Course and Exam Statistics in Electrical Engineering

D Blandford
University of Evansville, blandfor@csserver.evansville.edu

Mark Randall
University of Evansville, mr63@evansville.edu

Jessica Lofton
University of Evansville, jb363@evansville.edu

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Abstract
This paper examines the course and national exam records for about sixty-three students in electrical engineering. The data includes the following: SAT scores, high school math and science grades, high school GPA, and grades for math, science, and engineering courses in the first two years of the major for undergraduates in electrical engineering. The data is analyzed seeking a correlation with success in the major which is measured by the cumulative GPA at or near graduation.

Two types of correlation data are presented. First, correlation with individual data items and success in the major is established. The results of this analysis shows that there are better items that can be used to predict success in EE than the results of standardized test scores. Second, linear combinations of various data items or formed and an optimal weighting sequences is established for prediction of success in the major.

The analysis may be useful to establish entrance requirements for high school students coming into the major and for consideration of upper level admission for those programs which further restrict entrance to the junior and senior level course work.

Introduction

The first SAT test was given in 1926 and was intended to measure student's readiness for college.[1] The SAT and its competitor the ACT have better correlation to college performance in some majors than in others. In this paper we examine the correlation between SAT scores and performance in an electrical engineering program. In addition, we have examined the data collected by the college admissions process and the student scores in the first two years of the electrical engineering program to determine if some single factor or some linear combination of factors can provide a better correlation to performance in electrical engineering. The data we collected includes the high school transcripts and the college transcripts of sixty-three electrical engineering students who have either graduated or are very close to graduation. The high school record provided grades in math and science classes, overall grade point average for four years of high school, and SAT scores. The college transcripts provided grades in calculus, physics, chemistry, differential equations, and the grades in the sophomore level EE courses (circuits, logic design, electronics, and programming classes).

To determine success in electrical engineering we used the overall grade point average at or near graduation. We realize that the overall grade point average in electrical engineering can be problematic and may not always be a good indicator of success. But it is readily available, convenient to use, and is generally accepted as a strong indicator of success in a graduate program.

Size of the Study

The study size is admittedly small by the usual statistical standards. Nevertheless, there are some mitigating factors that indicate that the study is valid and presents useful data. First, the data is not sampled. The sixty-three students in the study represent every student who has graduated in electrical engineering over the past three years for which data is available.

International students are, in general, not included in the study because their high school data is non-standard and valid comparisons to domestic students are difficult to make. In many cases, international students also do not take the standardized SAT and ACT exams. Class rank for international students is not typically available. In addition some domestic students attended high schools where grades were kept in a non-standard manner. In some schools, for example students are given a percentage number for a grade with no indication on the transcript as to how this translates to a letter grade. Likewise, several high schools have stopped listing a class rank on the transcript because they feel that it is unfair to compare the class rank of college bound students with those who may have taken a less demanding set of courses.

Second, the data presented here is largely in agreement with much larger studies. For example, the paper by van Alphen and Katz[7] examined the high school records of more than 240 students and found a significantly better correlation to the high school GPA and the college GPA than the SAT score and the college GPA.

Finally, a similar study[4] of about sixty mechanical engineering majors at the University of Evansville and a small study[6] published at the ASEE Conference in Columbus, Ohio for electrical engineering students at two different universities show very similar results.

SAT Scores

For the purposes of this paper the SAT score consists of three numbers: the math score which ranges from 200-800; the reading and writing score which ranges from 200-800, and the total score which is the sum of the two and ranges from 400-1600. We compared the math SAT score and the total SAT score to the total grade point average (GPA) after or near graduation in electrical engineering for sixty-three students chosen from the past three years. The GPA is calculated on a 4.0 scale with plusses and minuses as shown in Table 1.

Table 1

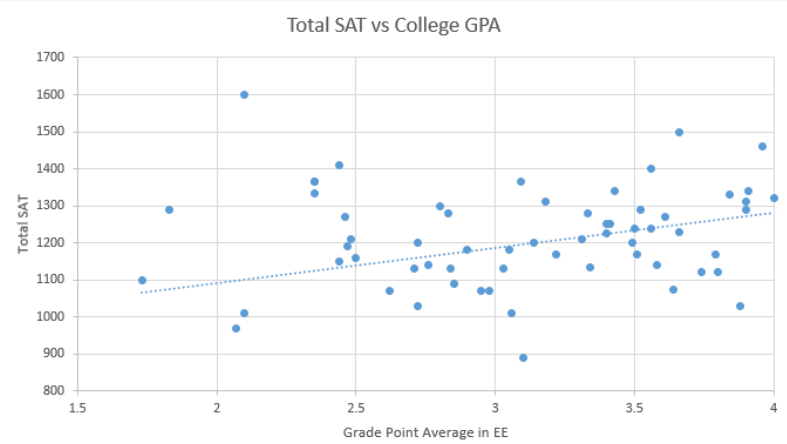
The 4.0 grading scale with plusses and minuses.

A	A-	B+	B	B-	C+	C	C-	D+	D	F
4.0	3.7	3.3	3.0	2.7	2.3	2.0	1.7	1.3	1.0	0.0

The results of the comparisons are shown in Figures 1 and 2. Each figure also has a list of statistics including the mean, median, and standard deviation of the data, and the correlation value. The correlation[2] value is calculated using:

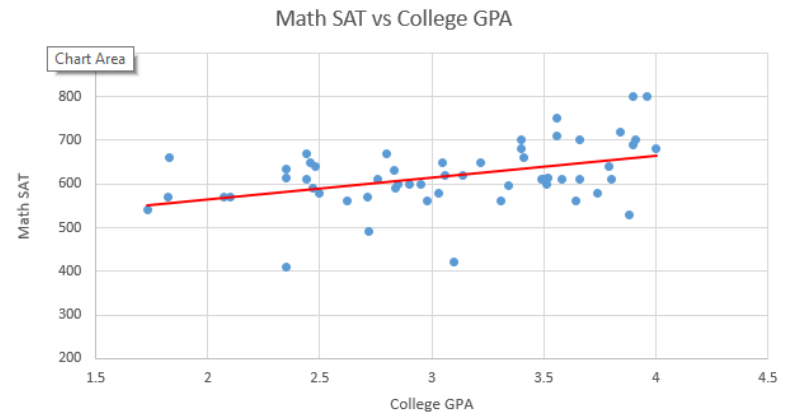
$$\text{Correlation} = r = \frac{\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{N}(x_i - \bar{x})^2 \sum_{i=1}^{N}(y_i - \bar{y})^2}}$$

Each graph also has a trend line, also called the regression line. The correlation value, r, is the slope of the trend line.



Correlation	0.29
Mean	1169.23
Median	1175.00
Std Dev	195.56

Figure 1
Comparison of total SAT score and GPA for electrical engineering graduates.



Correlation	0.43
Mean	618.75
Median	610.00
Std Dev	72.927

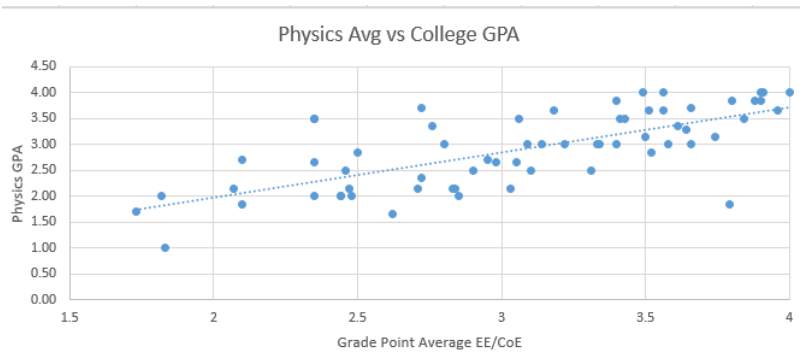
Figure 2
Comparison of math SAT score and GPA for electrical engineering graduates.

The correlation calculation is known to be sensitive to outliers[3]. There were two outliers in the data in Figure 2. If the outliers are in place the correlation falls to just 0.30.

Using freshman and sophomore courses to predict success in EE

In addition to the SAT scores and college GPA in EE we also compare the student averages in two physics course, three calculus courses, a course in differential equations, and two sophomore level courses in linear systems. Figure 3, 4, 5, and 6 show this data along with the relevant statistics.

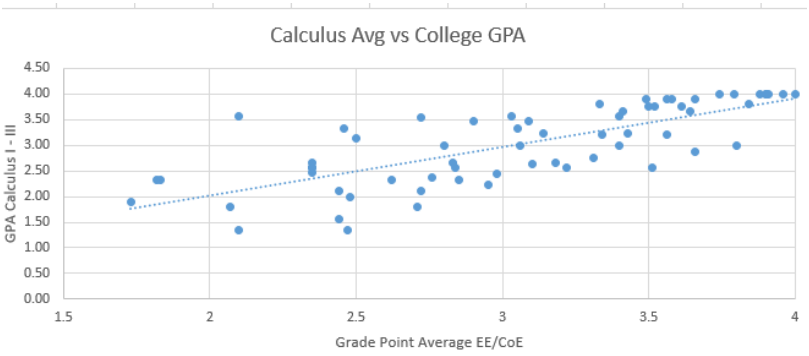
We note that the best predictor for success in electrical engineering as measured by the graduation GPA is the average grade in the sophomore circuits classes although the grades in physics, calculus, and differential equations all prove to be better predictors of success in electrical engineering than do the SAT scores.



Correlation	0.69
Mean	2.85
Median	2.93
Std Dev	0.74

Figure 3

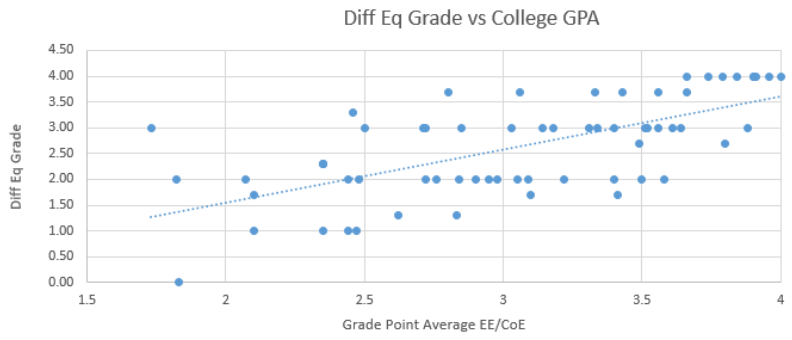
Average grade in two physics courses vs GPA for electrical engineering graduates.



Correlation	0.75
Mean	2.96
Median	3.00
Std Dev	0.79

Figure 4

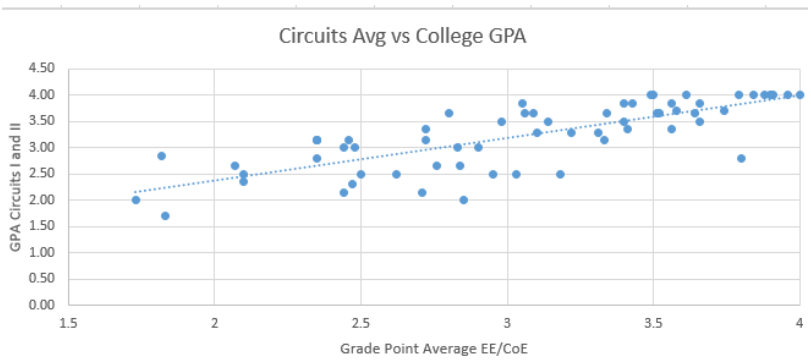
Average grade in three calculus courses vs GPA for electrical engineering graduates.



Correlation	0.66
Mean	2.57
Median	2.70
Std Dev	0.91

Figure 5

Average grade in differential equations vs GPA for electrical engineering graduates.



Correlation	0.79
Mean	3.19
Median	3.30
Std Dev	0.65

Figure 6

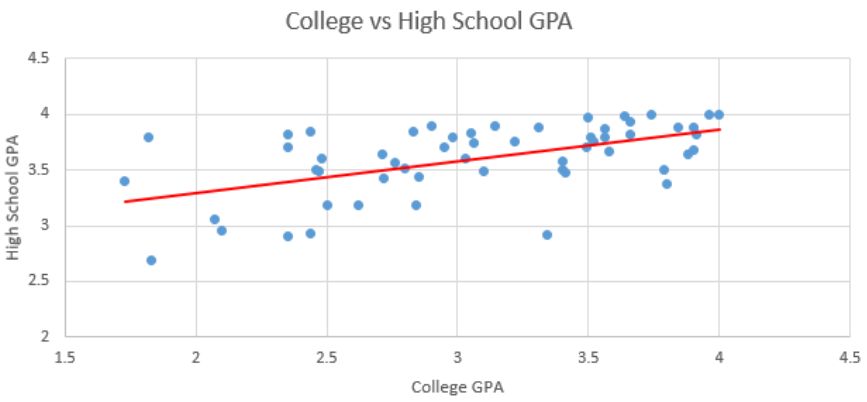
Average grade in two sophomore circuits courses vs GPA for electrical engineering graduates.

The High School Data

The high school data was taken from high school transcripts which were submitted as an entrance requirement to the University. We were primarily interested in the high school GPA, the high school class rank, the SAT scores for the Math portion of the SAT, and the average grades in the science and math courses taken in high school. There is some variability in the data between high schools which we list below:

1. Many high schools do not keep track of class rank. In our data only about 75% of high schools had class rank data available. Since this number is unavailable for so many students we dropped it from consideration.
2. Some high schools keep track of grades using a percentage number. In cases where the high school provided a method to translate this number to a letter grade we did so – otherwise we discarded the record. The number of schools in our sample which had percentage scores was 4 and 2 of those provided a translation to letter grades.
3. Most students in our area take the SAT exam or they take both the SAT and the ACT exams. For those students who took only the ACT exam we translated the math score to an equivalent SAT score. Translation tables are readily available online.[5]
4. For the math average grade we included all of the math courses shown on the transcript. This generally included geometry, algebra I and II, trigonometry and/or pre-calculus, and calculus. Some high schools do not offer a calculus course and in some cases algebra I was taken prior to high school and not recorded on the transcript.
5. For the science average grade we included chemistry, physics, and biology. In some cases, students took two years of chemistry but no biology. Many (about half) of the high schools in our area do not provide a formal physics course in which case it is not included.
6. High schools are of variable quality and a 3.5 GPA at one school may reflect a very different quality of work than a 3.5 GPA at another. The high school GPA is admittedly imperfect as a measure of performance. This is mitigated to some extent by the fact that we are only considering high school students who have applied and have been admitted to an electrical engineering university program.

Figure 7 shows the relationship between the high school GPA and the college GPA. Note that the correlation of 0.55 is better than the correlation between the Math SAT and the college GPA in Figure 2.

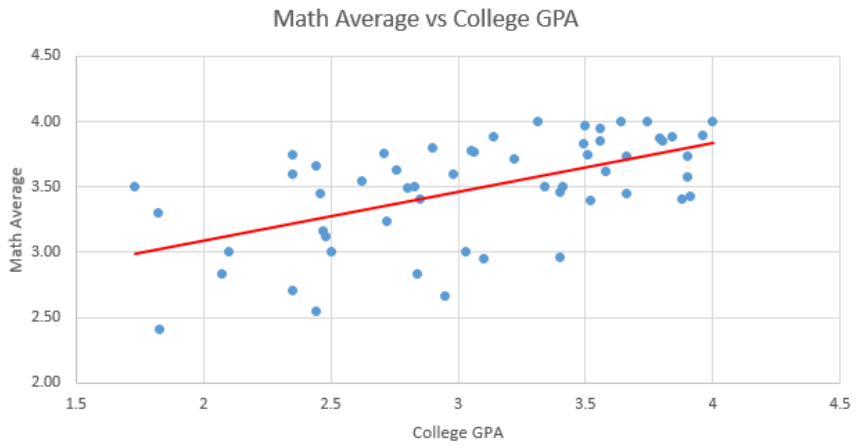


Correlation	0.55
Mean	3.60
Median	3.69
Std Dev	0.320

Figure 7

High school vs College Cumulative Grade Point Average

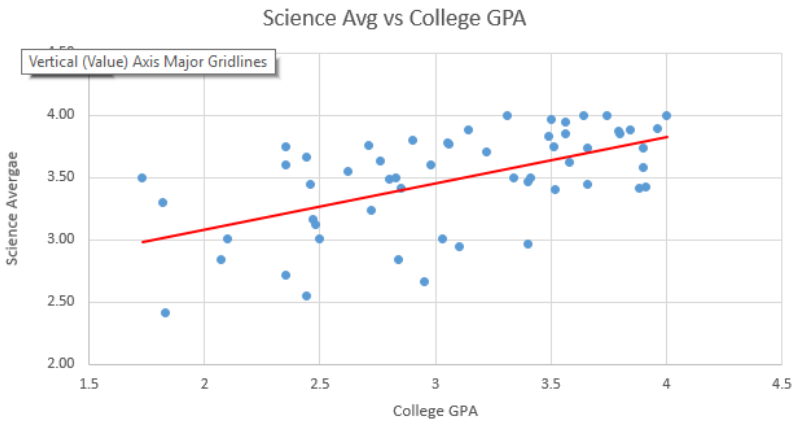
Figure 8 shows the high school math courses average vs the college GPA. Figure 9 is that of the high school science courses average vs the college GPA. Note that both graphs have higher standard deviations since the averages for the math and science course grades are over a relatively small set of numbers. In most cases there are only two or three science grades and four math grades.



Correlation	0.57
Mean	3.49
Median	3.57
Std Dev	0.405

Figure 8

High school math courses average vs College Cumulative Grade Point Average



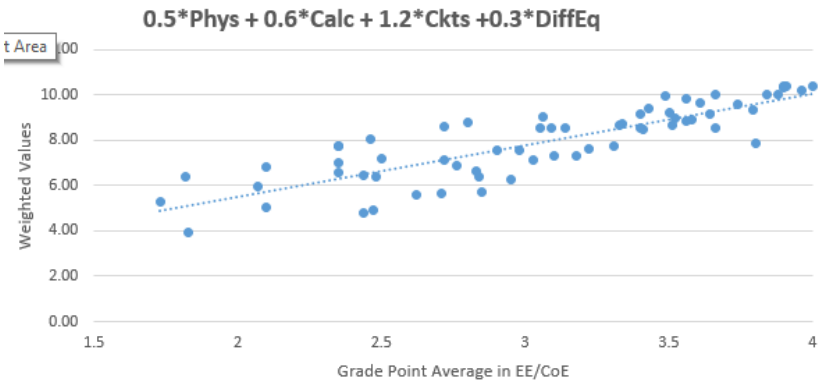
Correlation	0.49
Mean	3.41
Median	3.45
Std Dev	0.479

Figure 9
High school science course average vs College Cumulative Grade Point Average

Linear Combinations for better Correlation

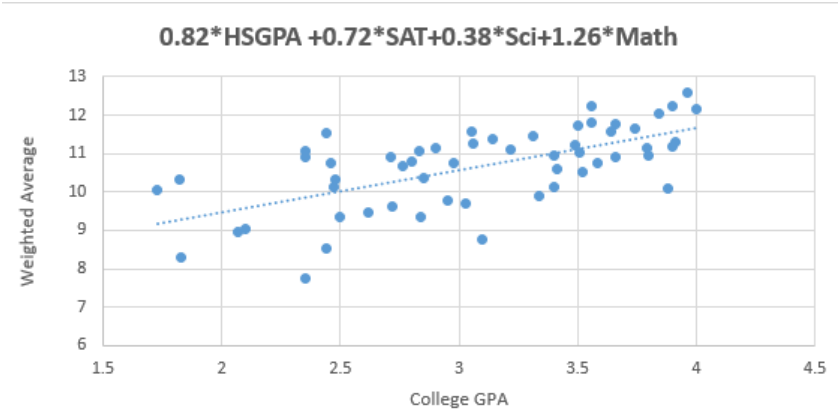
It is possible to combine some of the data with appropriate multipliers to form a function which has a much better correlation to the college GPA. Note that the correlation function is non-linear but the multiplication coefficients can be found by an exhaustive search over a small range of values.

For the college data we considered the following function:
f = K1x(Chemistry) + K2x(Physics) + K3x(Calculus) + K4x(Diff Eq) + K5x(Circuits)
where each of the values in parenthesis were the average values of grades in those areas. For example (Physics) here means the average grade in two university physics courses. The constants were allowed to vary from 0 to 3 in small increments to produce a value for f for each of the 60 students. The correlation of this value with the college GPA was determined and a computer program exhaustively tested all values for each K in the range. We began with a relatively large increment of 0.1 and determined that the chemistry grade was not likely to be relevant. From there we reduced the increment to 0.02 to find values for K2, K3, K4, and K5. The results are shown in Figure 10.



Correlation	0.85
Mean	7.79
Median	7.77
Std Dev	1.65

Figure 10
Correlation with college GPA with the weighted average from physics, calculus, circuits, and the differential equations classes.



Correl	0.63
Mean	10.65
Median	10.90
Std Dev	1.049

Figure 11

Correlation with college GPA with the weighted average from high school GPA, normalized math SAT, science average and math average.

Conclusions and Remarks

The data presented herein has been gleaned from the high school and college records of 63 electrical engineering majors who are graduating this year (2018) or have already graduated in the past two years. All students for those years were included except when there was no data available as was the case for many international students and some domestic transfer students. All of the data was taken from the college and high school transcript.

The data shows that for electrical engineering majors at the University of Evansville, the SAT scores are not as good a predictor for success in electrical engineering as is the high school cumulative grade point average. A better predictor of success can be obtained by using a linear combination of items from the high school transcript. Figure 11, in particular, shows that a linear combination of the high school grade point average, the normalized math SAT score, and the average values of the science and math courses provides a relatively good predictor for success.

For the college level data the sophomore circuits class, not surprisingly, seem be the best single predictor of success in the electrical engineering program. But, as with the high school data a linear combination of physics, calculus, circuits, and the differential equation scores provides the best correlation with the college level GPA. For programs using an upper level admissions process a similar linear combination of lower division grades is probably the best predictor of upper level success.

References

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