AC 2009-474: A COMPARISON OF STUDENT PREREQUISITE MATH SKILLS WITH DATA FROM A CIRCUITS CONCEPT INVENTORY

Jeff Jalkio, University of St. Thomas

Jeff Jalkio received his PhD in Electrical Engineering from the University of Minnesota and worked for thirteen years in industry in the fields of optical sensor design and process control. In 1984, he co-founded CyberOptics Corporation, where he led engineering efforts as Vice President of Research. In 1997 he returned to academia, joining the engineering faculty of the University of St. Thomas where he teaches courses in digital electronics, computing, electromagnetic fields, controls, and design.

A Comparison of Student Pre-requisite Math Skills with Data from a Circuits Concept Inventory

Abstract

In this paper, we assess the impact of student preparation in mathematics on their ability to learn new concepts in a sophomore level circuit analysis course. While it is widely known that a wide variety of mathematical skills are essential for success in electrical engineering, it is not clear how these skills impact the ability to integrate new concepts. To study this effect, we assessed student performance in several circuit analysis courses. We administered a circuit concept inventory at the beginning and end of each semester to measure conceptual gains in circuits topics. We also administered a math test at the beginning and end of the semester to assess student performance in several prerequisite math topics, such as basic algebra, complex arithmetic, integral and differential calculus, and linear algebra. Results from the four tests were compared to determine correlations between prerequisite math skills and conceptual learning gains.

Introduction

It is widely known that by comparing results from multiple independent assessment instruments, it is possible to obtain a higher level of confidence in these measurements[1]. However, we have found that it is also useful to compare assessment results for different outcomes to determine how these results might be correlated. In some cases, such as the one reported here, the results can be surprising.

At our university, we have used a variety of concept inventories to obtain externally normed assessment of several student learning outcomes. These concept inventories[2] consist of a pre-test administered at the beginning of the term and a post-test administered at the end. Both tests consist of multiple choice conceptual questions intended to measure the students' understanding of the concepts presented in the course. The percentage gain from pre-test to post-test can be compared between sections of the same class and between participating schools. A number of such inventories have been, or are being, developed[3] and a substantial body of research exists regarding the validity of some of the more established inventories[4]. We decided to use a readily available Circuits Concept Inventory in our sophomore level linear circuit analysis course.

In what was intended as a completely independent assessment, we also decided to administer a basic math skills test to the same group of students. This decision was based on anecdotal evidence that many of our sophomore engineering students were poorly prepared in algebra and trigonometry and that this was affecting our ability to teach more advanced concepts. Rather than approaching the mathematics department with this anecdotal evidence, we chose to evaluate the basic math skills of our sophomores so that we could determine if a problem really existed and work with the mathematics department to solve it if it were real. Since it seemed likely that using algebra in the circuit analysis class would improve the students' math skills, we decided to administer the math skills test with the circuit concept inventory at the beginning and end of the semester.

Test Design and Administration

The circuit concept inventory was obtained from its authors[5], who have asked that the questions remain unpublished. The version of the inventory that we used includes 9 problems, each of which consists of a figure and one to four multiple choice questions relating to that figure. There were a total of 25 questions with 4 choices for each. The topics covered by the assessment tool covered most of the learning outcomes for the course. To these 25 questions, we added our own internally developed assessment for basic math skills.

Our math skills assessment was based on previous work that identified math skills needed in engineering[6]. This assessment consisted of 5 multiple choice questions with 5 choices each, 15 true and false questions, and 3 questions requiring numerical answers. The multiple choice questions were designed to identify common misconceptions in algebra and trigonometry, with each incorrect answer corresponding to a common misunderstanding. Each of these misconceptions had been identified as fundamental concerns by faculty members. They included the ability to add rational functions, the ability to apply the Pythagorean theorem, the recognition of the relationship between exponentiation and logarithms, and the relationship between sine and cosine. The three questions requiring numerical answers involved multiplication and division of complex numbers and finding the magnitude of a complex number. The 15 true or false questions consisted of the set of proposed equalities shown in figure 1. Students were asked to indicate which were true.

1. $(x^y) * (x^z) = x^{y+z}$
2. $\sqrt{x^2 + y^2} = x + y$
3. $\dfrac{x}{y+z} = \dfrac{x}{y} + \dfrac{x}{z}$
4. $\log(a+b) = \log(a) + \log(b)$
5. $\log\left(\dfrac{a}{b}\right) = \log(a) - \log(b)$
6. $\sin^2(a) = 1 - \cos^2(a)$
7. $\dfrac{1}{\sin(\theta)} = \cos(\theta)$
8. $(x-y)^2 = x^2 - y^2$
9. $(x^y)^z = x^{(y+z)}$
10. $\cos(\dfrac{\pi}{2} - \alpha) = \sin(\alpha)$
11. $\sin(2\theta) = 2\sin(\theta)$
12. $\cos(-\beta) = \cos(\beta)$
13. $\tan(\theta) = \dfrac{\sin(\theta)}{\cos(\theta)}$
14. $x^{\log_x y} = y$
15. $\log_5 1 = 0$

Figure 1. Correct and Incorrect Equalities

This combined test was administered on the first and last class day of the semester and students (a class of 19) were given 45 minutes to complete the combined test. The tests were graded by our assessment coordinator and the initial analysis of the results was done without knowledge of student identity. After the results were analyzed for assessment purposes, individual student results were compared with student quiz scores during the semester to measure the correlation between traditional grading and student grasp of concepts as measured by the circuit concept inventory.

Results

The results of the individual instruments were both encouraging and are tabulated in Figure 2. As can be seen, class averages in the post-tests were both considerably better than the corresponding pre-tests and respectable on their own. There were perfect scores on the post-test and none in the pre-test. Although external norms are not yet available for the circuit concept inventory, the normalized gains are quite good compared to the average normalized gains reported on other concept inventories. These results confirm that students were learning circuit concepts in the circuits class (as one would hope) and that the use of math skills in their sophomore level courses had improved their basic math skills.

	PreTest Average	PostTest Average	Normalized Gain
Circuits	0.45	0.79	0.88
Math	0.65	0.85	0.38

Figure 2 – Instrument Averages

Surprisingly, there was only marginal correlation between quiz scores and the circuit concept inventory post test scores as shown in figure 3. In this and in all following figures, we have provided both the equation of the best fit line and the correlation coefficient. The low correlation could be an indication that the quizzes did a poor job of testing understanding but instead focused on the students' ability to solve problems similar to those they had seen in class examples and homework. Similarly, there was marginal correlation between quiz scores and math pre-test scores as shown in figure 4, indicating that the ability to solve these problems was in some degree related to the students' initial math skills.

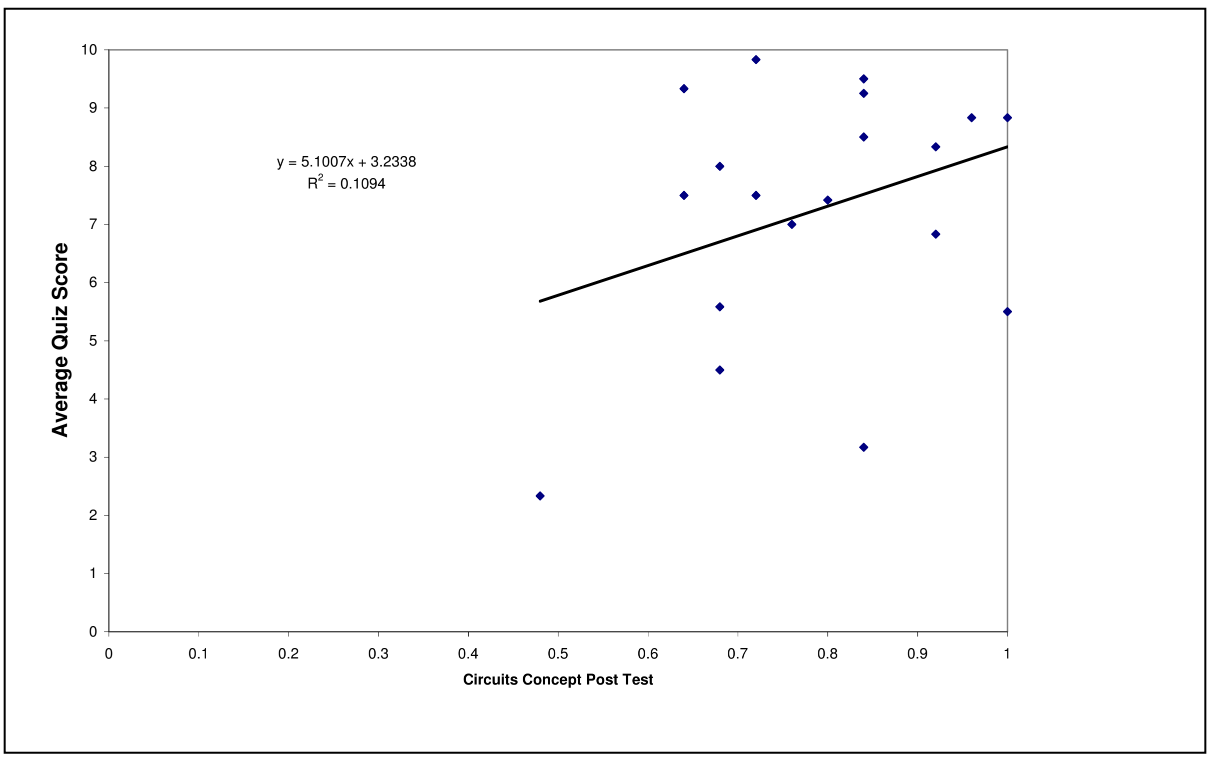

Figure 3. Correlation between Quiz Scores and Circuits Concept Inventory Post Test Scores

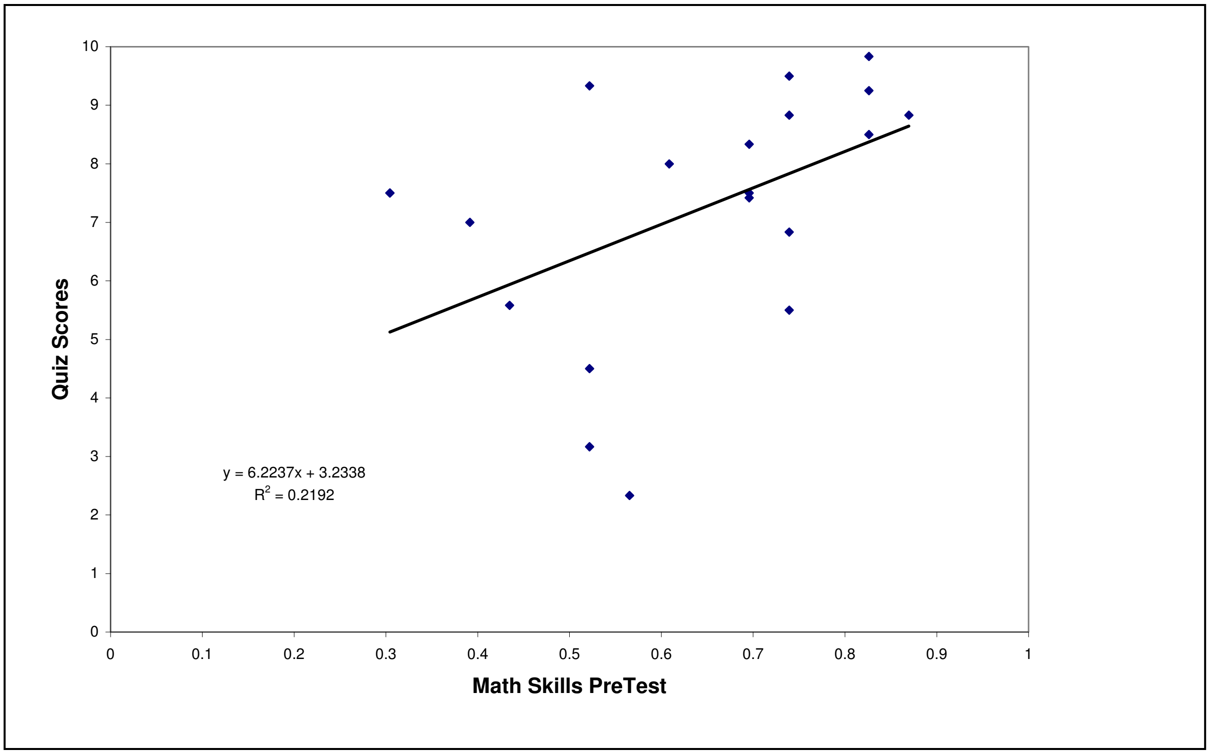

Figure 4. Correlation between Quiz Scores and Math Skills Pre Test Scores

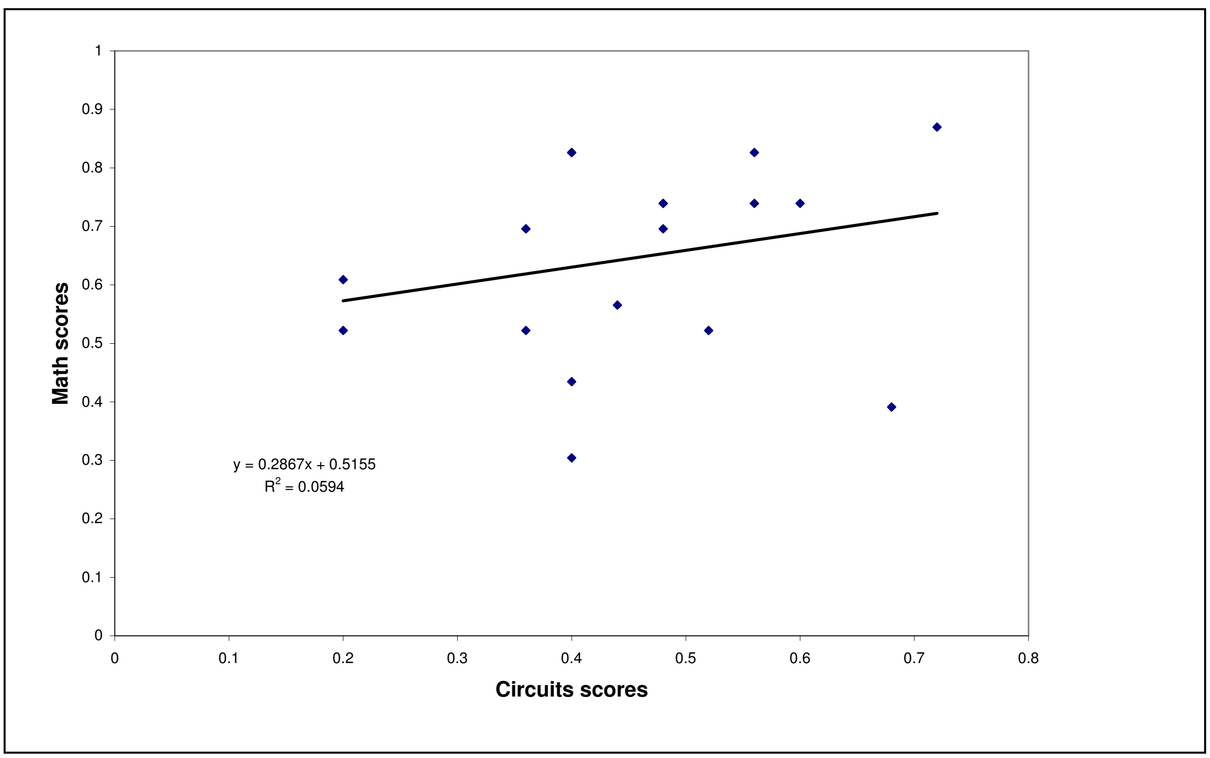

Figure 5. Correlation between Math Skills and Circuits Concept Understanding as demonstrated on pre-tests

The surprising results came when we compared the math and circuits concept instruments. First, as shown in figure 5, there was essentially no correlation between the pretest scores on math and circuits concepts while there was a broad range of scores on each. There was also no correlation between gains in understanding of circuit concepts as measured by the circuit concept inventory and the students' math skills as measured by the pretest. This is shown in figure 6. It should be noted that the greatest percentage gains on the circuits concept inventory are only possible for students with low circuit pre-test scores, so a correlation between pre-test scores on circuit concept understanding and math skills would effectively cancel a correlation between post-test circuit concept understanding and math skills. Therefore it is the absence of both correlations that is significant.

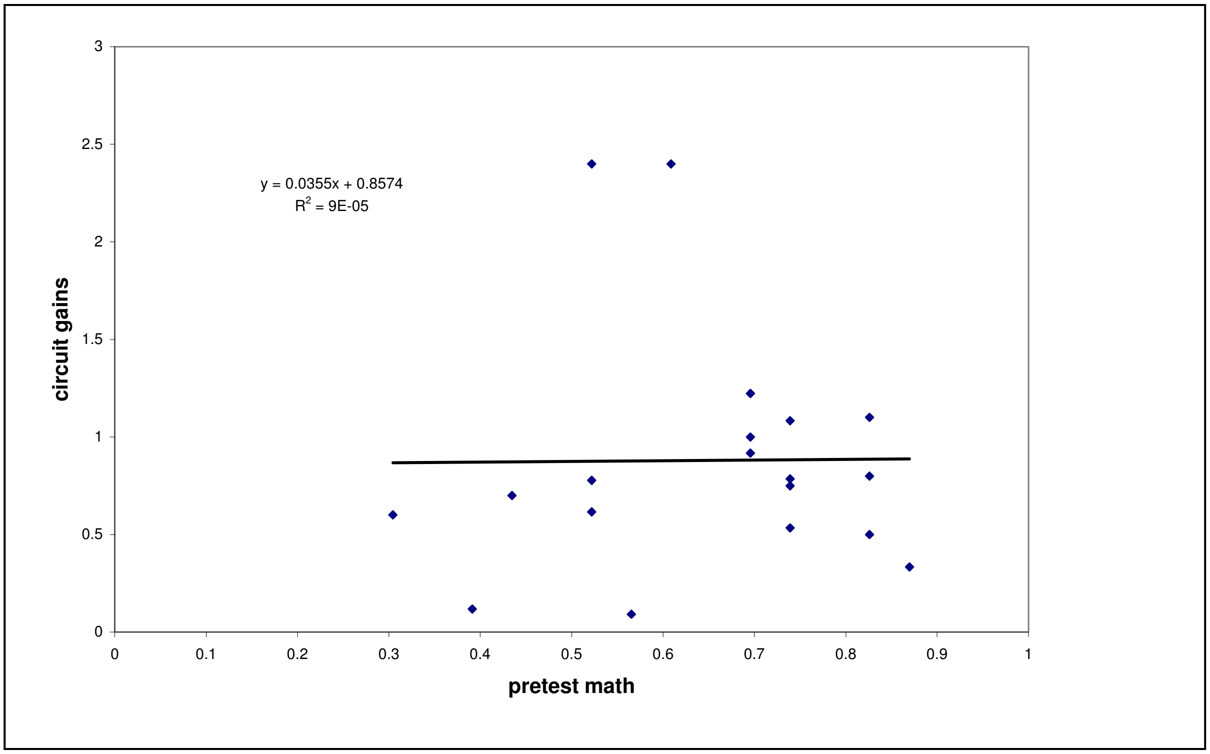

Figure 6. Circuit Concept Gains vs. Math Skills

Conclusions

As engineering educators, we generally assume that students need an acceptable level of basic math skills in order to learn key engineering concepts. These results indicate that while these skills are needed in order to apply those concepts in practice, conceptual gains might be possible prior to the acquisition of some of these basic math skills. This may lead to new ideas on improving math skills in engineering students by focusing first on conceptual gains and using those gains to motivate development of the math skills needed for application.

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