Improving Student Learning of Basic Electric Circuits Concepts Using Current Technology

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Abstract

This paper describes web-based supplemental materials developed at California State Polytechnic University Pomona that enable students at any time during their academic career to review and practice fundamental network analysis concepts. Students interact with these materials via a web browser, making them platform independent. The project targets improving both learning and retention by providing engaging interactive online resources, including lectures, motivated by practical real-world examples and supported by embedded self-tests. These learning materials are being used to enrich student learning in the initial networks course, but can also be accessed by students in follow-on courses to refresh their knowledge at any time. The original project focused on web-based learning materials, but is now being extended to include a variety of related tools including the web-based simulation tools CircuitLab [1] and National Instrument's myDAQ [2] measurement and instrumentation devices. Our preliminary assessment results indicate that the web-based resources improve students' learning. Also, our surveys indicate weak students benefit significantly from our short videos of problem solutions.

Introduction

Student success in electrical engineering is built on mastery of fundamental network analysis concepts such as Kirchhoff's laws, nodal and mesh analysis, and the Thevenin and Norton theorems. However, the course in which these concepts are taught comes early in the student's post-baccalaureate career. Many students at this level have not yet understood that mastery of these concepts is essential to success in later courses. Enabling students to access these learning materials when they need them, whether during the first course or later in their academic career, helps them to become more active participants in the learning process. Development of new learning materials for basic circuit concepts began with a realization that the course covering these concepts has one of the lowest pass rates in our curriculum. The first focus was on development and assessment of web-based learning materials covering the concepts listed above. The project is now being supplemented with simulations using CircuitLab[1], an online schematic editor and circuit simulator that is free for academic use, and the low-cost National Instruments myDAQ data acquisition device[2] for experimenting with physical components and circuits. Combining the web-based curriculum materials with a circuit simulator and data acquisition device provides students the ability to do the following:

(a) Watch online problem solving tutorials
(b) Assess their understanding and receive feedback on their progress with self-test problems
(c) Verify their results, as well as and investigate the effects of parameter variations and other modifications of a circuit with CircuitLab and,
(d) Validate their results by building the circuit and testing it with the myDAQ

None of the above activities require specialized laboratory facilities, so a student can work on all phases of circuit analysis and design in their normal study environment (for example, their dormitory room). This flexibility allows students to actively explore circuit concepts and remedy deficiencies outside of the traditional classroom and laboratory. The use of the myDAQ supports a key requirement of engineering pedagogy: comparing actual measurements with the predictions of simulation and analysis.

Our suite of tools can benefit both those who are beginning their study of electrical engineering and those who need to improve their understanding of a specific concept.

Prime Motivating Factors and Design Strategy

Low cost devices such as tablets and smartphones, plus the proficiency of today's students with these devices, suggested web-based technology for providing assistance to students who are currently enrolled in freshmen circuit analysis classes and those who need assistance with basic circuit concepts. The primary goal of developing cloud-based tools is to provide interactive experiences designed to serve students with a variety of learning styles.[5-7] The resource set we have developed includes lectures, example and practice problems supported by step-by-step solutions, online and hands-on circuit simulation, and YouTube videos. Five minute videos replicate the experience of a tutor sitting next to a student and solving the problem on a piece of paper. All of these learning materials are online to enrich freshman electrical engineering learning, but can also be accessed by students in follow-on courses to refresh their knowledge at any time.

Topics were identified by interviewing professors and student club members, and also by conducting in-class surveys. Based on these inputs, the following topics were selected: nodal and mesh analysis, plus Thevenin and Norton equivalent circuits. Lecture notes that provide narrative explanations are being developed. Each topic discussion begins with a relevant practical application.A minimum of four examples are available for each topic. Each example includes a detailed narrative of how to approach the problem, along with equations and figures. The goal of these examples is to teach the problem-solving process. Students can access the solutions in html, pdf, and YouTube video formats, allowing them to choose the medium that best fits their learning style and resource availability. The CircuitLab [1] schematic that is attached to each example provides both verification of the solution and the opportunity for visual and kinesthetic learners to interact more directly with the material.

Several practice problems provide students guided practice in applying each topic. These problems have been supplied by a variety of instructors, and so are representative of the teaching styles and approaches to a topic that are used in our curriculum. After working the detailed examples for each topic, students can attempt these practice problems, receiving feedback not only on their answer, but also on intermediate results Students also have the option to see a complete hard copy solution directly or watch the video solution on YouTube.

CircuitLab is used to simulate the circuits in the examples and problems [1]. Students can also create a new problem by modifying the circuit to experiment with the sensitivity of the node voltages or branch currents to the component placements and values. A minimum of four exercise problems are provided for each topic. These problems are similar to actual final exam questions, so they test the student's ability to apply the concept in a typical context. We have only provided the final answer to each exercise problem. In the future, we may provide some multiple choice problems so that student can develop experience with this form of testing and also learn to recognize absurd or impossible choices.

The first phase of our project, developing and assessing these web-based learning resources, is now entering the assessment phase. A second phase, adding the National Instruments myDAQ measurement and instrumentation device, will begin in the spring of 2014. The myDAQ, coupled with simulations in CircuitLab, enables replication of the full circuit analysis and design process outside of the traditional classroom and laboratory. Engineering students, especially those who are visual or kinesthetic

learners, gain significant benefit from independently experimenting, gathering data.

Typical Scenarios of Online Web-Tools in Operation

Online web tools have been created in the HTML5 format for compatibility with many different platforms and web browsers. Each example and practice problem are available in html and pdf formats. A link is provided at the end so that students can watch the solution on YouTube and/or simulate the circuit with CircuitLab. Fig. 1 shows a sample problem with its solution and the links to additional resources. CircuitLab has an in-browser schematic capture and circuit simulation software tool to help students rapidly modify and analyze circuits, as shown in Fig. 2. A video solution for each example and practice problem is available on YouTube. Our short videos encourage students to watch the entire presentation, and also allows them to stop or rewind as necessary for full comprehension. Fig. 3 shows a sample of a video session. This environment makes a student feel that the professor is solving the problem for them one-on-one. Our survey has indicated that this is the most popular format in our toolkit.

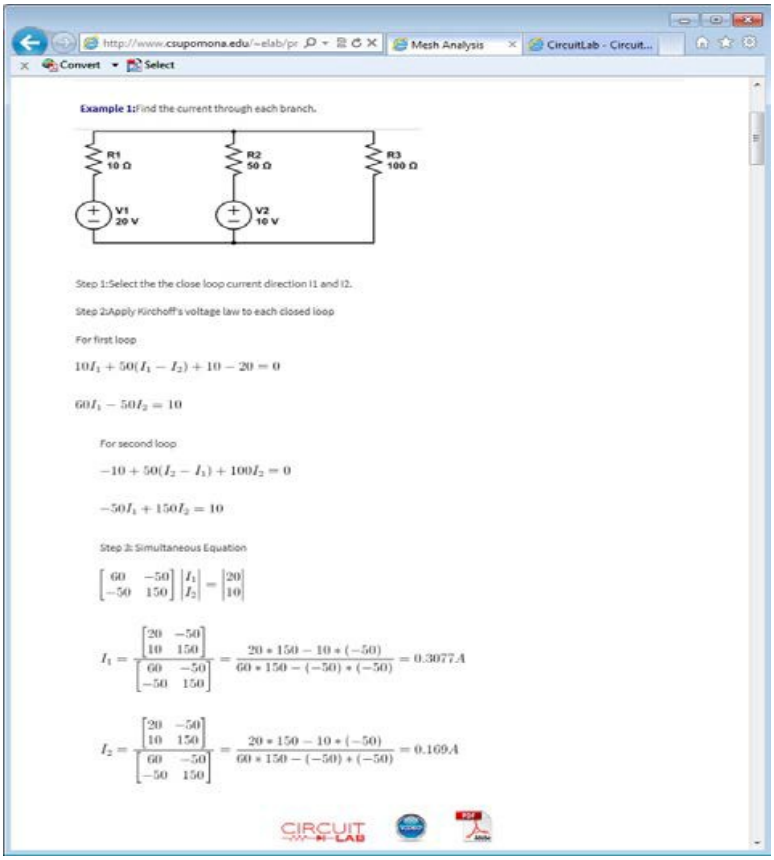

Figure 1. Example of problem solution and related links.

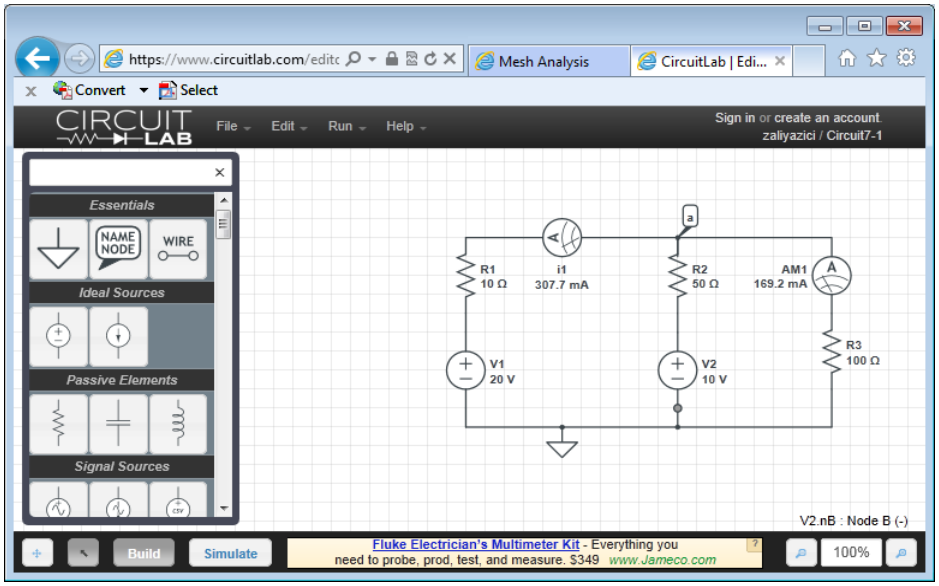

Figure 2. Example of problem solution and links.

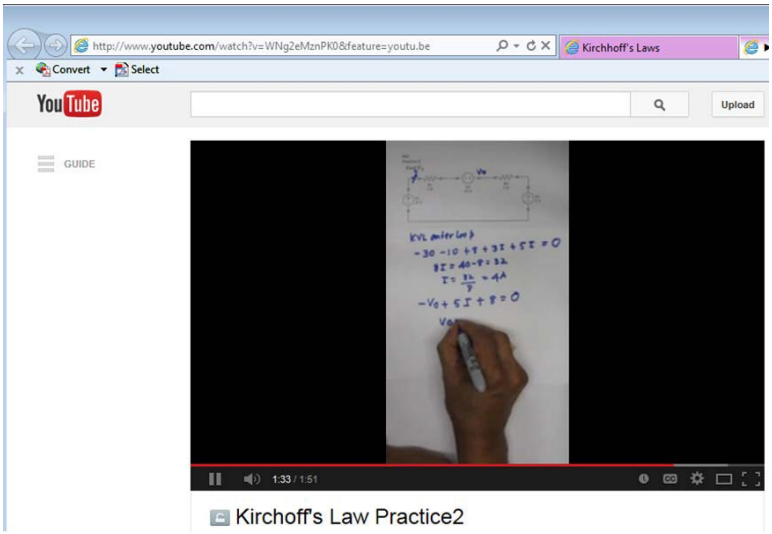

Figure 3. Video session on YouTube.

The myDAQ is an inexpensive data acquisition device that can be used in the Labview environment to provide a cluster of virtual measuring instruments. This device gives students the ability to compare the analytic solution to circuit problems with measurements of a physical implementation [3]. First, students are asked to calculate selected voltages or currents in a circuit. Then they measure the values of these voltages or currents in an actual circuit using the myDAQ. Finally, they can compare the two for any discrepancies between the calculated and measured values. This approach helps build a student's confidence by validating the results of calculation and simulation, and also develops facility with measurements and troubleshooting.

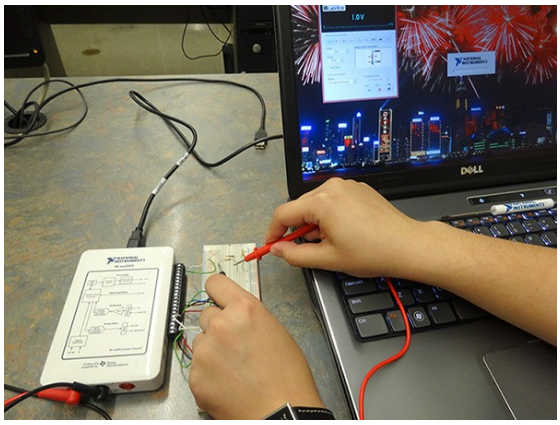

Figure 4. myDAQ experimental setup.

Performance Assessments

We have developed surveys to obtain student feedback. The survey questions are as follows:

1. The online tutorial provided sufficient information about ECE 109 materials
2. The tutorial examples are in depth and useful
3. The tutorial helped me to better understand fundamental ideas presented in ECE 109.
4. Online videos help me to learn concepts
5. Online examples are helpful in making the course concepts very clear
6. The online resources presented would improve my learning of ECE 109 materials and be a helpful reference for future courses.
7. The tutorial has increased my confidence to do well in Circuit Analysis Class.
8. The tutorial helps me in employing right technique for solving to a specific type of problem.
9. Which topics are difficult to understand and needs more help?
10. What did you like LEAST about the tutorial?
11. What did you like MOST about the tutorial?
12. Any suggestion to improve?

Answers to questions 1 through 8 are chosen from one of the following: **SD** = Strongly Disagree; **D** = Disagree; **N** = Neutral; **A** = Agree; **SA** = Strongly Agree.

The survey results are summarized in Fig. 5. It shows that 99% of the students taking the survey agree or strongly agree that "online resources presented would improve my learning of ECE 109 materials and be a helpful reference for future courses." Also, most of the students agree or strongly agree that the online resources enhanced student confidence to do well in Circuit Analysis Class and make course concepts very clear. A number of these students asked if it would be possible to develop similar study aids for other freshman classes such as the introductory C programming course [4].

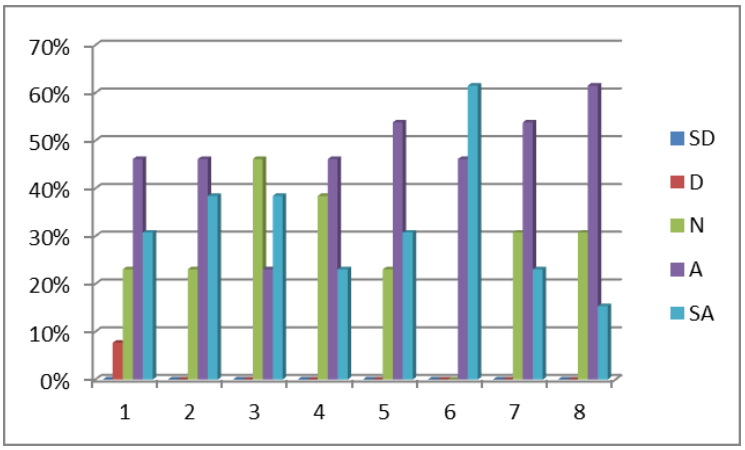

Figure 5. Survey results. (**SD** = Strongly Disagree; **D** = Disagree; **N** = Neutral; **A** = Agree; **SA** = Strongly Agree).

In the fall 2012 and winter 2013 quarters, we offered five sections of our freshman circuit analysis class. Two sections (a total of 82 students) used our course materials. The other students from the remaining three sections (a total of 92 students) were not exposed to our materials. A comparison of the grades received by these two groups is shown in Fig. 6. This data indicates that both the pass rate and the average grade increased in the class whose students used our online web tools.

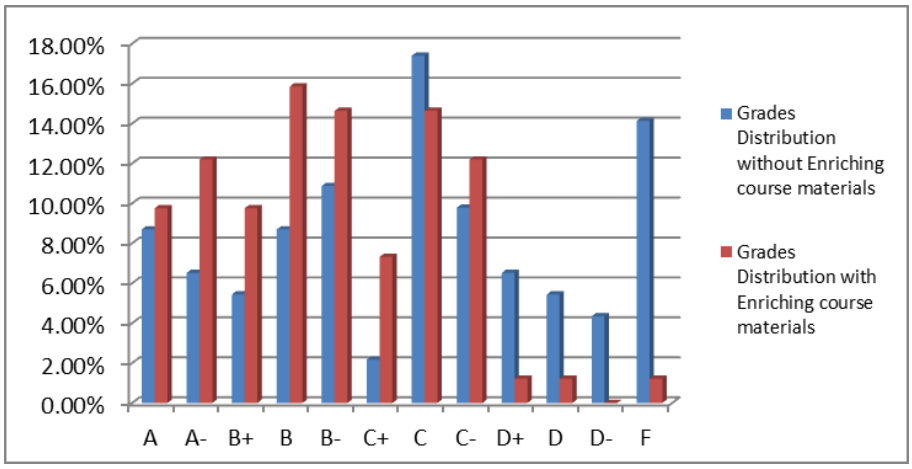

Figure 6. The grade distributions for ECE 109 for two different classes.

Conclusions

Previous studies [4-7] present different teaching styles and online tools. A suite of web-based instructional tools has been developed and was introduced to freshmen students at electrical and computer engineering in Cal Poly Pomona. Preliminary assessment data demonstrates that students respond favorably to these new learning resources, and also that access to these resources correlated with improved student performance as demonstrated by class grades. Both pass rate and average grade were improved with use of these tools. These learning materials were developed to enrich the introductory electrical circuits course, but are also available to students who need to review. Several important conclusions from this project are listed below:

- The first electric circuits course is one of the significant bottleneck classes for students in our department, having a low pass rate.
- Many different web based resources allow students to choose a format that is most accessible and meaningful to them.
- The YouTube videos of problem solutions are found to be extremely popular with students because it allows a student to clearly see the evolution of the solution process.
- Online circuit simulation software provides students with a means of validating their solutions to given problems, as well as a platform for developing and checking similar problems.
- Use of myDAQ helps students to explore circuit on their own time outside lab. This device also allows students to correlate calculated values with the measured values.
- Students who are using the web tools have indicated that they are more confident about their mastery of circuit analysis concepts.

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