Electronics Lab Bench in a Laptop: Using *Electronics Workbench*® to Enhance Learning in an Introductory Circuits Course

Edward R. Doering

Department of Electrical and Computer Engineering
Rose-Hulman Institute of Technology
Terre Haute, IN 47803-3999

Abstract *– Electrical Systems, part of the Foundation Coalition Sophomore Engineering Curriculum at Rose-Hulman, serves as the introductory circuits course for students participating in the curriculum. The quarter-long three-credit course is designed to provide breadth in DC, transient, and AC circuits for all engineering majors. Rose-Hulman is in the second year of requiring entering students to purchase their own laptop computer, so this year each student in Electrical Systems has a 486-based laptop that can be used to support classroom activities as well as homework assignments. Circuit simulators are well-recognized as effective learning aids in circuits and electronics courses, and PSpice serves the needs of the upper division courses. However, the learning curve of PSpice is sufficiently steep that it could not be used productively in Electrical Systems without sacrificing a major portion of the course content. Electronics Workbench (EWB), on the other hand, provides an intuitive drag-and-drop user interface by which students can build a circuit, insert measuring devices such as voltmeters and ammeters, and click the "power switch" icon to simulate the circuit and see the results displayed immediately on the instrument panels. In effect, the student's laptop simulates an electronics lab bench. At the start of the quarter I spent zero class time lecturing about how to use EWB, yet students were able to productively use the simulator by the second week. In class the students experience circuit behavior as new concepts are introduced. Homework is structured around the design process: students "design" an analysis procedure, and verify their "design" with an EWB simulation. Survey results show that the students believe that the in-class simulations help them to better understand the concepts, and rate the tool highly in terms of its ability to help the learning process.*

Introduction

The Foundation Coalition Sophomore Engineering Curriculum (FCSEC) at Rose-Hulman [1] provides sophomores with fundamental skills in conservation and accounting principles, mechanical systems, thermal/fluid systems, electrical systems, and applied mathematics. The quarter-long three-credit Electrical Systems course introduces circuit theory and is designed to provide breadth in DC, transient, and AC circuits for all engineering majors (electrical and computer engineering majors go on to take two more circuits courses which cover circuit theory in depth). The time limitation on Electrical Systems prevents course time from being used to teach a SPICE-based circuit simulation package (e.g., PSpice), so previously students had to forgo the benefits of experiencing circuit behavior via simulation.

Two separate events occurred this year to make it possible to introduce circuit simulation into the classroom experience without jeopardizing class time devoted to the course syllabus. First, Rose-Hulman is in its second year of the Freshman Laptop Program, so each sophomore now has a network-capable laptop computer. Second, each student purchased and installed the student edition of *Electronics Workbench* (EWB) on their laptop. EWB has a completely integrated and interactive simulation environment which enables the user to drag-and-drop and connect components into the workspace, add lab-style instruments such as voltmeters, ammeters, and an oscilloscope, press the "power switch" icon, and observe the circuit behavior unfold in real time. In effect, the student's laptop is transformed into an electronics lab bench. EWB's user interface is intuitive enough that students could achieve productive simulation results without spending a lot of time learning SPICE syntax to setup a simulation.

This paper will describe the methods I used to integrate EWB into the Electrical Systems course, including usage in and out of the classroom as well as assessment methods, and will report the results of student-self assessment of EWB as a tool to enhance the learning process.

Methods

Institutional Context

The Foundation Coalition and Rose-Hulman have made a significant commitment to using technology in the classrooms. This year the Electrical Systems course was conducted in a laptop-enabled classroom consisting of power/network ports for each student, and a computer projector for the instructor.
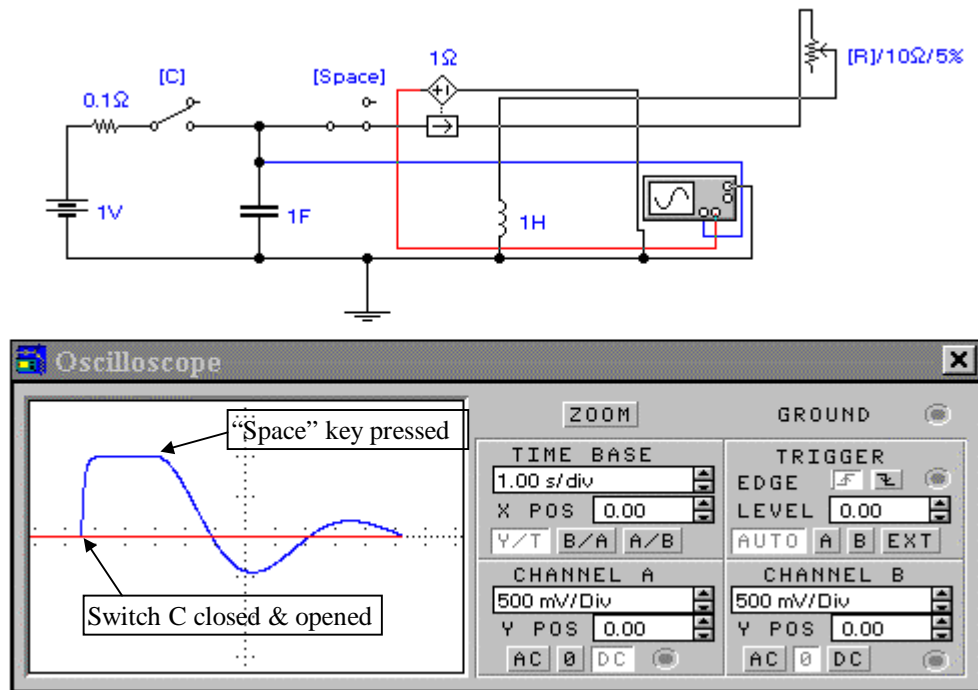
Figure 1. Circuit used to illustrate transient response. The switch positions are manipulated by pressing the "C" and space keys on the keyboard; pressing "R" increases the series resistance, and pressing "r" decreases the resistance. Setting Channel B to DC would display the current.

Usage in the Classroom

I used EWB to supplement the lecture whenever it was appropriate to demonstrate actual circuit behavior, particularly when motivating a new topic. For example, I used an underdamped second order circuit (Figure 1) to motivate discussion about transient circuit responses. The switches can be operated from the keyboard while the simulation progresses, and the oscilloscope trace moves repeatedly across the screen just like a real oscilloscope. I posed "what-if" type questions, then showed what would actually happen when the switches were manipulated. The students showed a particularly high degree of interest in these type of demonstrations and more readily contributed to class discussion than other times.

I designed other demonstrations to allow students to make their own experiments and draw their own conclusions. For example, students measured the voltage-current characteristics of "mystery" devices (the "educator version" of EWB allows the instructor to password-lock subcircuits to make true "black boxes"), experienced the open-loop behavior of operational amplifiers, and studied sinusoidal circuit.

Usage Outside the Classroom

Students made significant use of EWB to verify the results of their homework problems. I modeled the homework procedures on the design process by requesting the student to develop an analysis procedure which is tested via simulation before concluding that it is correct; the analysis *procedure* (not just the answer at the end) is considered to be the final "product" to be verified by simulation. This mechanism allowed students to test their predictions against "reality" rather than merely comparing it to an end result given by the instructor.

Assessment Procedure

I used surveys at mid-term and at the end of the term. The end-term survey focused more on how the students used EWB and how they felt that it impacted their own learning.
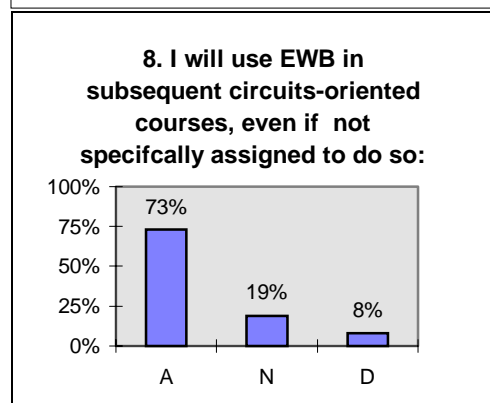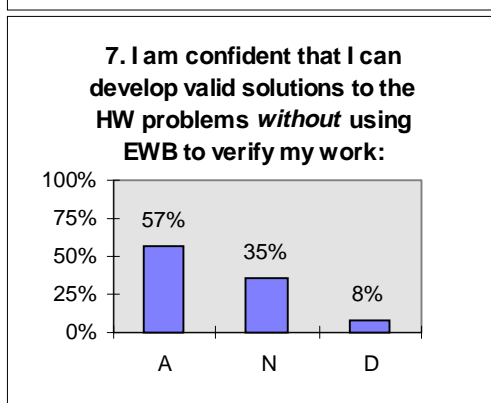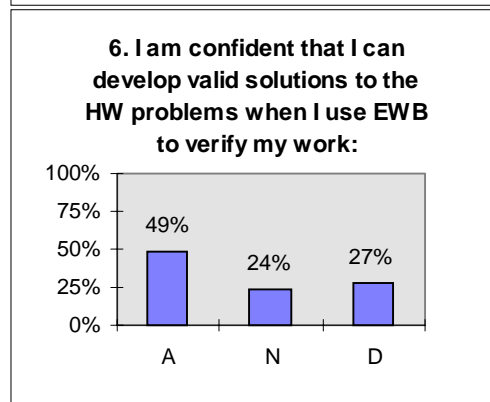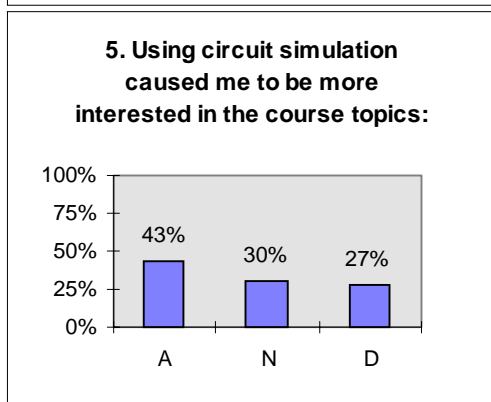
1. Using circuit simulation improves my understanding of how circuit devices work:

	A	N	D
	65%	16%	19%

2. I believe that using circuit simulation has helped me to more rapidly understand the course material:

	A	N	D
	43%	30%	27%

3. Using circuit simulations in class helps me to better understand the concepts *as they are presented*:

	A	N	D
	65%	19%	16%

4. Using circuit simulations in class helps me to *remember* concepts presented in class:

	A	N	D
	35%	38%	27%

5. Using circuit simulation caused me to be more interested in the course topics:

	A	N	D
	43%	30%	27%

6. I am confident that I can develop valid solutions to the HW problems when I use EWB to verify my work:

	A	N	D
	49%	24%	27%

7. I am confident that I can develop valid solutions to the HW problems *without* using EWB to verify my work:

	A	N	D
	57%	35%	8%

8. I will use EWB in subsequent circuits-oriented courses, even if not specifcally assigned to do so:
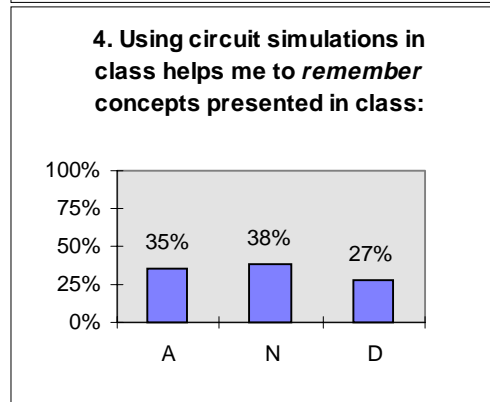
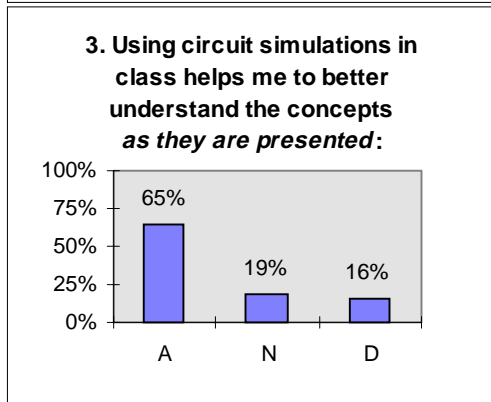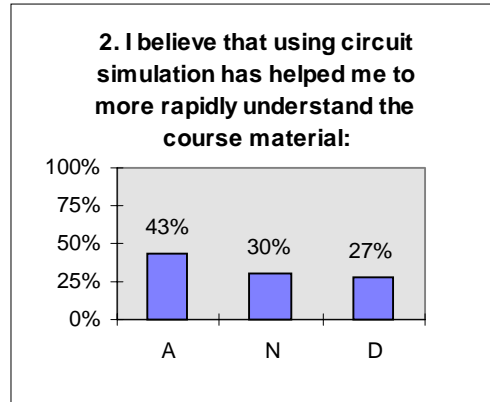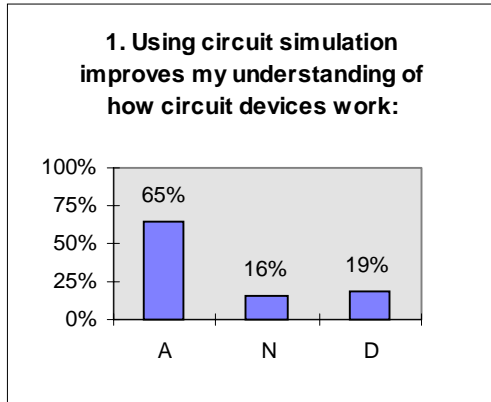|	A	N	D
	73%	19%	8%

Figure 2. End-of-term survey questions and responses (37 students total).

Results and Conclusions

Survey Data

Questions used on the end-term survey and the associated results are shown in Figure 2. Questions 1 through 4 deal with student self-assessment of learning. Strongest agreement (65%) occurred with using EWB to promote understanding of device behavior (Question 1) and understanding of concepts while class is in session (Question 3). Agreement with statements that circuit simulation accelerated the rate of learning was somewhat less (43%), and the students were divided as to whether use of circuit simulation improved long-term retention. Based on these results, I conclude that using circuit simulation in this introductory circuits course was most successful at helping the students to develop a feel for circuit behavior.

Question 5 dealt with stimulating and motivating student interest in the course. Note that a majority (43%) of the students agreed that using circuit simulation caused them to be more interested in the course topic, and 27% disagreed (30% neutral). I attribute the positive response to this question to the ease of using EWB and its user-friendly interface.

Questions 6 and 7 dealt with using EWB to assist the learning process when doing homework problems. Half (49%) of the students felt confident they could develop valid solutions when they used EWB to verify their work, and even more students (57%) agreed they could do the same thing without doing an EWB-based verification. These results were encouraging since they indicate the students do not believe their ability to solve problems depends on using the circuit simulator.

Finally, Question 8 dealt with general interest in using the simulator in subsequent classes. A large majority (73%) agreed that they would use EWB of their own volition, and only 8% (two students of 37) indicated that they would not use it again. I conclude that overall the experience was positive for the large majority of students.

Anecdotal Evidence

Many students indicated that they really liked using EWB to support the class activities. In addition to using EWB to provide rapid feedback when doing homework problems, they liked being able to do "what-if" experiments on their own, and thought that simulations helped them to better integrate the material. One student jotted a comment in the margin of a homework problem that "it's always comforting to see the EWB results match your answer."

Summary

Electronics Workbench (EWB) and laptop computers were used to create a "lab in a laptop" to support an introductory circuits course. EWB's intuitive drag-and-drop user interface allowed the students to rapidly become productive with circuit simulation as a means to experience circuit behavior and to provide feedback during homework. Self-assessment results from an end-of-term survey showed that EWB was most effective at helping students to better understand how circuit devices work, and in-class use of EWB helped them to better understand concepts as they are presented. Students liked being able to use the simulator to verify their homework solutions and to experiment with "what-if" situations on their own.

References

1) Richards, Donald E. "Developing a Sophomore Engineering Curriculum - The Rose-Hulman Experience," *Proceedings Frontiers in Education 95*, D. Budny and R. Herrick, eds., p. 2b61.