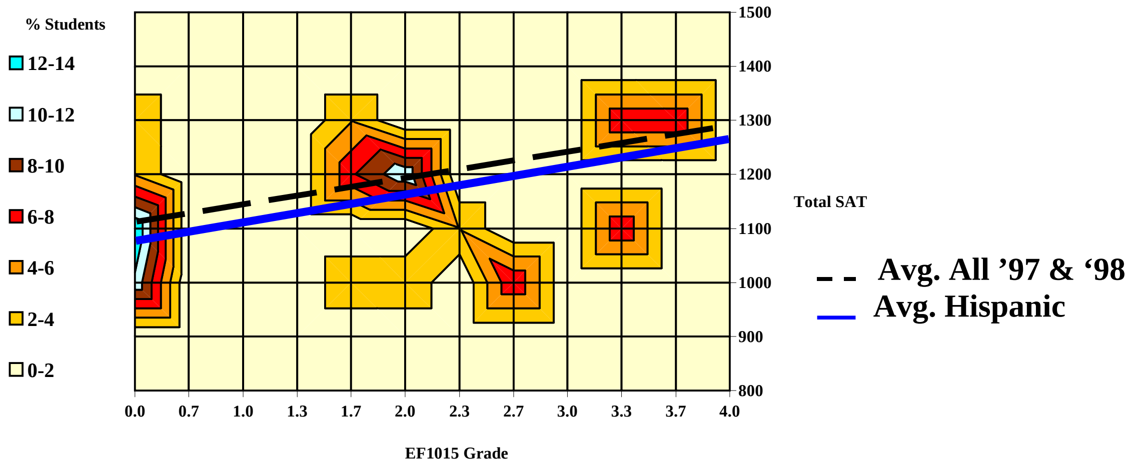

Figure 16. Spring '98 Hispanic Freshman-Engineering Student Performance.

Figure 16 displays the Spring ’98 Hispanic group data that again reflects prior group trends. The grade shifts reflect the overall group norm. The 35% failure rate continues to be the highest of any group although it decreased 18%, from 53% in Fall ’97.

'99 All (Spr EF1015)

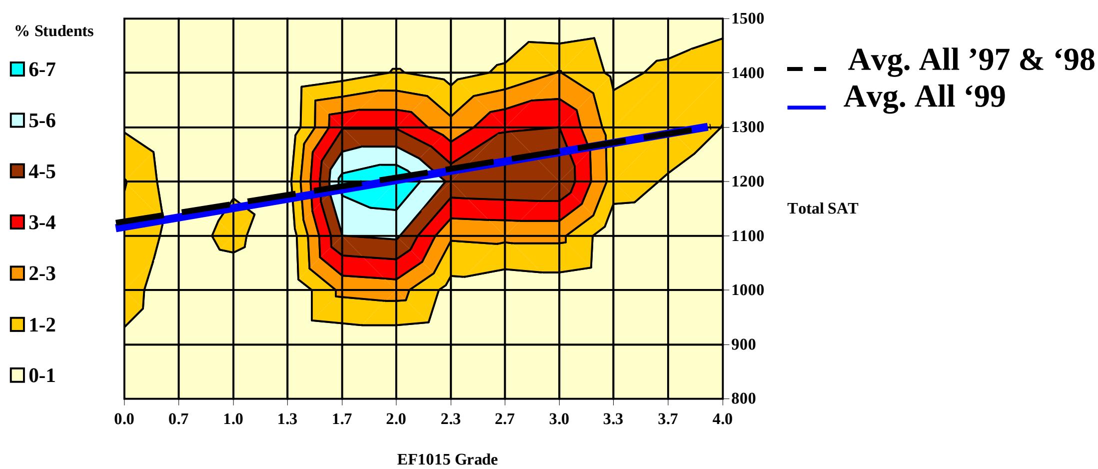

Figure 17. Spring '99 Overall Freshman-Engineering Student Performance.

Figure 17 shows that there is little difference between the best fit line for the Fall ’97, Spring ’98, and Spring ’99. The overall relationship correlation between student total

Copyright O 2001, American Society for Engineering Education

SAT scores and their EF1015 grade remains constant. The rightward flow of grades also continues to grow while there is a 12% decrease in “F”s, from 19% to 7%. As previously stated, this migration of grades is attributed to the “C-“ rule since there was little variation in the course or student makeup.

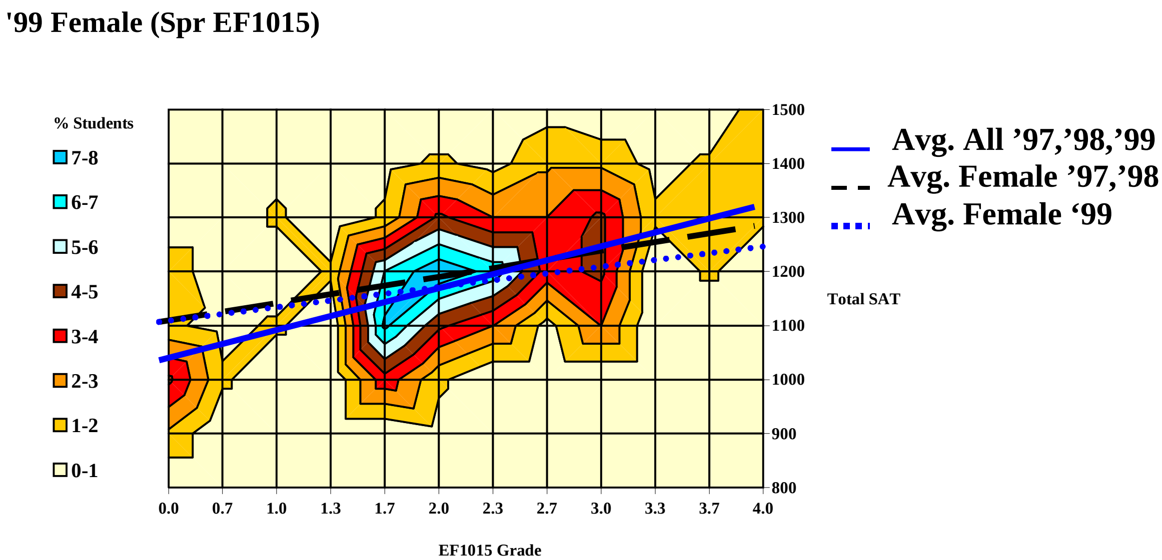

Figure 18. Spring '99 Female Freshman-Engineering Student Performance.

Figure 18 displays the Spring ’99 female total SAT score versus EF1015 course grade relationship and the best fit lines of the female group in comparison to the overall student database. Again, there are slight variations but nothing substantial. The variations can be attributed to the student population change, not group trends or differences. The female group did make up 21% of the total failures in the course, or 9% of the overall “F”s versus the 7% norm.

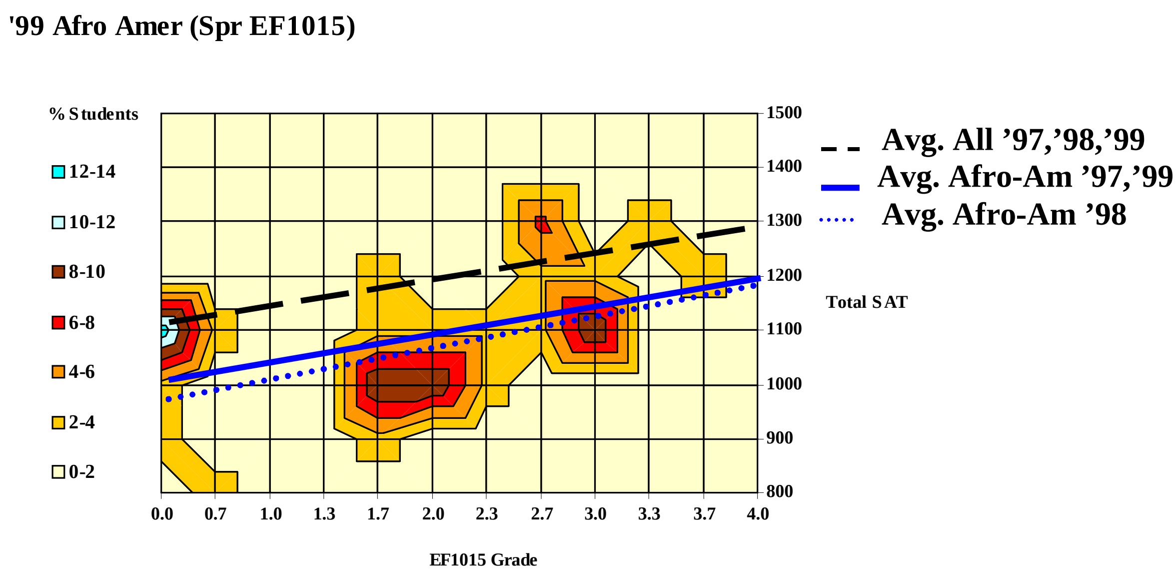

Figure 19. Spring '99 Afro-American Freshman-Engineering Student Performance.

Copyright O 2001, American Society for Engineering Education

Figure 19 shows the same correlation between Afro-American total SAT scores and EF1015 grades as previously displayed. The figure also shows the elimination of grades from 0.7 to 1.3 along with a high percentage of failures. The group had 20% "F"s as compared to the 9% overall student norm, 15 of 73 "F" students. Although the 20% is a 9% improvement from the previous year's 29%, the high percentage of failures is of continued concern when considering support programs offered Afro-American students.

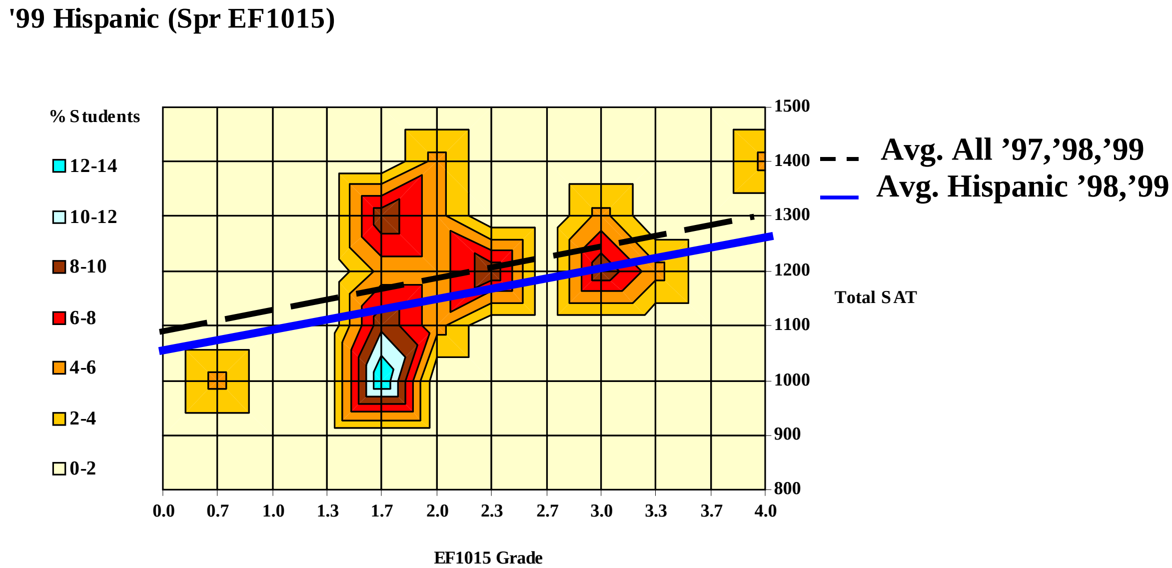

Figure 20. Spring '99 Hispanic Freshman-Engineering Student Performance.

Figure 20 displays the same best line fit for the Spring '98 and Spring '99 Hispanic group. As in all cases, there is a migration of grades from the 0.7 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 35% decrease in Hispanic group failures and the improvements are attributed to targeted support programs.

III. Conclusions

The presented data represents the initial results of a study that the authors hope to continue for several years. 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 "Total SAT" score is **NOT** a reliable predictor of their introductory freshman engineering course performance. Although there is a consistent "Total SAT" to "EF1015 Grade" correlation, the relationship is significantly clouded by other factors as proposed during the data analysis.

Copyright O 2001, American Society for Engineering Education

- 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 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 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 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 total SAT score provides little indication that a student will pass or fail their first engineering introductory course. Although students with low SAT scores are more likely to fail, many students with high SAT 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. [8]

IV. Recommendations

The following recommendations are provided.

- A student's total SAT score should only be used as a limiting requirement for entry into the College of Engineering. It is suggested that each student have at least a 1000 total SAT score.

- Support services foster better student performance in relation to SAT scores and should be made available to all students.

Copyright O 2001, American Society for Engineering Education

- 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 looking at math & verbal SAT scores separately and student performance in other first semester courses.

Bibliography

1. "Virginia Tech" is a trademark for "Virginia Polytechnic Institute and State University", Blacksburg, Virginia.
2. Gilbert, A. C. F., "Predicting Graduation From An Engineering School," *Journal of Psychological Studies*, Vol. 11, 1960, pp. 229-231.
3. Johnson, A. Pemberton , "The Prediction of Engineering Potentiality in High School Students," *Journal of Engineering Education,* Vol. 46, 1955, pp. 135-139.
4. Shell, Kevin D. , "Utility of SAT Scores in Predicting Engineering and University Retention," paper presented at the *Frontiers in Education Conference 1982*, Piscataway, NJ, USA pp. 244-250. Available from IEEE Service Cent (Cat. Published by IEEE, New York, NY, USA. n 82CH1829-1).
5. Van Mater, David D., "Prediction of Academic Success in Manufacturing Engineering Technology at Texans A&M University," Ph.D. Thesis (DAI, 52, no. 02A, (1990): 0447), Texas A&M University, 1990.
6. Colwell, Stephen M., "The Relationship of Intellective and Demographic Variables to the Academic Performance and Persistence of Technical College Students," Ph.D. Thesis (DAI, 50, no. 04A, (1988): 0930), The University of Connecticut, 1988
7. Devi, Nirmal, "Predicting Success in Four Different Programs at a Technical University (Florida)," Ed.D. Thesis (DAI, 49, no. 12A, (1988): 3600), Florida Atlantic University, 1988.
8. Prather, Edward N., "A Study of the Effectiveness of an Extended Bridge Program on the Academic Success of Minority First-Year Engineering Students," Ed.D. Thesis (DAI, 57, no. 03A, (1996): 1049), University of Cincinnati, 1996.

PATRICK DEVENS

Pat Devens is an assistant professor at VPI & SU and teaches computer-aided design, programming, and engineering fundamentals. He received his B.S. at the United States Military Academy and M.S. in Civil Engineering at VPI & SU. He has authored numerous publications and developed and directed several engineering programs. His project accomplishments include a $23 million renovation and a $30 million new facility. He has managed annual facility operation/maintenance budgets exceeding $2.5 million and provided engineering support throughout the world.

THOMAS WALKER

Tom Walker is an associate professor at VPI&SU. He teaches introductory engineering courses and computer programming. He received his B.S. in electrical engineering at Purdue University and his M.S. in mechanical engineering at the Naval Postgraduate School. He has 17 years of experience as an engineering educator.

Copyright O 2001, American Society for Engineering Education