Web-based Interactive EE Lesson Development: A Modular Approach

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Abstract

This presentation discusses the development of Web-based lessons on the basics of electronic circuit design and theory. Gary Daniels, adjunct assistant professor in Electrical and Computer Engineering at The University of Texas at Austin, partnered with the College of Engineering's Faculty Innovation Center to develop a series of interactive lessons targeting freshmen in the ECE program. With nearly 2000 ECE undergraduates at UT-Austin, these lessons can potentially impact a large number of students.

Understanding complex theoretical topics is challenging for many electrical engineering students. These lessons directly address their needs by presenting the information in small chunks, encouraging learners to process each concept before moving on to the next one. Graphics and animation visually illustrate difficult concepts, and lessons are enhanced by liberal use of humor.

Prototype development is discussed, including the problems and limitations encountered. Student responses and evaluation results are presented. A modular approach was taken after completion of the first lesson. The team storyboarded content and developed the interactive lessons using templates to improve the production rate. The result is an effective technology-enhanced supplement to classroom instruction that can be efficiently produced.

1 Introduction

1.1 Disclaimer

We caution readers that this paper is intended to be an interactive on-screen demonstration; words on paper will not do it justice. Try it online at www.engr.utexas.edu/rgd1.

1.2 Rationale

The genesis of this project was influenced by a number of factors, including issues specific to our institution, changes in the higher education environment, and technological advancements. The University of Texas at Austin has a large and growing electrical engineering enrollment, with typically poor retention rates in the first two years. A solid understanding of engineering fundamentals is essential for future success, both in college and after graduation. Students today expect technology-enhanced instruction with high production value. Trends in higher education are to make more material available via the Web, as a supplement to, if not a replacement for, on campus courses[1]. According to Stoney and Oliver, "The use of interactive multimedia can foster and develop cognitive engagement through its ability to attract and hold students' attention and focus."[2] Media-rich instructional materials can be more efficiently produced now, thanks to state-of-the-art software such as Macromedia's Flash. Furthermore, students can more easily access these materials because high performance desktop and notebook computers are ubiquitous. Students who don't own a computer can readily access computers in labs and libraries across campus.

1.3 Project Initiation and Development

Following a presentation on Web-based instructional media in the UT's College of Engineering, Professor Daniels was inspired to develop an animated interactive lesson focusing on Ohm's Law for his freshman course, Introduction to Electrical and Computer Engineering. The idea was to adapt a physical demonstration that he traditionally performed in the classroom – rolling balls down a ramp as an analogy to electron flow in a circuit. The Web-based lesson was intended to supplement, not replace, classroom instruction.

The Faculty Innovation Center (FIC) supports instructional innovation within the College of Engineering at UT Austin by providing media and instructional development services. When Professor Daniels came to the FIC with his ideas in 2001, Matt Mangum, senior Web designer, agreed to produce the interactive lesson. Development of the first lesson was viewed as a prototype and perhaps as a model for future engineering course development.

The decision was made to use Macromedia's Flash MX authoring tool, which allows delivery of elaborate animation and complex interaction while keeping file sizes small so the user doesn't experience long waits while files load. All the user needs is a Web-browser equipped with the Macromedia Flash plug-in. As the most widely distributed browser plug-in[3], Web sites developed with Flash are accessible by the widest possible audience[4]. Additionally, Flash application development is faster and easier than similar technologies, such as Sun's Java.

Storyboarding is commonly used in interactive multimedia development to specify visual, interactive, and audio elements. This allows the development team to work through decisions on paper before moving on the more costly media production and programming phase. Because this lesson was considered a prototype, the development team decided to forego storyboarding. The process was consequently very fluid and iterative. This also resulted in a rather lengthy development timeframe (approximately one year) because frequent code revisions were necessary to refine and finalize the interactivity and visual design.

2 The Prototype

2.1 Ohm's Law

One of the difficulties facing freshmen electrical engineering students is that, while all the action in an electrical circuit is the result of electrons in motion, electrons cannot be seen, heard, felt, tasted or smelled – or easily envisioned.

To assist in student understanding, Professor Daniels conceived of an analogy of balls rolling down a ramp. This analogy was more "visible" to students, and it lends itself to computer animation.

The flow of balls down the ramp is proportional to the ramp height (h), with k as the constant of proportionality. We stipulate that each ball has 3 stars marked on it and that what we can measure easily is the flow of stars down the ramp per second.

From this, we derive "Mho's Law": h = J r, where h is the ramp height, J is the flow of stars in "Erepma" (Ampere spelled backwards) and r is a constant, $\frac{1}{r} = \frac{k}{3}$. The derivation of Mho's Law is shown in Figure 1.

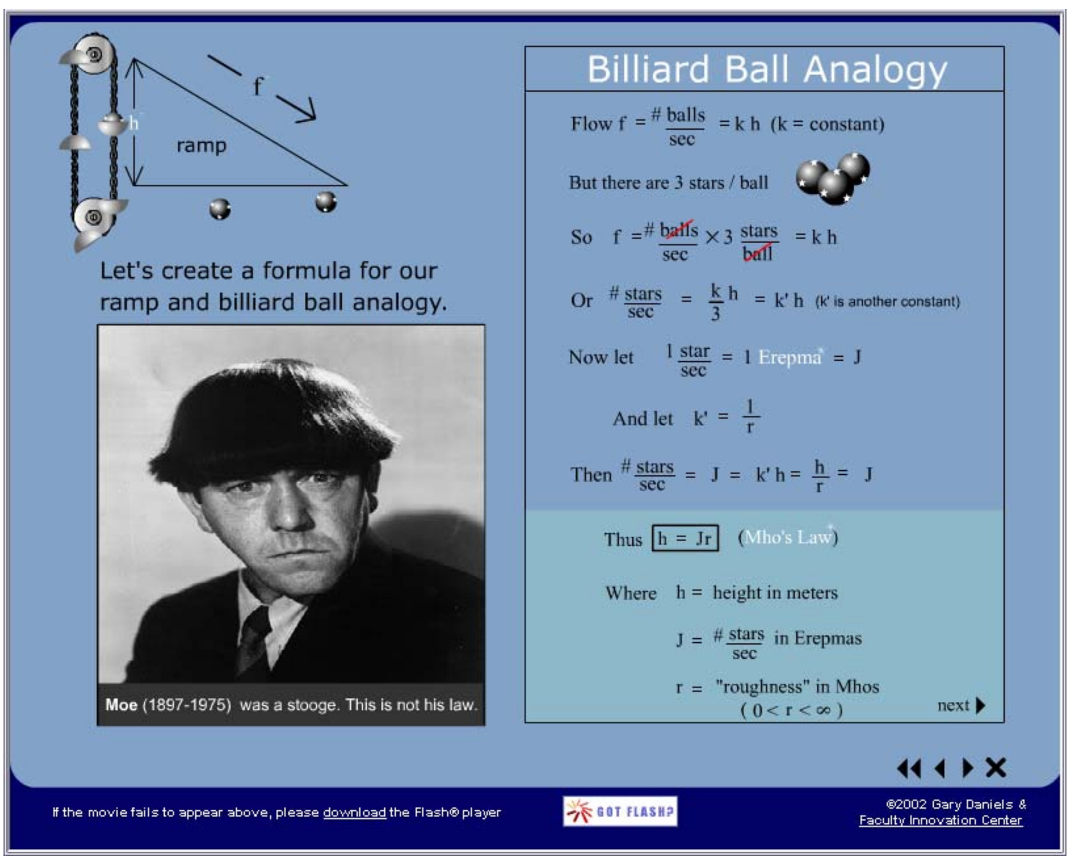

FIGURE 1: Derivation of Mho's Law (Analogy)

A little humor is included with a subtle reference to the Three Stooges character Moe.

The ramp model is then merged into an electrical circuit, with electron flow proportional to the battery voltage V and with k as the constant of proportionality. Now we stipulate that each electron has a charge of 1.6×10^{-19} Coulombs and that what we can measure easily is the flow of charge per second (which is true).

From this, we derive "Ohm's Law": V = I R, where V is the battery voltage, I is the flow of charge in Amperes and R is a constant, $\frac{1}{R} = \frac{k}{1.6x10^{-19}}$. The derivation of Ohm's Law is shown in Figure 2.

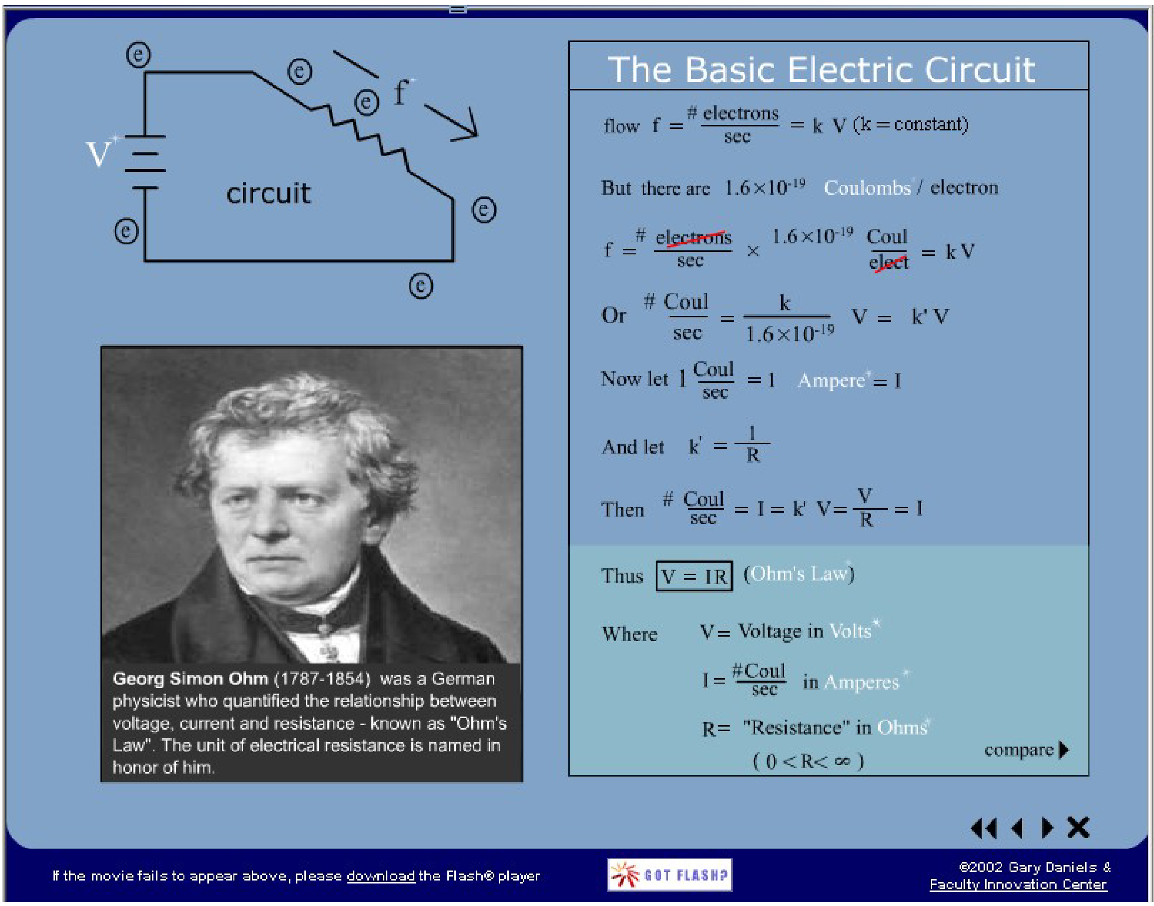

FIGURE 2: Derivation of Ohm's Law

The comparison of these two derivations is shown in Figure 3. Height h is analogous to voltage V. The flow of stars per second J is analogous to the flow of charge per second, or current, I. And the constant r is analogous to the constant R, which we call resistance.

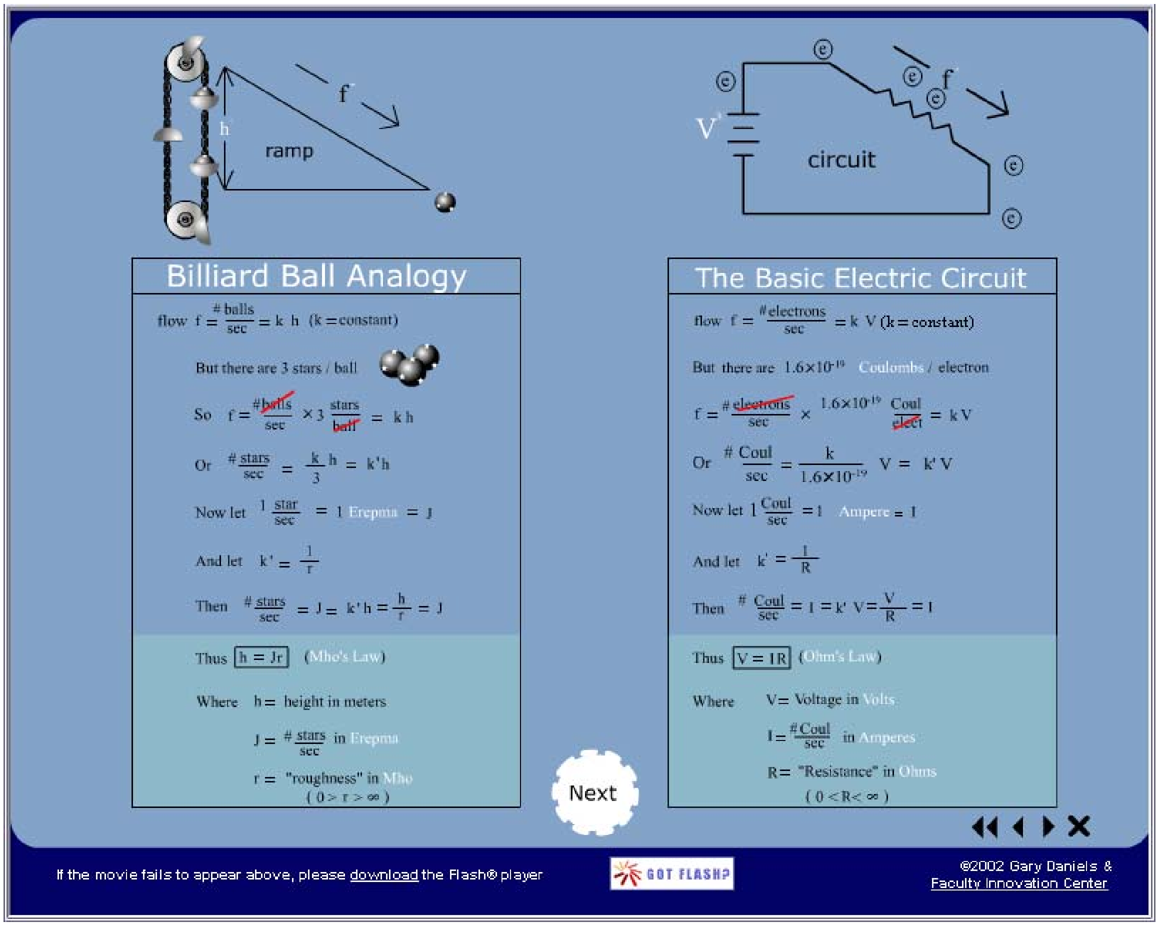

FIGURE 3: Comparison of Ohm's Law and Mho's Law Derivations

We added a page of "footnotes" to confess that Ben Franklin guessed the wrong direction for current flow and that Robert Millikan determined the actual charge of an electron in his famous Oil-Drop Experiment – some 100 years after the pioneering work of Ohm, Volta, Ampere and others.

The finale is a 10 question Quiz for students to check their understanding. A typical quiz question is shown in Figure 4.

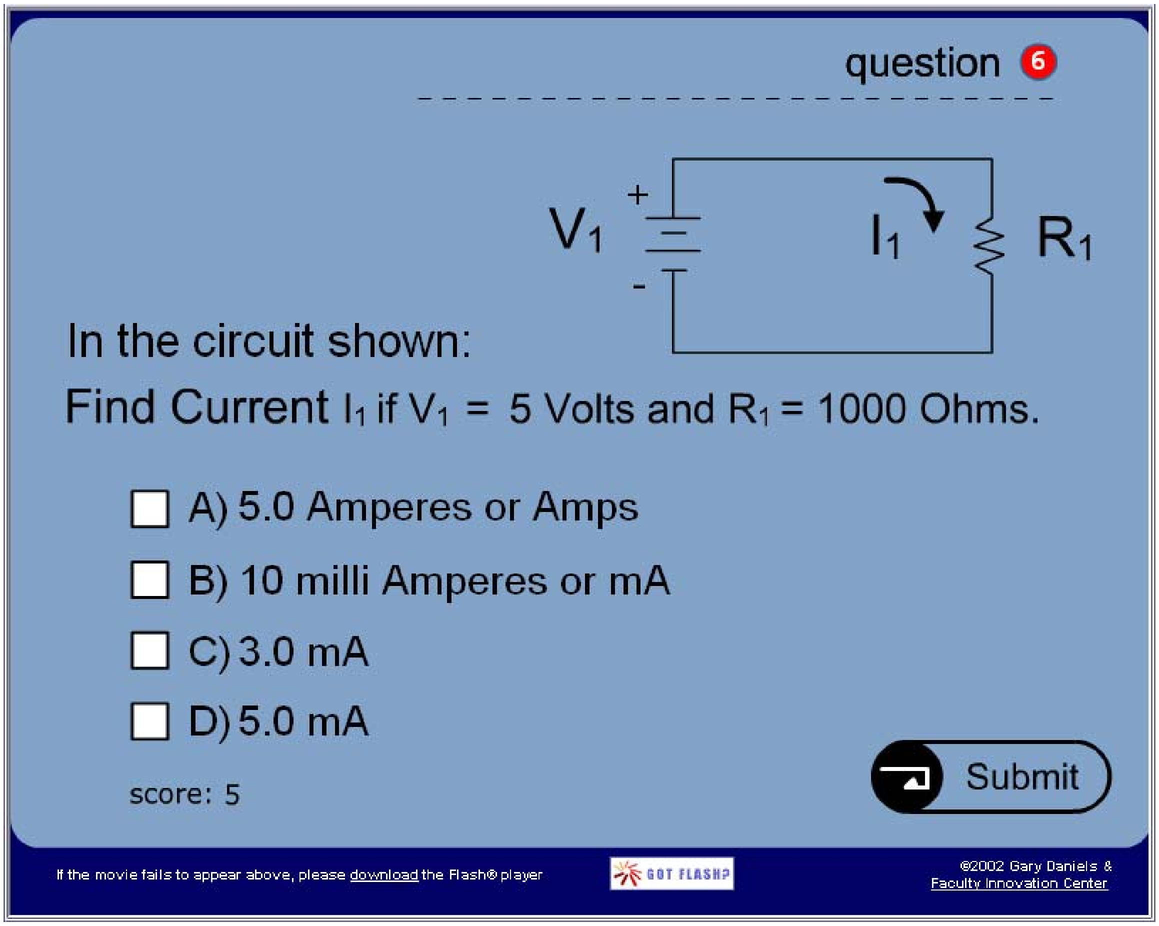

FIGURE 4: Typical Quiz Question

Students progress through the lesson step-by-step at their own pace (and on their own time). They may retake the quiz as often as they feel is necessary.

2.2 Student Evaluation

A typical UT-Austin freshman EE class was asked to try this lesson as a beta test and provide evaluation comments. A summary of their evaluation is given in Figure 5. Sixty-five percent of the students gave overall positive comments. We found it interesting that the most often mentioned suggestion was to add some sound effects – which we did.

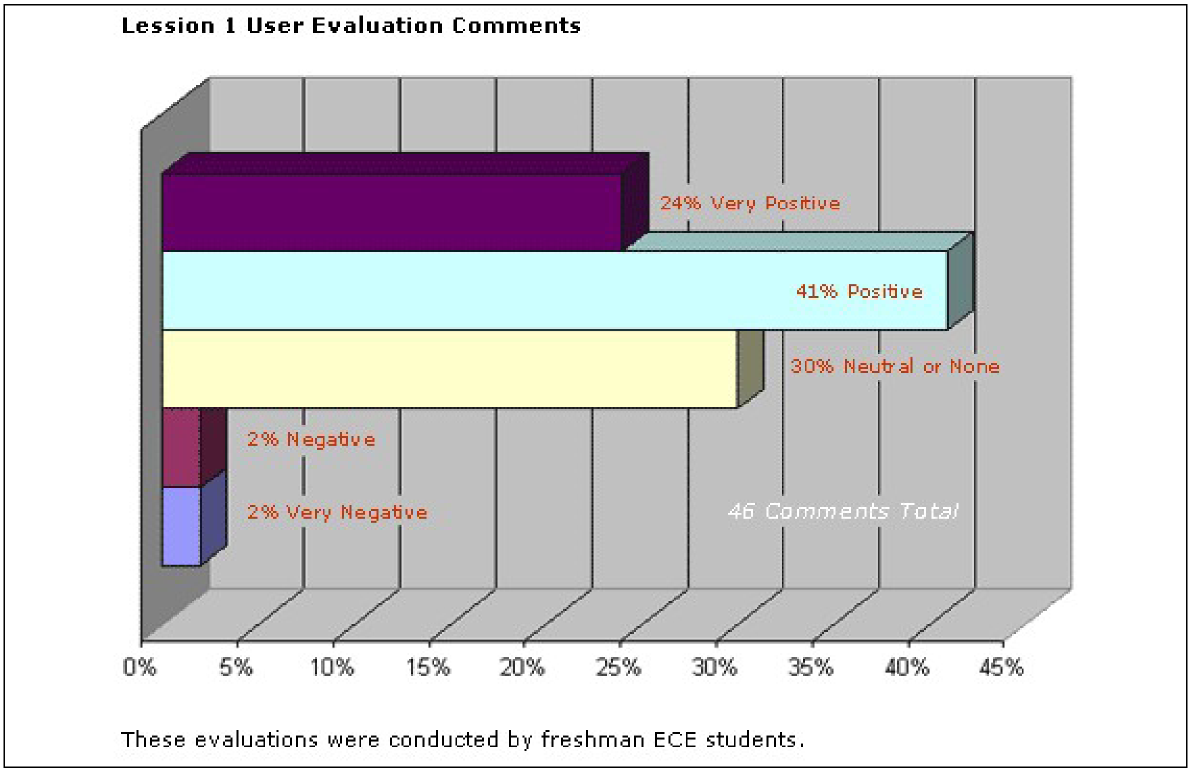

FIGURE 5: Beta Evaluation Results

2.3 Developers Evaluation

The lesson developers (Daniels & Mangum) were also satisfied overall with the result. However, it required considerable time and effort; we asked, "Is there an easier way to do the next one?" We also noted several shortcomings.

- Navigation within the lesson is totally linear and there are places with no user control options.
- In terms of coding, the lesson is not modular. It is a single Flash file.
- The quiz has no easy exit path.
- The development process was very time-consuming, partly due to the fact that there was little pre-production and no storyboarding.

3 Sequence of Modular Lessons

3.1 Initial Goals and Plans

With a firm foundation on which to build and some lessons learned from the prototype, Professor Daniels requested to continue working with the FIC to produce a series of lessons on the basic concepts in electronic circuit theory. An instructional designer, Mary Crawford, joined the development team at that point.

Moving into the second phase of the project, we defined two main goals:

1. Improve the development process by establishing more efficient methods of generating content specifications and programming lessons.
2. Enhance the user experience by improving navigation within the lessons, particularly within the Quiz section.

In addition to within-lesson navigation, a between-lesson navigation system would also need to be developed to accommodate multiple lessons. We also decided to create an animated character to add personality and humor to the Web site.

The team agreed that a modular approach would address the first goal of improving development efficiency. We agreed to initiate development of a second lesson as the vehicle for establishing templates to support standardized content design and programming. Because it would be, in essence, another prototype, development of lesson two would not be typical of the process we hoped to establish.

3.2 Initial Development

Lesson 2 on Power and Energy (with a review of Ohm's Law) became our launch pad for developing a template-based process. Some of the design considerations for the lesson menu were to develop a clean, user-friendly interface, include UT branding, and harmonize the visual appearance with the prototype lesson. Figure 6 shows the introductory screen and menu of lessons.

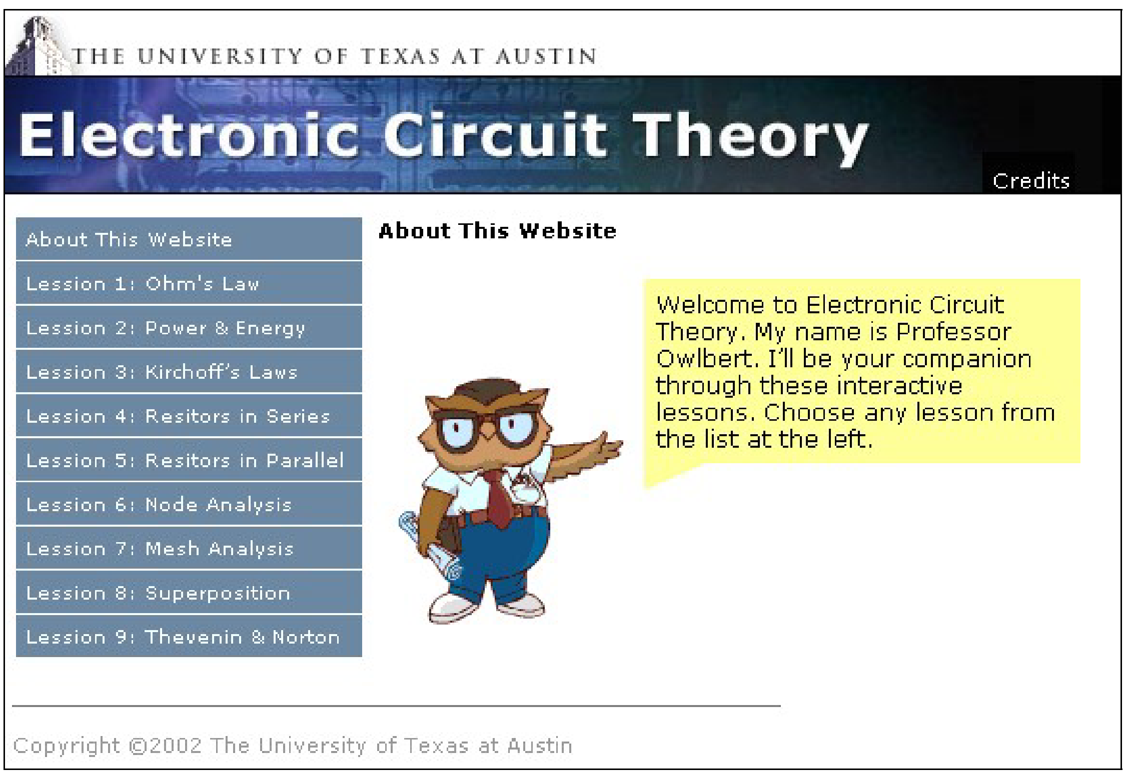

FIGURE 6: Lesson Menu with Professor Owlbert

The FIC's staff artist, Erik Zumalt, developed a clever cartoon owl character with a distinct engineering personality. The animated character was dubbed Professor Owlbert. While engaging and amusing in moderate doses, the team acknowledged that constant use can reduce the effectiveness of animated media resulting in distraction or even annoyance of the students.

The approach for lesson two was similar to lesson one with regard to presenting small segments of information in a step-by-step fashion. Additionally, a within-lesson menu was added, allowing the student to move to any specific page of the lesson. In other words, linear navigation through the lesson sequence is not required. This adds to the "replay value" by supporting easier review and reference to individual pieces of information. Figure 7 shows the open menu, which uses meaningful page names rather than a numbering system that does not reflect the content of each page.

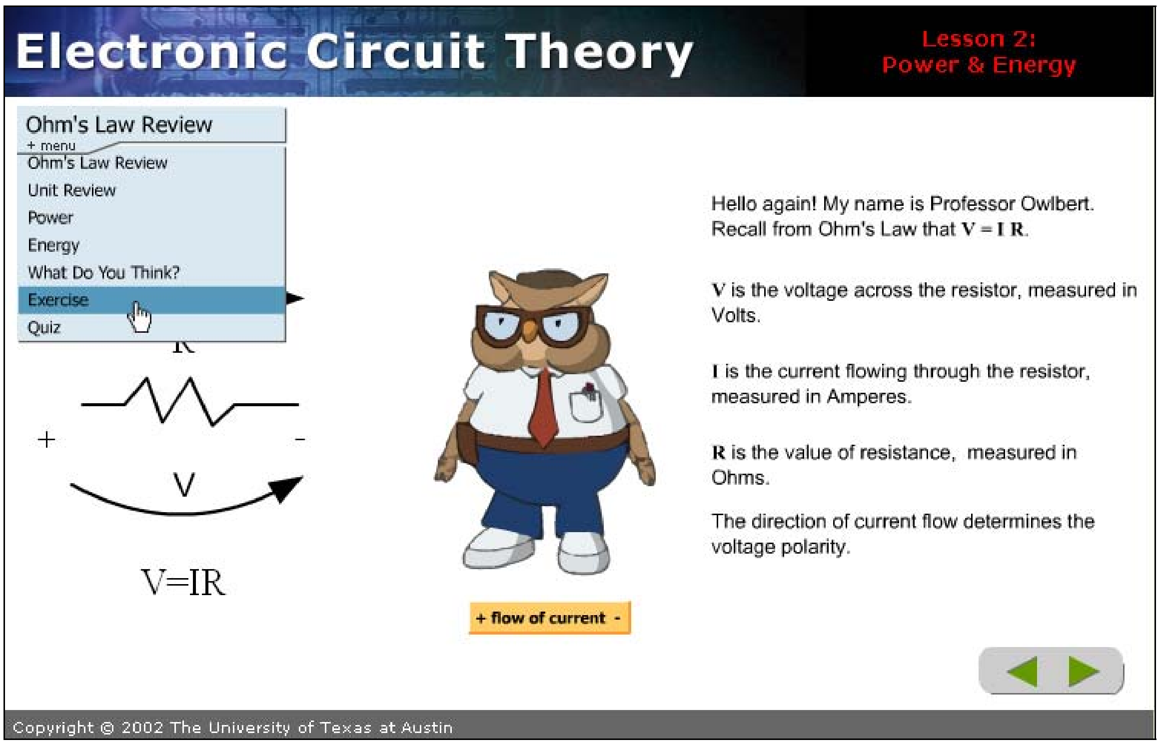

FIGURE 7: Navigation within a Lesson

In addition to presenting information, we introduced a new element in lesson two, which we envision to be included in all subsequent lessons. At an appropriate point in each lesson, the student can experiment with an interactive toolkit. This type of interaction is consistent with an active, learner-centered approach and allows students to test and modify their understanding of underlying principles. Figure 8 shows an example where the student can place different batteries and resistors into a circuit and see the resulting current and power.

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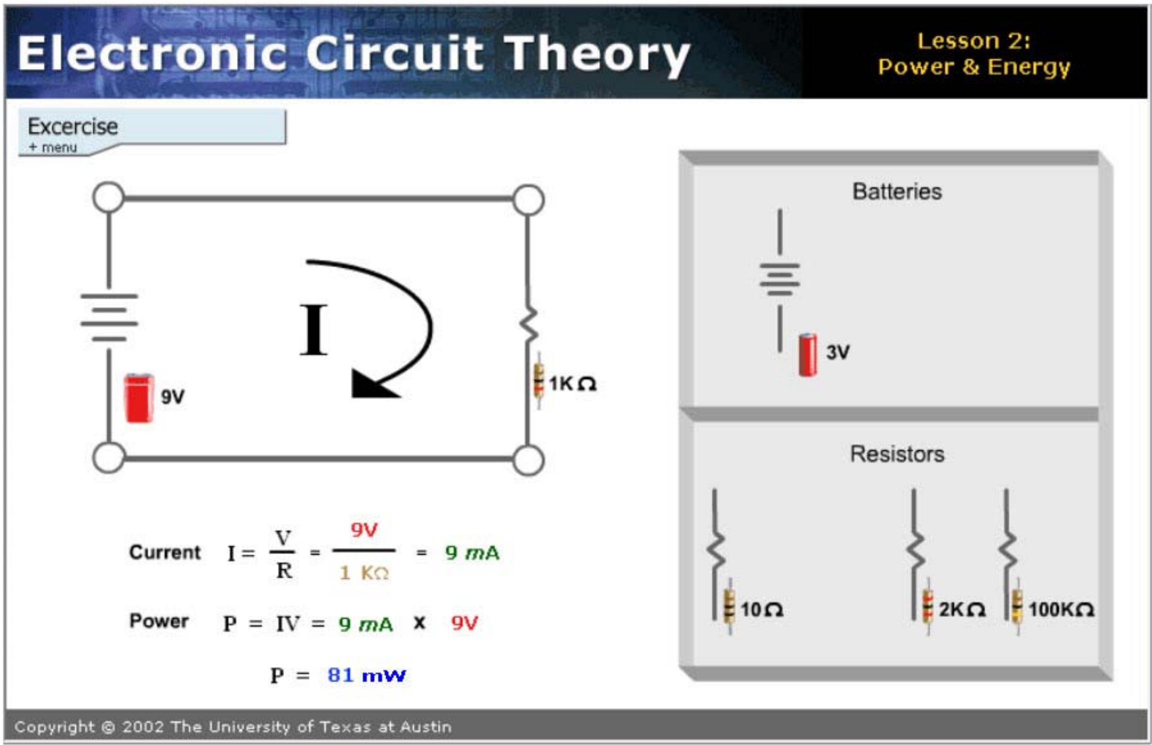

FIGURE 8: Interactive Electronic Toolkit

The scripting capabilities of Flash have been used extensively to develop the interactive activities, as well as more powerful quiz feedback. Additionally, quiz usability was improved in the following ways:

- The number of the current question and the total number of questions are displayed along with the student's score.
- The menu of lesson pages is available, providing a way to exit the quiz and return to the lesson for review if desired.
- Display of feedback is not timed. The student decides when to advance to the next question.
- Feedback is displayed along with the question and responses, reinforcing the correct answer or allowing the student to reconsider the other choices before moving on.
- Space was left to optionally display additional information indicating why that response is incorrect or providing additional guidance.

Figure 9 shows the revised quiz format.

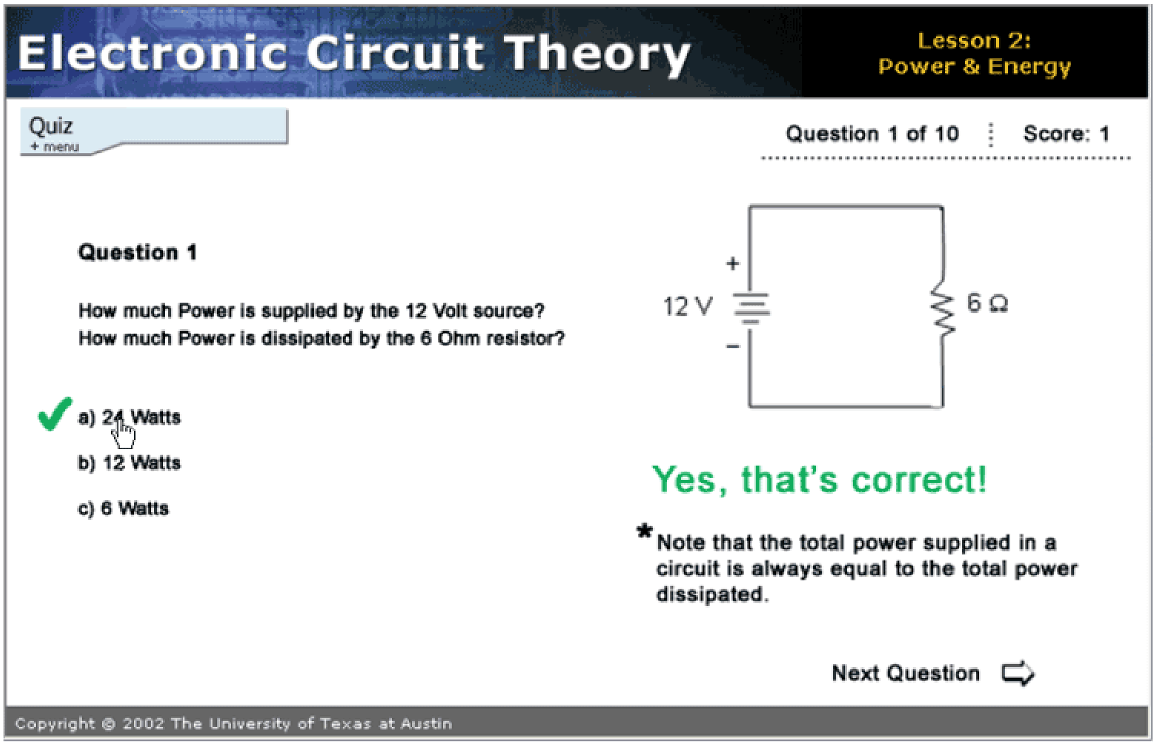

FIGURE 9: Correct Feedback on Quiz Question

The development of lesson two was an evolutionary process that involved several iterations of trial, review, and revision. Our goal was to work through the kinks in lesson two to develop a re-usable template with fewer decision points. All general navigation and design decisions have been made. The storyboard form supports finalizing content and interaction decisions before we move into the more costly production phase. By using a storyboard form for subsequent lessons, the production process can proceed rapidly with fewer decision points and less revision.

4 Conclusion

We are confident that we are on the right track to now develop a full set of cost-effective, interactive multimedia lessons that will truly enhance student learning and can be developed within a reasonable timeframe. We agree with Henson, et al in their conclusion: "… a responsibility exists by instructors to provide students with the best learning tools that are available. Not all students learn in the same way, nor do all professors have the same teaching styles. The Internet provides a means to reach a wide variety of learning styles regardless of the instructor's teaching style. Internet-based supplemental education may not be right for every class, but it is another tool available to instructors for educating engineers."[5]

Since these lessons are available on the World Wide Web, they are, of course, available to students, faculty, and life-long learners worldwide. Consistent with The University of

Texas at Austin's Digital Knowledge Gateway[6] initiative, the College of Engineering is committed to expanding the global engineering educational resource base.

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