2006-771: USING THE SAT AND ACT SCORES FOR PLACEMENT INTO ENGINEERING FRESHMAN COURSES

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I. Introduction

Engineering education research has shown that the placement of a freshman in his/her first semester in engineering is a key factor in his/her successful retention and eventual graduation. A first-term course that is too difficult may discourage a student from pursuing a degree in engineering.[6] Recent college retention literature has emphasized the need for early assessment and intervention. [10,11,12]

As part of an early assessment program, most engineering colleges use a placement test during college orientation to place a student into the most appropriate calculus course. A literature review shows that some engineering schools are having success using the ACT or SAT results as part of their placement process for the appropriate calculus course. If a student scores high on the ACT or SAT Math test, he/she is placed into Calculus I without a placement test. As an example, the University of Pittsburgh places a student with a SAT Math of 650 or higher into the first Calculus course without a placement test.[9] If the ACT or SAT Math could be used to place a majority of the students, significant savings in placement testing would be the result.

Recently, ACT, Inc. has issued a report[4] recommending a cut-point on the ACT Math test of 27 for predicting success in the first college level calculus course. At most engineering colleges, the first term courses include engineering courses that are math-intensive. This paper looks at the question of whether this ACT Math cut-point of 27 could be used to predict success in most first term engineering courses. This paper also compares ACT Math to the SAT Math scores as predictors of success in the first term engineering courses. Success is defined as having earned a "C" or better.

Placement in the College of Engineering

At the University of Michigan's College of Engineering, there currently is a placement test for both calculus and chemistry. The result of the math placement test is a placement of a student into either pre-calculus or calculus I. AP tests are used to place students in Calculus II or higher. Because it is recognized that the correct placement into the appropriate calculus is a critical part of the learning process, both a placement test and a math advisor is part of this placement process. The result of the chemistry placement test is a placement of a student into the regular freshman college chemistry course or a remedial section of the freshman chemistry course. The chemistry placement test is also used to place students into the sophomore level chemistry course.

In addition to calculus and freshman chemistry, most freshmen engineering students take either Engineering 100 or Engineering 101 in the first term of their freshman year. Engineering 100 is a project-based introduction to engineering course and Engineering 101 is a course on programming with engineering applications. There are no remedial sections or courses associated with Engineering 100 or 101.

For Calculus, correct placement includes a decision on whether to place a student into Calculus or Pre-Calculus. For Chemistry, correct placement includes a decision on whether to place a student into the regular or remedial sections of Chemistry. For Engineering 100 or 101, correct placement is equivalent to asking which students will need academic intervention such as tutoring or mentoring. Engineering Physics is not being considered because most students take Physics the 2nd term of their freshman year and this analysis is limited to first-term courses.

Research Questions:

Two research questions will be addressed in this paper:

1. Can the ACT Math or SAT Math tests predict a passing grade of a "C" or better for the typical freshman first term engineering courses: Calculus I and II, Chemistry, Engineering 100 and Engineering 101?

2. Which test, the ACT Math or SAT Math, produces a better prediction?

First, these two questions will be considered on a theoretical basis and then on an empirical basis using recent student data from the University of Michigan College of Engineering.

II. Theoretical Basis for Prediction with the ACT and SAT tests

In the College of Engineering at the University of Michigan, the core engineering courses taken by freshmen during their first term are:

- Calculus I or Calculus II
- Chemistry I
- Introduction to Engineering (Engineering 100)
- Computing in Engineering (Engineering 101)

Both the ACT and SAT tests are accepted as part of the admission process at the College of Engineering at the University of Michigan. The ACT test has four major subtests: English, Math, Reading and Science Reasoning. The SAT test has two major subtest; Verbal and Math.

With respect to preparation for freshman engineering courses, there are two significant differences between the ACT and SAT tests.[3,14]

1. The SAT Math tests only for competence in 9th grade basic geometry and Algebra II while the ACT Math tests for competence in high school math courses through trigonometry.
2. The SAT does not test for Science while the ACT has a full sub-test on scientific reasoning.

From a theoretical basis of testing, with the higher rigor of a math background needed for freshman engineering courses, it would seem that the ACT math test would be a better predictor of a passing grade than the SAT math test. Calculus I, Engineering 100 and Engineering 101 use higher level math concepts. For predicting a passing grade in Chemistry, it would seem that the

ACT Science would be a good predictor. For this data discussed in this report, the ACT math was a better predictor than the ACT Science so the discussion is limited to the ACT math and SAT math tests in the remainder of this report.

ACT Literature Review

A literature review was conducted of research papers published on the ACT website. ACT researchers have published a significant research paper showing that the ACT math cut- points can be used to predict the success of students in Calculus. In their study including a large number of colleges, ACT researchers established an ACT Math cut-point of 27 for students having a 50% chance of earning a B or better in the first college calculus course and a 75% chance of earning a C or better.[4] See ACT Research Report 2005-3 [5] for a detailed explanation of the techniques used to established these cut-points. These cut-points may also be referred to as college readiness benchmarks. [1] In addition, an ACT report shows an increase in the average ACT Math score with more college-prep high-school math courses.[2]

Scaling of the ACT and SAT

The scaling of the two tests is different. Each subscore of the ACT test has a range of 0 to 36. Each subscore of the SAT has a range of 0 to 800. Efforts have been made to cross-reference the equivalent scores for each test. It is generally accepted that an ACT Math score of 27 is equivalent to a SAT math score of 610.[8]

Summary

The freshman engineering courses require a strong mathematics background. The ACT test would seem to better identify whether a student is prepared for the academic rigors of engineering college because of its testing focus on both mathematics and scientific reasoning. The ACT Math tests trigonometry concepts while the SAT Math does not. As previously discussed, ACT has established a cut-point of 27 on the ACT Math test as a good indicator of success in Calculus I (across all universities)

III. Empirical Results at the University of Michigan's College of Engineering

Empirical results are based on student data from a recent freshman class in the University of Michigan College of Engineering. This freshman class had approximately 1000 students. For purposes of comparing the ACT versus SAT predictive power of success in the freshman first term engineering courses, only the records of students who took both the ACT and SAT were included in this analysis. 461 students reported both the ACT and SAT scores. A validity check was conducted to verify that the distribution of grades were approximately the same for this group of students compared to the overall freshman class.

Methodology

Because of the strong math components of all the engineering courses in the University of Michigan College of Engineering, it was hypothesized that the ACT math cut-point of 27 could

be used for not only identifying students who may struggle in Calculus I , but also for identifying students who may struggle in the other first term freshman engineering courses. Therefore, an analysis was conducted to establish the test efficiency, test specificity and test sensitivity of the ACT Math score compared to the SAT Math Score for the freshman engineering courses. A 2x2 contingency table methodology was used. For the ACT math score of 27 (or equivalent SAT Math score of 610), the two levels were either less than or greater than/equal to the ACT/SAT Math cut-point. For the grade associated with a subject, such as calculus, the two levels were either less than or greater than/equal to a C letter grade.

Table 1 illustrates an example for Calculus I.

Table 1: Example of Contingency Table Analysis

Calculus I	**Number of Students with a Grade < C**	**Number of Students with a Grade ≥ C**
ACT Math < 27	7	20
ACT Math ≥ 27	4	136

In this example, 167 students were included.

The ***test efficiency*** is defined as the percent of students whose grades were accurately predicted (less than or greater than/equal to a C) by the ACT Math score using a cut-point of 27.[13] Thus, in this example,

$$\text{Test Efficiency} = (7 + 136)/167 = 86\%$$

The ***test specificity*** is defined as the percent of all students who scored an ACT Math ≥ 27 and earned a C or higher in the freshman engineering course (i.e., the ACT Math cut-point of 27 predicted success in the course).[13] For the example in Figure 1,

$$\text{Test Specificity} = 136/140 = 97\%$$

The ***test sensitivity*** is defined as the percent of student who scored an ACT Math < 27 and earned less than a C in the freshman engineering course (i.e., the ACT Math cut-point of 27 predicted a low grade in the course)[13] For the example in Figure 1,

$$\text{Test Sensitivity} = 7/27 = 26\%$$

Results

Table 2 shows the test efficiencies for whether the ACT Math and SAT Math will predict if a student will pass (C or better) a course.

Table 2: Efficiencies for Predicting the Success of the Freshmen Engineering Courses (C or better) with the ACT Math and SAT Math scores.

Freshman Engineering Course	Number of Students	ACT Math Efficiency	SAT Math Efficiency	Difference	ACT/SAT Math Cut point
Calculus I	167	86	74	12	27/610
Calculus II	125	92	92	0	27/610
Chemistry I	270	86	79	7	27/610
Engineering 100	215	89	83	6	27/610
Engineering 101	252	90	89	1	27/610

Significantly, both the SAT Math and ACT Math have relatively high test efficiencies for **each first term freshman engineering course**. The ACT efficiency is always higher than or equal to the SAT efficiency. Since the ACT Math tests for higher level high school math concepts than the SAT (see section II), it would be expected that the ACT would perform better as a predictor. The largest difference in efficiencies exists with the Calculus I course.

Table 3: Test Specificity and Test Sensitivity for Predicting the Success of the Freshmen Engineering Courses (C or better) with the ACT Math and SAT Math scores.

Freshman Engineering Course	Test Specificity for the ACT Math	Test Specificity for the SAT Math	Test Sensitivity For the ACT Math	Test Sensitivity For the SAT Math
Calculus I	97	95	26	12
Calculus II	97	97	0	0
Chemistry I	94	94	24	14
Engineering 100	99	98	15	8
Engineering 101	95	96	7	10

Table 3 shows the test specificity and test sensitivity for predicting the success of the first term freshman engineering courses using the ACT Math and SAT Math scores. For all courses, the ACT Math cut-point is 27 and the SAT Math cut-point is 610.

There is no significant difference in test specificity using the ACT Math compared to the SAT Math scores. The test specificity statistics are within 2% for all courses.

The major difference in Table 3 is that the test sensitivity for a low grade using the ACT Math cut-point of 27 is more than twice that of using the SAT Math cut-point of 610 for the Calculus I. For Chemistry I and Engineering 100, the test sensitivity is significantly higher with the ACT Math cut-point than with the SAT Math cut-point. The Test Sensitivity for Calculus II is 0, probably because an AP test is required to test into Calculus II. For the Engineering 101, the Sensitivity is 3 points better for the SAT Math test. For the Calculus I and Chemistry I, the efficiency for the SAT Math is less compared to the ACT Math because of the lower sensitivity of the SAT Math test. In other words, when a low SAT Math score is achieved, the test gives a much higher percent of good grades (C or better); this yields a lower efficiency number. The leads to the conclusion that the SAT Math is a poorer predictor for Calculus I and Chemistry I.

For the interpretation of Table 3 with respect to test sensitivity, consider an example using the calculus I results. Table 4 summarizes the Calculus I results in a 2 x 2 contingency table using the SAT scores. Table 5 summarizes the Calculus I results in a 2 x 2 contingency table using the ACT scores. The percentages are column percentages for a given row.

The major difference between Table 4 and Table 5 is the distribution of the students with poor grades in Calculus I with respect to the breakout of low versus high SAT or ACT scores. In other words, most of the difference is in the 2nd column of Table 4 and Table 5. ***The error of a good course grade given a low SAT/ACT Math score is much higher at 88% for the SAT than the 74% for the ACT (shown in bold).***

Table 4: Calculus I Results in a 2x 2 Contingency Table Format using the SAT Math Scores (cut-point = 610)

Calculus I	**Poor Grade**	**Good Grade**
Low SAT	5 12%	38 **88%**
High SAT	6 5%	118 95%

Test Efficiency = (5+118)/ 167 = 74%
Test Specificity = 95%
Test Sensitivity = 12%

Table 5: Calculus I Results in a 2 x 2 Contingency Table Format using the ACT Math Scores (cut-point = 27)

Calculus I	Poor Grade	Good Grade
Low ACT	7 26%	20 **74%**
High ACT	4 3%	136 97%

Test Efficiency = (7+ 136)/ 167 = 86%
Test Specificity = 97%
Test Sensitivity = 26%

In this analysis, the ACT Math or SAT Math were considered as predictors of achieving a grade of less than a "C" or greater/equal to a "C". A separate analysis considered using the same ACT Math cut-point to predict the predictive power of the ACT Math or SAT Math as predictors of achieving a grade of less than a "B-" or greater/equal to a "B-". With this criterion, the results achieved lower test efficiency. Using a cut-point of a grade of a "C" gave a stronger prediction.

IV. Summary and Recommendations

In this case study at the University of Michigan's College of Engineering, the ACT Math cut-point of 27 worked well in predicting whether a student would earn a passing grade (C or better) for each of the first term freshman engineering courses. For all courses, the test efficiency (probability of correctly predicting a either a C or better or less than a C) was 86% or higher when the ACT Math was used. The efficiency was less for the SAT Math, especially when predicting the grade in Calculus I.

These results are significant because most retention studies use the SAT or SAT Math score as an indicator for preparation level. The analysis presented in this report suggests that the evidence is clear, both theoretically and empirically, that the ACT Math is a better predictor for success of students in first term engineering courses.

A Purdue University study showed that success in the first term contributes significantly to a high graduation rate in engineering. [6] With the analysis in this report, a recommendation is made that researchers re-consider the ACT test scores as a predictor of engineering student success in terms of retention rates. Because of the higher math content of the ACT test, consideration of the ACT over the SAT deserves further consideration for engineering student retention studies.
The overall significance is that the ACT Math may be a very significant process tool for identifying students who need early intervention in the first term of their freshman year of engineering. More confirmatory studies are needed to verify the results of this study.

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