Regression Analysis to Predict Student Electric Circuits Performance

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Introduction

The ability to predict future engineering student performance based upon previous academic performance would be a useful tool for identifying at-risk students and increasing retention in engineering programs. Student persistence in engineering programs relates to previous course performance [1]. Many courses offered in engineering programs occur in specific sequences such that one course can have several prerequisites. An analysis of prerequisite course performance can be useful for predicting future student performance [2]. In fact, studies have shown that pre-college academic performance can be a predictor of program graduation [3].

Electric Circuits is a fundamental course in any electrical engineering program. This course provides students with knowledge of essential analytical skills that apply to problems both in and out of the discipline. Such concepts taught include but are not limited to Kirchhoff's Laws, Nodal and Loop Analysis, Superposition, Thevenin's Theorem, and transient behavior of circuits including resistors, capacitors and inductors.

Prediction of success in Electric Circuits must be dependent upon the prerequisites to Electric Circuits I that typically includes a sequence in Calculus I and Calculus II. In this paper, we utilize a regression analysis to explore the extent to which certain academic metrics could serve as predictors of performance in an Electric Circuits I course. If students are successful in their first 4-semesters of a program, it is likely that they will continue to graduation. Therefore, it is important to develop a model that is useful in identifying at-risk students enrolled in an Electric Circuits I course.

Model

We used the statistical language R to produce an ordinal logistic regression of data obtained from institutional records at our university. Students' earned grades in Electric Circuits I, Calculus I, and Calculus II were included in the model, as well as ACT scores (Math and Composite) and Cumulative GPA. Since some students take advanced placement (AP) exams in their pre-college academic careers, it was necessary to create a grade map so the model would function properly. Table 1 provides details on the grade map used in the model. The column, "Letter Grade Used in Model" provides the letter grade, input as ordinal data into the model. The column "Mapped Grades" provides how non-standard grades mapped to the ordinal data in the model.

Table 1. Mapping of letter grades used in the ordinal model. TA = "Transfer A", TB = "Transfer B", AP4 = "a score of 4 on the AP exam", TC = "Transfer C", "CE = C Equivalent", "AP3 = "a score of 3 on the AP exam", TD = "Transfer D", TF = "Transfer F", W = "Withdraw", and TW = "Transfer Withdraw".

Letter Grade Used in Model	Mapped Grades
A	TA
B	TB, AP4
C	TC,CE,AP3, AP
D	TD
F	TF,W,TW

A proportional odds logistic regression (polr from the MASS package [4]) was performed on the data with earned grades in Circuits I as a response and various other data (earned Calculus I grades, Cumulative GPA, ACT scores, etc.) as a linear predictor. Table 2 provides details on the number of records used for the various predictors and the response in the model. A Type III ANOVA analysis was applied to the output of the regression. A single predictor was utilized for each model run.

Table 2. Grade data implemented in the model. Circuits I grades were used as the response whereas Calculus I and Calculus II were used as predictors.

	Number of Grades				
Course Name	**A**	**B**	**C**	**D**	**F**
Circuits I	250	276	177	86	53
Calculus I	255	302	250	34	0
Calculus II	190	248	302	98	3

Results and Discussion

The means for the cumulative GPA, composite ACT, and math ACT scores used in the model were 3.046, 25.21, and 26.22 respectively. Given our dataset, cumulative GPA shows the strongest significance. Earned Calculus I grades are the next most significant predictor. Model runs were also trialed with Calculus II and ACT scores as predictors but these predictors did not show as strong of significance.

The plot in Figure 1 shows that students' cumulative GPA has a significant bearing on a students' earned grade performance in Electric Circuits I. The vertical axis provides the total cumulative probability (summed to 1.0) while the horizontal axis shows cumulative GPA plotted on a log scale. By examining a student who has a cumulative GPA of 2.5, this data allows for the prediction that the student has a 0.13 probability of earning an F, a 0.27 probability of earning a D, a 0.37 probability of earning a C, a 0.2 probability of earning a B, and close to 0.03 probability of earning an A. For a 2.5 GPA student taking this Electric Circuits I course, the odds favor them earning a C or better in the course. However, when the GPA dropped to 2.3, there was only a 50% probability of earning a C or better in the Electric Circuits I course.

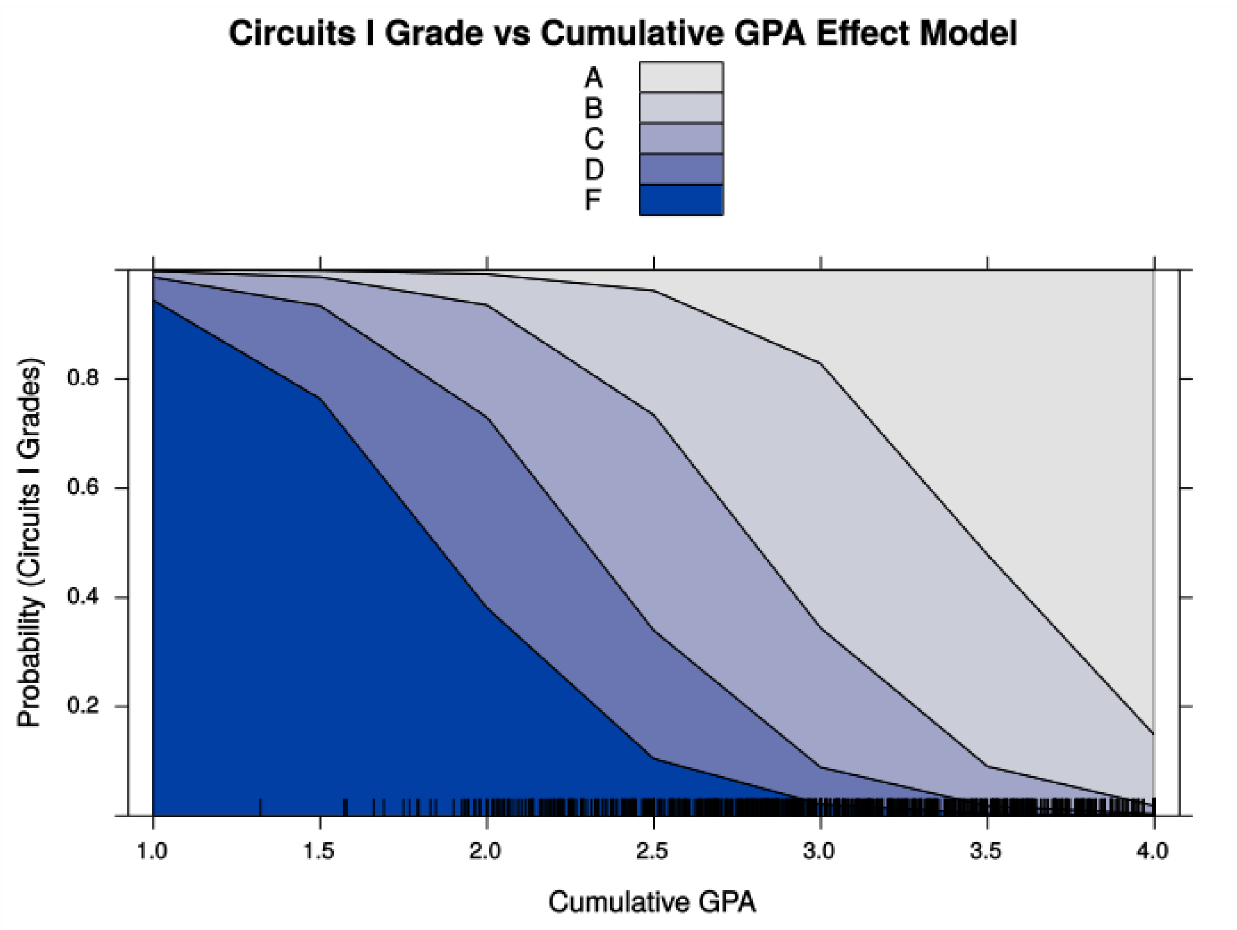

Figure *1*. Earned grade probability for an Electric Circuits I course plotted against students' cumulative GPA.

Figure 2 shows the relationship between grades students earned in Electric Circuits I and the grades earned in Calculus I. As in Figure 1, the vertical axis provides the cumulative probability of earning a grade in Electric Circuits I. The horizontal axis represents the grade in Calculus I with a 4.0 = A, a 3.0 = B, a 2.0 = C, and so on. For a student earning a 2.5 in Calculus I, the student most probably will earn a B or C in Electric Circuits I. Students who earned a D in Calculus I (1.0 on the x-axis) had a slightly better than 50% probability of earning a C or better in the Circuits I course. Similar results were obtained from the Calculus II grade distribution compared to the Circuits I grades.

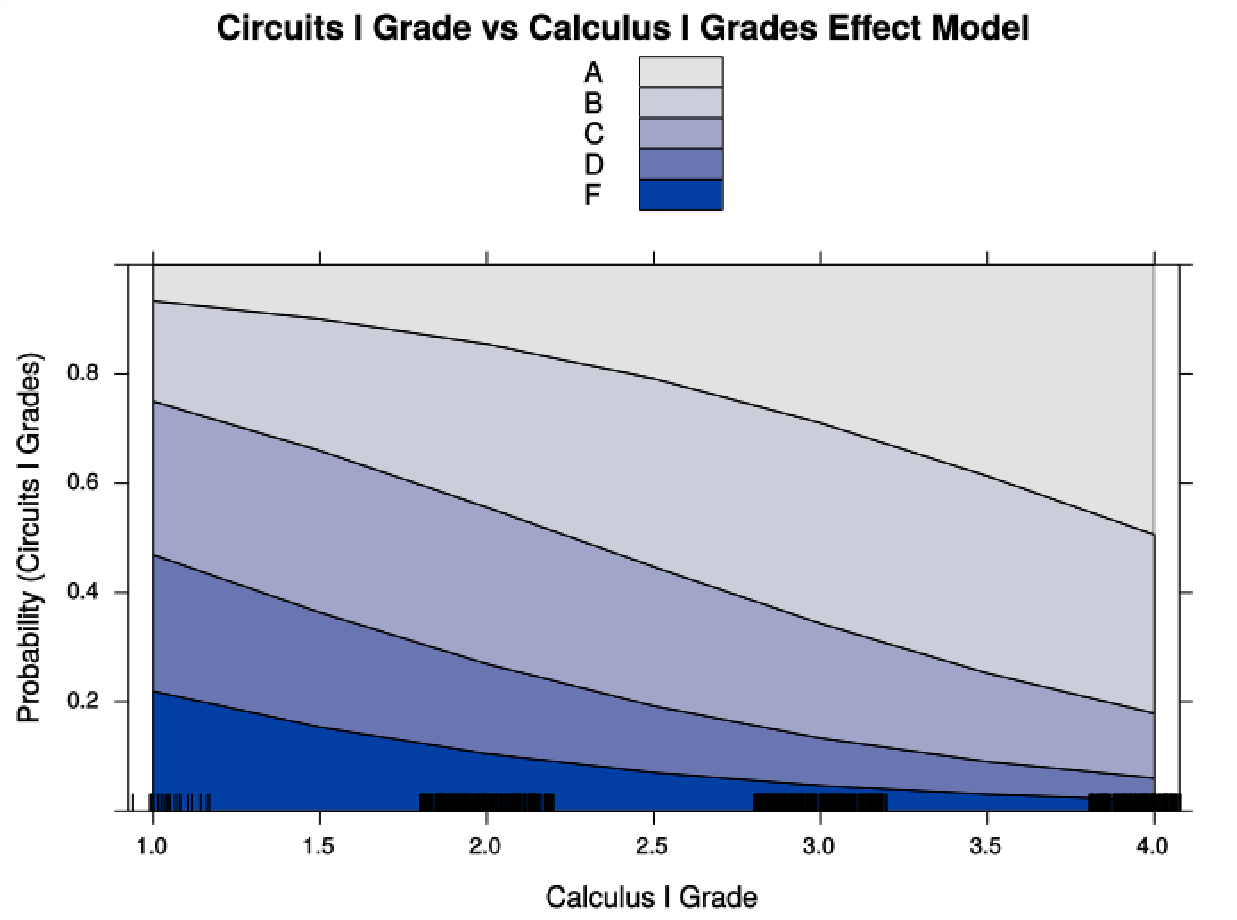

Figure *2*. Earned grade probability for an Electric Circuits I course plotted against students' final grade earned in a Calculus I course.

It is apparent from viewing Figure 2 that students' Calculus I grades do not have as significant of a bearing on Electric Circuits I performance as compared to the cumulative GPA data in Figure 1 owing to the overall behavior of the grade delineations in Figure 2. It is interesting to examine the probability of success in Circuits I (earning a C or better) for students that earn a C in Calculus I (2.0 on the x-axis in Figure 2) with the students with a 2.0 cumulative GPA in Figure 1. In Figure 1, students with a 2.0 cumulative GPA have only approximately a 40% probability of earning a C or better in Circuits I whereas students that earn a C (2.0) in Calculus I (Figure 2) have close to a 70% probability of successfully completing Circuits I with a C or better.

Randomly sampling the existing student population data could increase model validation. Two data sets could be produced, one for training the regression and the other for testing. If the model is found to be valid, then it provides for a method of making future predictions of student performance in Electric Circuits I prior to course enrollment. This is a key area of future work that will be addressed.

Conclusion

The ability to define a metric to identify which students may be in jeopardy of successfully completing Circuits I will allow an intervention to help these students achieve their goals. In this study, the performance in Circuits I was evaluated based on Calculus I and Calculus II prerequisite courses and the students cumulative GPA. Although only Calculus I data are included in this report, the Calculus II data produced similar results. Students who earned a C in Calculus I had approximately a 70% probability of completing Circuits I with a C or better, and students with a cumulative GPA of 2.5 had approximately a 60% probability of earning a C in Circuits I. Based on these results, students with below a cumulative 2.5 GPA and a C or less in in Calculus I require close monitoring of their academic performance in their Circuits I course.

References

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