Student Participation in EE Lab Teams as a Predictor of Acquired Skills and Knowledge

E. Carl Greco, Jim D. Reasoner, Ronald E. Nelson
Electrical Engineering Department – Arkansas Tech University

Abstract

In a fundamental electrical engineering laboratory course, the current model utilizing laboratory groups of two or more students to perform assignments reduced the student's ability to learn rudimentary laboratory skills and knowledge and the ability to apply them to a basic circuits analysis application. The students' performance on the laboratory final exam provided an indicator of their individually acquired knowledge and skills. Several factors were investigated as contributors to a student's performance on the laboratory final exam. The two factors that were found to be significant were (a) the student's grade in the Electric Circuits II lecture course and (b) the student's active participation as a "builder-tester" during the weekly laboratory exercises. The only factor that significantly and independently contributed to the students laboratory skills and knowledge base was the latter. The results of this study indicate that students must be fully engaged in the fundamental laboratory exercises to thoroughly and properly learn the skill and knowledge required to apply them in basic circuit analysis applications.

Background

The Electrical Circuits Lab course at Arkansas Tech University is an introductory laboratory class used to introduce electrical and mechanical engineering students to circuit simulation, use of electronic test equipment, and proper laboratory procedures by performing basic experiments that parallel the University's Electric Circuits I and II course work. The University has adhered to the generally accepted course model of employing two person "lab teams" to build and test experimental circuits. This model was believed to maximize the learning experience for the individual students.

Following completion of the 12 laboratory class syllabus for the Spring 2008 session, a final examination was administered. The final exam was straight forward, laboratory skill based, and covered only material presented in the 12 labs of the syllabus. The test was composed of the following problems:

1. Measurement of the current and voltage at various points in a resistor network.
2. Measurement of the gain of an op-amp, non-inverting amplifier.
3. Measurement of the resonant frequency and bandwidth of an RLC filter.
4. Capturing the input and output waveforms of a half-wave rectifier and measurement of the input and output V_{rms}.

Grades on the Electric Circuits Laboratory final exam for the 30 students are shown in Figure 1.

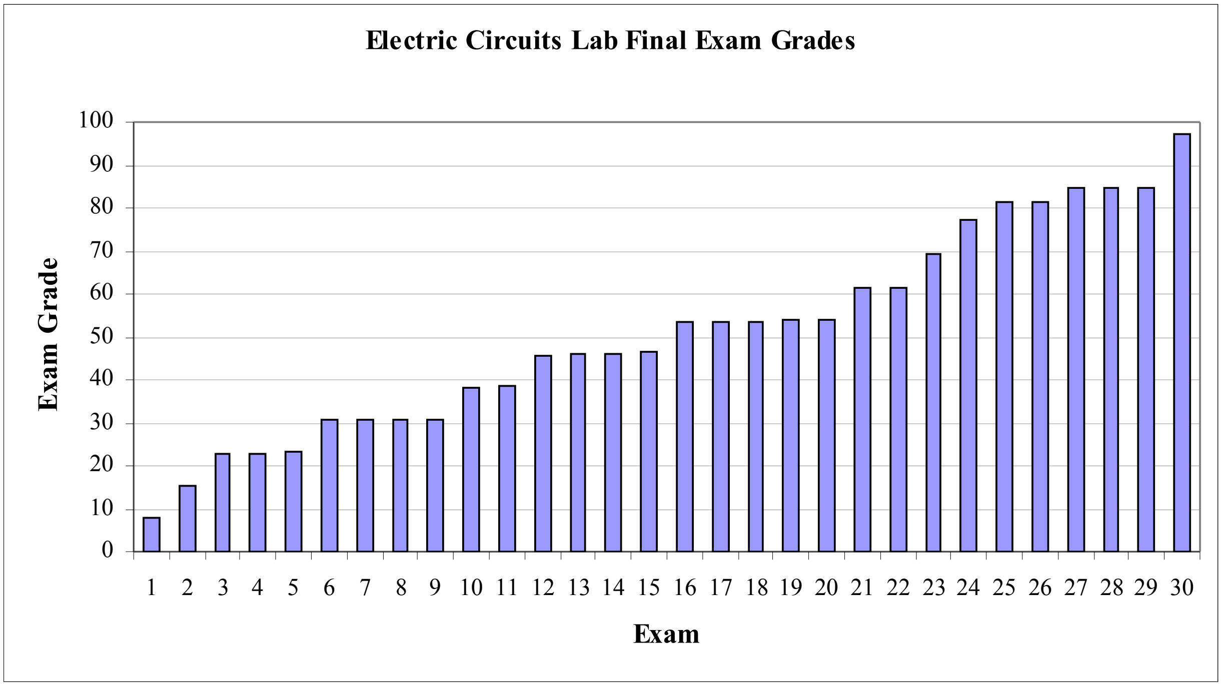

Figure 1: Grade distribution on Electric Circuits Lab final exam

As can be seen from the grade distribution, only 6 students scored above 80% while 15 students scored below 50%. The unexpectedly less than desirable performance from several students led to an analysis of the lab practices with the objective of determining the root cause for this performance.

Analysis

Selection of Variables

Analysis of Electric Circuits Lab practices isolated three variables that were believed to be significant contributors to the problem. These were:

1. Segregation of student lab duties
2. Student performance on the pre-lab assignments
3. Student performance in the Electrical Circuits II class work

Segregation of Student Lab Duties

It has been a generally accepted practice for a university to organize electrical engineering lab students into teams of 2 or more. The primary reason for this has been the belief that students gain more knowledge in groups where interaction sparks discussions that provide answers to questions arising during performance of the lab[1]. A secondary reason is the reduced cost associated with providing half the capital and teaching assets when 2 (or more)-student lab groups are utilized. Arkansas Tech University is no exception and has utilized the "lab partner" concept for years.

For the Spring 2008 Semester, the Electric Circuits Laboratory course was initially comprised of two sections of 31 students total. Both sections were taught by two university instructors. The class organization consisted of fourteen 2-person teams and a 3-person team. Following the 4^{th} lab session, one student dropped the course and remaining lab partner worked as a "single" person team for the remainder of the semester.

Early in the semester the instructors noticed that a majority of the teams began to segregate their duties. One duty was building and testing the experimental circuit while the other duty encompassed the collection and organization of data and its generation into a report. It is theorized that, from the students' perspective, this division of labor was developed for team efficiency and expediency in accomplishing the lab work. The unintended consequence of this team organization however was that the "recorder/writer" received less hands-on circuit building and test equipment operating experience than did the "builder-tester."

For the purpose of this analysis, a metric was developed to capture student participation as a "builder-tester" or "recorder-writer" on each team. From personal interaction with each lab pair, the lab instructors could judge team distribution of labor for "building-testing" and "recording-writing." The metric captures the percentage of participation of a student as a "builder-tester" within the team. It ran from a 50% meaning the duties were shared equally, to a 99% where one student did the predominate share of "building-testing" while the other student rarely touched the equipment and concentrated solely on capturing data and writing the report. Figure 2 displays a distribution of "building-testing" and "recording-writing" by lab team.

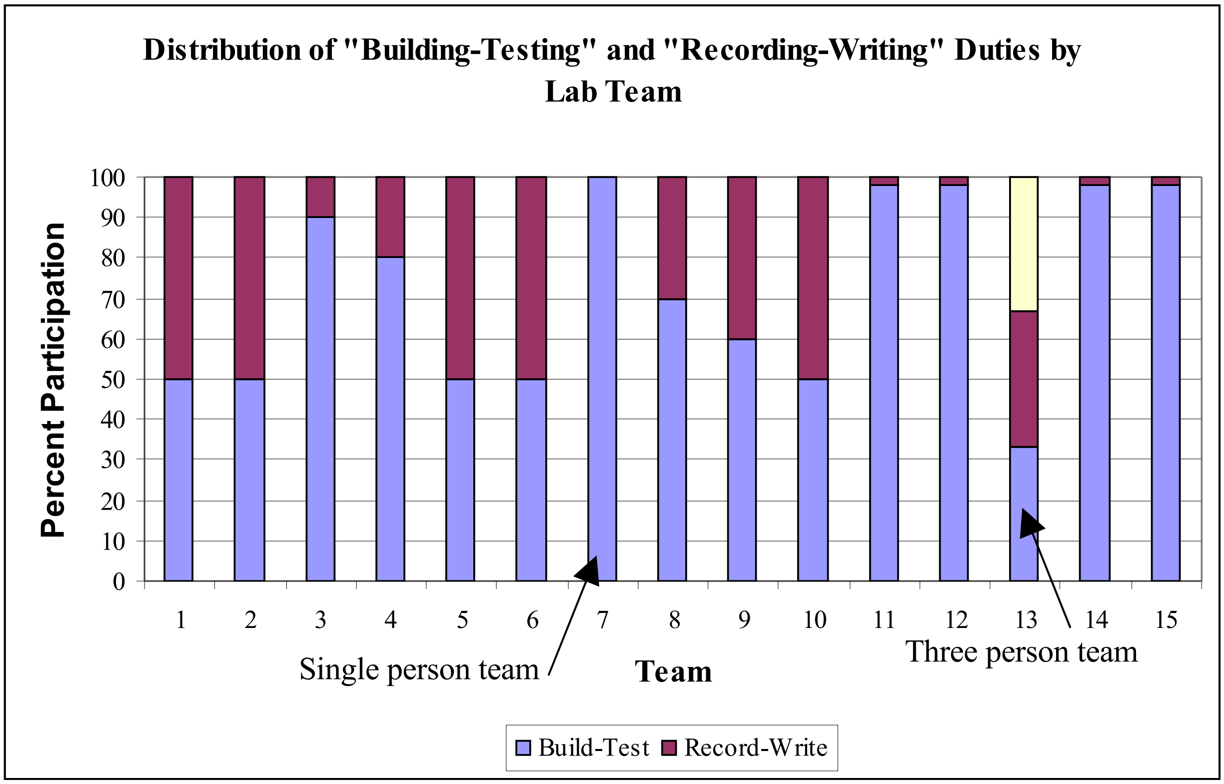

Figure 2: "Building-testing", "recording-writing" duties by lab team

Performance of Pre-Lab Assignments

Pre-lab assignments are included in 9 of the 12 Electric Circuits Labs. These are performed individually by the student and submitted prior to the lab. It was felt that if students diligently and independently performed the pre-lab assignment they would gain the knowledge to perform the associated lab thus maximizing their potential for understanding the lab material. For the analysis, a metric was developed to capture pre-lab performance. The metric, ranging from 0 to 100, is the percentage of the points awarded for all the pre-lab assignments in relation to the total points available. Figure 3 displays a distribution of the pre-lab assignment metric for the students.

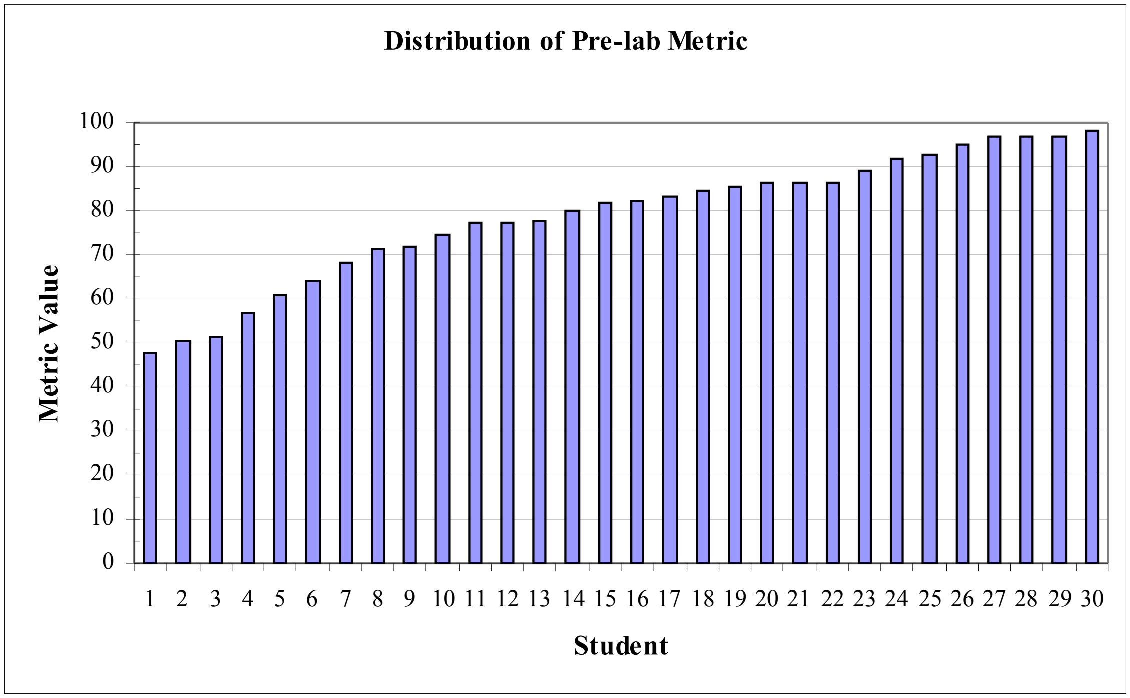

Figure 3: Distribution of pre-lab assignment metric

Performance in Electric Circuits II Course

For a student to take the Electric Circuits Lab, he must have completed or concurrently be enrolled in the Electric Circuits II lecture course. The vast majority followed the recommended curriculum and were registered in the lecture and lab concurrently. Only two students in the study had taken the lecture course in a previous semester. Since the Electric Circuits Lab is designed to complement the Electric Circuits II coursework, a metric was developed to reflect the students' performance in Electric Circuits II and consisted of the course final grade. The distribution of grades in Electric Circuits II was: 11 A's, 13 B's, 4 C's, and 1 D.

Analysis and Results

The students' performance on the electric circuits laboratory final was first evaluated with respect to their grades in the electric circuits lecture course in order to establish the relationship between the students' basic understanding of circuit theory and knowledge and their performance on the laboratory final. The distribution of laboratory final grades with respect to the respective grades in the lecture course is shown in Figure 4. A one-way analysis of variance confirmed the statistical differences between the combined A and B grade group and the combined C and D grade group with no statistical difference between the A and B groups individually.

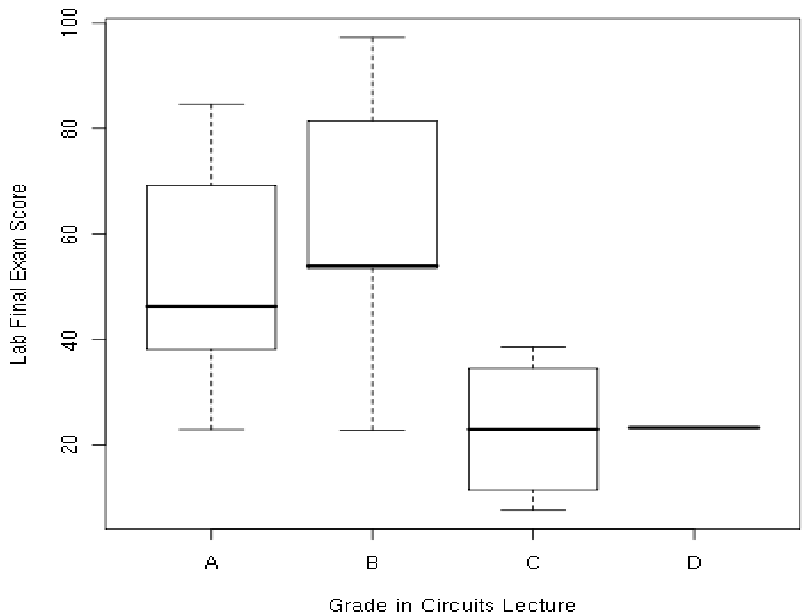

Figure 4: Students' laboratory final test grade with respect to their respective grade in circuit lecture where the top and bottom whisker are the data extrema, the top and bottom of the boxes are the upper and lower quartiles and the dark lines are the medians.

Circuits II Grade	Mean of Electrical Circuits Lab Final Exam	Number
A	53.1	11
B	60.2	13
C	23.0	4
D	23.3	1

In light of this lab final grade to lecture course grade distribution and in order to remove the potential influence of a student's lack of basic circuit knowledge from the performance on the Electrical Circuits Lab final exam, a reduced data set was developed that included only students who earned an A or B in the Electrical Circuits II course.

Since the lab final grades were equally distributed without statistically significant difference between the lecture A and B groups, these two groups were combined. In order to evaluate the other measurable factors within the combined A and B group which may have contributed to the students' performance on the Electric Circuits final exam, a multiple linear regression analysis was performed against the students' "builder-tester" percent performance and their pre-lab assignment grades. The results are shown below:

$$y = a_1*x_1 + a_2*x_2 + b$$

y: Score on Electric Circuits Lab final exam

x_1: Percentage of performance of a team member as a "builder-tester"

x_2: Performance of pre-lab assignments

Coefficient	Estimate	Std Error	t Value	Pr(>|t|)
a_1	0.337	0.133	2.54	0.019
a_2	0.165	0.301	0.55	0.589
b	24.55	25.97	0.945	0.355

Note: The multiple linear regression resulted in a $R^2 = 0.245$ and an adjusted $R^2 = 0.173$ with a $p > .05$, i.e., not significant. Therefore, within this combined A and B group, the only significant factor which contributed to the lab final exam grade was a team members percentage of employment as a "builder-tester."

The model was now reduced to a single independent variable based on the previous analysis showing that the "builder-tester" metric was the only significant contributor to the Electric Circuits Laboratory final exam grade.

The regression model for all the students who earned an A or B in the circuits lecture course is shown below and graphically displayed as the dashed line in Figure 5.

$$y = a_1 * x_1 + b$$

Coefficient	Estimate	Std Error	t Value	Pr(>|t|)
a_1	0.338	0.131	2.59	0.0167
b	38.02	8.31	4.58	0.00015

The linear regression resulted in an $R^2 = 0.2338$ with an adjusted $R^2 = 0.1989$ which was significant with $p < 0.05$. Note that this adjusted R^2 value is greater than the corresponding adjusted R^2 values for the previous linear models implying that of the three independent variables examined, the "builder-tester" metric was the only parameter required to predict student performance on the final exam.

A single linear relationship did not appear to be the best model for the data in Figure 5. Instead a piece-wise linear, or segmented, model with a node at the 50% Builder-Tester was a better fit. The two segments are displayed as solid lines in Figure 5. The regression from region [0 to 50%] resulted in the following:

Coefficient	Estimate	Std Error	t Value	Pr(>|t|)
a_1	0.778	0.264	2.95	0.011
b	24.58	10.78	2.28	0.040

Where $R^2 = 0.40$ with an adjusted $R^2 = 0.355$. And the region [50 – 100%] was not significantly different from a flat line. The performance on the lab final exam for the students who participated as a "builder-tester" less than half the time correlated significantly with their level of participation; however, students who participated as "builder-testers" at a level of 50% or greater performed equally well on the laboratory final exam.

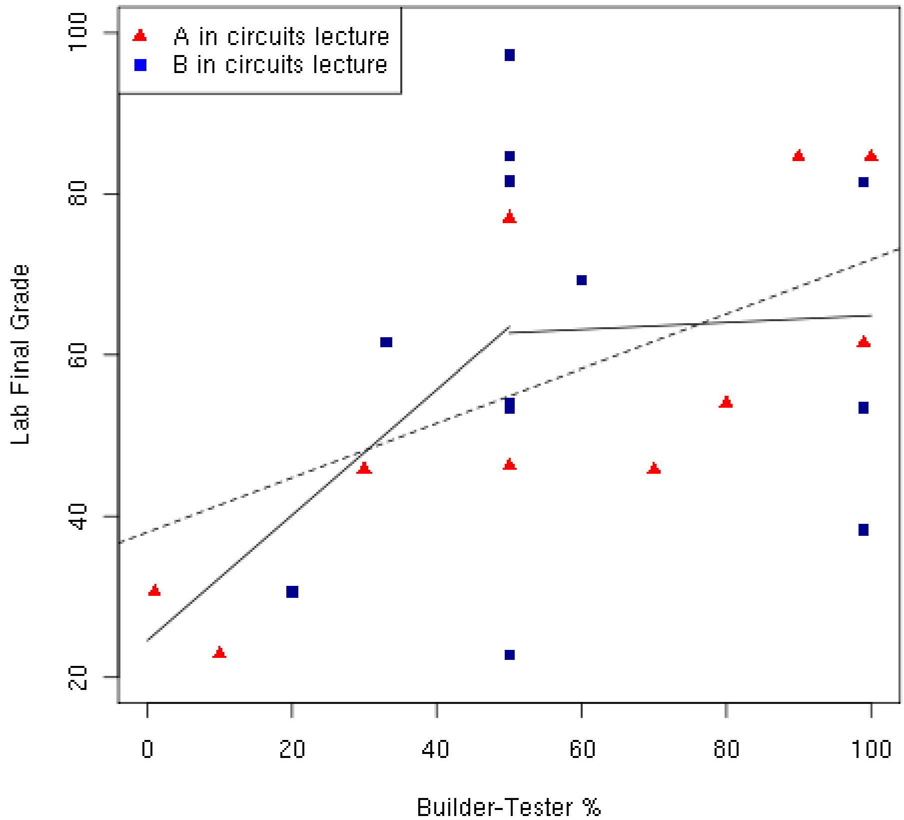

Figure 5: Lab final grade vs. Builder-Tester % for students that earned an A or B in circuits lecture. The dashed line was obtained from the regression over full range where the solid lines represent the segmented regression for the regions [0 - 50%] and [50 - 100%].

The statistical analysis was performed with the R statistical package[2] utilizing the Faraway's regression and Anova guide[3].

Summary

The analysis of results showed a strong positive relationship between the amount of student's employment as a “builder-tester” and his laboratory exam final grade when his employment as a “builder-tester” was 50% or less. Several factors potentially influenced the students' ability to display laboratory knowledge and skills on the final exam. Students who earned a grade of A or B in the Electric Circuits II lecture course performed significantly better on the laboratory final exam than those students that earned a C or less in the lecture course. The higher grade in the circuits lecture course, implying a more thorough knowledge of circuits, was a contributing factor in the performance on the laboratory final. When the student population was reduced to those who earned an A or B in the lecture course, the “builder-tester” participation during the laboratory exercises remained the only significant positive predictive factor in their laboratory final exam score. The results from this study indicate that for students to learn fundamental engineering laboratory skills and knowledge they must fully and equally participates in each laboratory exercise. A team environment where the laboratory duties are totally or partially segregated does not facilitate this learning experience.

References

1. Oakley, B.A. et al. Best Practices Involving Teamwork in the Classroom: Results From a Survey of 6435 Engineering Student Respondents. *IEEE Trans Education* **50**, 266-272(2007).
2. R: A Language and Environment for Statistical Computing. (2008). at <http://www.R-project.org>
3. Faraway, J.J. Practical Regression and Anova using R. (2002). at <http://cran.r-project.org/doc/contrib/Faraway-PRA.pdf>

E. CARL GRECO
Received the BSEE from Louisiana Tech University in 1967, the MSEE and Ph.D. from Rice University in 1974 and 1976 respectively. He an Associate Professor of Electrical Engineering at Arkansas Tech University and is a member of ASEE and a senior member of the IEEE.

JIM REASONER
Received the BSEE from US Naval Academy in 1971 and the MA in Defense Analysis and Strategic Studies from the US Naval War College in 1986. He is an Instructor of Electrical Engineering at Arkansas Tech University.

RONALD E. NELSON
Received the BSEE from Iowa State University in 1964 and the MSEE and Ph.D. from University of Missouri at Rolla in 1966 and 1987 respectively. He is a Professor of Electrical Engineering and Head, Department of Electrical Engineering at Arkansas Tech University. He is Registered Professional Engineering and a member of IEEE.