Improving Student Learning of Basic Electronic Circuits Concepts using Web-Based Tools

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Improving Student Learning of Basic Electronic Circuits Concepts using Web-Based Tools

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Abstract

Student success in electrical engineering is built on mastery of foundational circuit analysis concepts such as Kirchhoff's laws and the Thevenin and Norton theorems. However, the course in which these concepts are taught comes very early in the student's post baccalaureate career. Many students at this level have not yet developed sufficient skills such as effective note taking, building conceptual frameworks that integrate new ideas with existing knowledge, and the need to utilize concepts from prerequisite courses. This paper describes web-based supplemental study aids which are being developed at our university. Students may utilize these study aids to review and practice these key circuit analysis concepts at any time during their academic career. We intend to improve learning and retention by providing engaging interactive online resources such as lectures notes, examples, simulations, and practice problems. These learning materials are completely online to help beginning electrical engineering students learn, and they can also be accessed by students in subsequent courses to refresh their knowledge of these topics at any time.

Introduction

Students in Electrical and Computer Engineering (ECE) receive instruction in both lecture and laboratory settings. Laboratory exercises offer students immersive experiences designed to encourage problem solving skills in a real-world environment. Through observation, the ECE faculty has discovered that most of our students are “visual” or “kinesthetic” learners who are especially likely to benefit from these laboratory experiences. Furthermore, many of our students are the first in their family to attend college. They are new to the concept of courses building on each other, and thus lack basic skills. The lack of understanding of some of these basic concepts taught in a freshman electrical engineering course has a harmful ripple effect on a student's future success in ECE. Instructors in following courses consistently witness a continual lack of foundational concepts from the freshman electrical engineering classes.
**Key Motivating Factors**

High failure rate (about 29%) in our beginning circuit analysis class is strongly correlated with a change to a different major. Approximately 40% of students who fail this first course later change their major. This first course thus not only provides concepts that are essential for later success, but also appears to strongly impact a student's perception of their ability to succeed in the major.

Advances in technology make web pages increasingly effective at reaching the current generation of students. A 2012 poll by the Pew Research Center found that 67% of Americans between 18 and 24 reported owning a smartphone in February of 2012, and that percentage was an 18% increase over the previous year [1]. Thus, we have chosen to provide study aids on the web, a format that is becoming increasingly accessible through mobile devices as well as traditional platforms.

The primary goals of our web based tools are to improve student learning and concept retention. We accomplish these goals by providing a wide variety of interactive online resources designed to serve students with different learning styles, but especially those who are “visual” or “kinesthetic” learners. These resources include lectures, example and practice problems supported by step-by-step solutions, exercises that provide feedback on the correctness of an answer, online circuit simulation, and YouTube videos. Each individual component is short, typically requiring five to ten minutes. Videos are less than five minutes each and are designed to replicate the experience of a tutor sitting next to a student and solving the problem on a piece of paper. Each video shows how a given problem evolves from its definition to the final answer. All of these learning materials present basic circuit concepts at the freshman level, but are available to all students to refresh their knowledge at any time. The following section describes our strategy for designing our online tools.

**Design strategy for Web-Based Tools**

This section describes the overall design of our online resources, including their appearance and navigation options.

**Topic selection:** Topics were identified by interviewing professors and student club members, and also by conducting in-class surveys. Based on these inputs, we have selected the following topics as the primary focus: nodal and mesh analysis and Thevenin and Norton equivalent circuits [2,3]. Lecture notes for each topic were developed to give narrative explanations of the reasoning behind the mathematical derivations. Each discussion begins with a practical application to demonstrate the relevance of the topic.
a. **Detailed Examples:** A minimum of four examples are presented for each topic. Each example includes a detailed narrative of how to approach the problem, accompanied by equations and figures. The goal of these examples is to teach both the problem-solving process and the practical application of the topic. Students can find the solutions in html, pdf, and YouTube video formats, allowing them to choose the medium that best fits their learning style and available resources. Also, embedded with each example is a schematic that is drawn using CircuitLab [4], an online schematic editor and circuit simulator. This resource provides both validation of the solution and the opportunity for visual and kinesthetic learners to interact more actively with the problem.

b. **Practice Problems:** 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 programs. 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. Erroneous answers result in tips and hints as well as directing the student to appropriate lecture materials and examples so that the mistakes can eventually be corrected. Students also have the option to see a complete hard copy solution directly or watch the solution worked out in a YouTube video.

c. **Online simulation tools:** We used CircuitLab to simulate the circuits in the examples and problems [4]. As mentioned earlier, the CircuitLab simulations enable students to validate the answers to practice problems in a medium that, for many of them, speaks more directly to their primary learning style. Students can also create a new problem by changing the circuit parameters. This flexibility allows students to develop intuition about circuit behavior by experimenting with the sensitivity of the node voltages or branch currents to component placements and values.

d. **Self-Test Problems:** The self-test problems are representative of those used in quizzes, midterms, and finals in our freshman course. These problems test the student’s ability to apply the concept in a typical context. We provide only the final answer to each of these problems. In the future, we may add some multiple choice problems to assist students to develop test-taking skills (focus on the potential candidates by first eliminating absurd or impossible choices).

All of these resources are available through a web site maintained by the ECE department. Our assessment results, which we present in a separate section below, indicate that using the web-based toolkit alone has significantly improved students’ learning. Our assessment also indicates that weak students in particular benefited from the video solutions.
Although the original project focused on these web-based learning tools, the scope is now being extended to include a variety of related tools including the National Instrument’s myDAQ measurement and instrumentation device.[5] The myDAQ is an inexpensive data acquisition device that can be used in the Labview environment to provide common electronic circuit test and measurement capabilities such as a multimeter, oscilloscope, DC power supply, or signal generator.[6] With the inclusion of the myDAQ, students have the opportunity to do all of the following:

a. Watch interactive online circuit problems
b. Test the circuits with CircuitLab and,
c. Build the circuit and measure its performance.

The myDAQ, coupled with simulations in CircuitLab, fosters independence early in a student’s academic career, enabling test and experimentation 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, and observing and comparing results to explore what can in the traditional classroom and laboratory approach seem to be abstract and confusing concepts. The use of the myDAQ supports these activities by removing the requirements for specialized learning environments, allowing the student to engage with basic circuits concepts at the best times and places for them.

**Examples of Online Web-Tools in Operation**

Online web tools have been created in the html5 format because it is compatible with many different platforms and web browsers. Fig. 1 shows a sample view of our web-tools under Windows 7, on an iPad, and on an iPod.

![Fig.1: Online web-tools viewed with different platforms](image-url)
Each example and problem is available in html and pdf formats. At the end of the solution, we provided a link to watch the solution on YouTube and to simulate the circuit with CircuitLab. These options are shown in Fig. 2.

![Figure 2: View of problem solution and related links for simulation, video, and pdf.](image1)

CircuitLab [2] is an online circuit simulation tool. This online resource includes a powerful schematic editor and simulation tools which also has a user-friendly interface, making it accessible to a beginner. Fig. 3 shows a typical use of CircuitLab.

![Figure 3: Example of problem solution and links](image2)

A video solution for each example and practice problem is available from a link to YouTube. We intentionally kept each video short less than five minutes to encourage students to watch the entire presentation. Students tend to lose concentration, stop watching or be distracted by a
phone call or text during long videos. Fig.4 shows a sample of a video session. A professor who has taught the course many times is seen writing the solution out on paper. This environment makes a student feel that the professor is solving the problem for them personally. However, with the video a student can pause to take notes or can replay it again and again if needed. Our survey has indicated that this is the most popular format in our toolkit.

![Video session on YouTube](image)

**Fig.4: Video session on YouTube**

**Performance Assessments**

We have developed surveys to obtain student feedback. The first survey was given at the beginning of the quarter. The questions are:

1. Online materials will help me to understand circuit analysis course materials
2. If there are online videos, they will help me to understand concepts better in this course.
3. If there are online examples, they will be helpful in enhancing the concepts in this course.
4. I would look at online material to remember concepts on a course I already took.
5. The online resources would improve my learning of circuit analysis class materials and be a helpful reference for future courses.
6. The tutorial can increase my confidence to do well in circuit analysis class
7. Any suggestion?

Answers for questions 1 through 6, fall into one of the five groups **SD** = Strongly Disagree; **D** = Disagree; **N** = Neutral; **A** = Agree; **SA** = Strongly Agree.
The survey results are summarized in Fig. 5. This figure shows that 94% students agree or strongly agree that online examples will be useful and help them to understand concepts in this course. Also, 90% students agree or strongly agree that the online resources presented would improve student confidence to do well in a circuit analysis class.

Fig. 5: Result of the first survey

The second survey was given at the end of the quarter. These are the questions:

1. The online tutorial provided sufficient information about circuit analysis class materials
2. The tutorial examples are in depth and useful
3. The tutorial helped me to better understand fundamental ideas presented in circuit analysis class.
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 circuit analysis class 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?
13. Do you find a need for any additional topics?

As before, answers questions 1 through 8, falls into one of the five groups- **SD** = Strongly Disagree; **D** = Disagree; **N** = Neutral; **A** = Agree; **SA** = Strongly Agree.
The survey results are summarized in Fig.6. It shows that 99% students agree or strongly agree that online resources presented would improve my learning of circuit analysis 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 freshmen classes such as the introductory C++ programming course.

Every year, around of 300 students take freshmen circuit analysis classes in our department, with each class section having approximately 40 students. On the average 29% of students fail the class. Unsuccessful students either repeat the class again or change their major.

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.7. This data indicates that both the pass rate and the average grade increased in the class whose students used our online web tools.
Conclusion

A suite of web-based instructional tools has been developed and was introduced to freshmen students in circuit analysis course. Preliminary assessment data demonstrates that students welcome 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 the online tools. These learning materials were developed to enrich learning in circuit analysis course, but are also available to students who need to review. Specifically:

- Historically, the first network analysis class in our program is known for a high failure rate.
- Students who fail first in this course opted for a change of major.
- This class is one of the significant bottleneck classes for students in our department.
- In the survey, students responded favorably to the deployment of web based tools that are available to all students on a variety of devices.
- The variety of web based resources (short lecture materials, practice problems, exercise problems, and videos), allows students to choose a format that is most accessible and meaningful to them.
- The YouTube videos of problem solutions were 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 (*CircuitLab*) provides students with a means of validating their solutions to given problems, as well as a platform for developing and checking similar problems.

Fig. 7 Grade distributions for circuit analysis under two different styles.
• Survey results indicate that students who had access to the web toolkit have higher average grades and are less likely to fail than those who did not use the toolkit.
• Students who used the toolkit indicated that they were more confident about their mastery of circuit analysis concepts.

Inclusion of NI MyDAQ device into Circuit Analysis class is currently in progress

References

1. Aaron Smith, “Nearly half of American adults are smartphone owners,”
   http://www.pewinternet.org/2012/03/01/nearly-half-of-american-adults-are-smartphone-owners/
   (last referenced February 15, 2014)