Abort, Retry, Ignore – Electrical Engineering for Non-Engineers

Multimedia Session 2793

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Abstract - Electrical Engineering 2300 is a required course for certain undergraduate and graduate computer science students at Lamar University. This course for non-engineering majors covers a broad range of topics, including electrical energy, analog circuits, combinational logic, and digital circuits. Teaching a survey course in electrical engineering to a class with no prerequisite engineering knowledge except introductory calculus poses a considerable challenge for the instructor. What is the objective of such a course? Where does one begin? How can the material be condensed into twenty-five 50-minute lectures? Why should a non-engineer want to acquire this knowledge? Because engineering is much more than book learning, theory is reinforced by laboratory exercises in circuits and digital electronics. Typically, the students have no prior hands-on laboratory experience. The laboratory component seeks to meld the familiar (computer simulation) with the novel (hands-on synthesis and analysis) and relate each activity to current lecture material. Course exams lean heavily toward the practical application of skills, such as using technical data sheets. At its best, this course brings a real-world perspective to the future computer science professional and aids the development of problem solving skills. This paper presents a brief synopsis of the course, lessons learned by a new instructor, and recommendations for developing similar courses.

Introduction

The novice instructor was about to tackle her first semester teaching electrical engineering to undergraduates.

> "ELEN 2300: Analog & Digital Logic Circuits. Credits 3. For non-EE majors, this course covers a broad range of analog and digital circuits. Prerequisite: Calculus I."

It didn't seem so bad. The framework offered broad latitude for instructor discretion.

> "GOALS: Successive knowledge development leading to the understanding of basic computer architecture, including basic analog and digital logic circuits, number systems, memory devices, various building blocks of a computer, and interfacing real-world inputs/outputs to the computer."

Computer architecture? In a one-semester course for non-majors?

> "Prerequisites by topic:
> Physics
> Complex variables
> Basic computer skills"

What had I gotten myself into?

First, don't panic. As a novice instructor, I had the advantage of not knowing that I was in deep trouble, so I entered the classroom each day with confidence. Furthermore, the other professors were so glad not to be teaching ELEN 2300 that they wouldn't criticize any scheme or device that seemed to work for this course. My dual task, I would soon learn, was to teach the course while developing a successful strategy for doing so.

Know The Students

"My name is Monica Mallini-Rourke, and I am your instructor for ELEN 2300," I greeted my eight students on Monday morning. They were undergraduate computer science majors, a bit apprehensive about entering the world of electrons and hardware for the first time. All had fulfilled the prerequisite semester of calculus (except one who slipped through taking it concurrently, and this proved to be a major problem later). Most of the students had no prior hands-on laboratory experience. I passed out a newly revised syllabus, faithful to the previous instructor's model, and explained to the students that the course would culminate with the class building one or more computers during our final laboratory sessions. How would we accomplish that? "By successive knowledge development leading to the understanding of basic computer architecture," just as the catalog explained. Mrs. Rourke would guide her students through a survey of electrical engineering theory and practice, and the department would gain rebuilt computers as a result. So we began, and soon we were deep into basic electricity and vector algebra, prerequisite material for the study of electrical engineering.

A week later, I greeted eighteen students in the Monday morning lecture. The final class roster had not been published. I turned around to write review notes on the board and in privacy contemplated the surge in class population. Was I in the wrong class? Did I bring the wrong lecture notes? No, it was 9am Monday. I had prepared course materials and laboratory exercises for 8-10 students, and the computer science department had sent me ten more students, graduates and undergraduates. Unknown to me at the time, the department had tested some of its students, and those who seemed to be in need of remedial instruction were counseled to enroll in Electrical Engineering 2300 immediately. After the first exam, the students' level of skill—it was distressingly low—became apparent. The average grade was 71, which, in my judgment, was about 10 points too low for the introductory material tested. My class was populated with students who were not comfortable with the subject matter and who needed a firm foundation, much repetition, and a patient teacher. The course needed major changes to fulfill its purpose of serving the computer science students.

Re-inventing the Light Bulb

> "GOALS: Successive knowledge development leading to the understanding of ~~basic computer architecture, including~~ basic analog and digital ~~logic~~ circuits, number systems, combinational logic, Boolean Algebra, memory devices, and various building blocks of a computer. ~~and interfacing real-world inputs/outputs to the computer.~~"

ELEN 2300 was originally conceived as a fast-paced course for ambitious students who, but for a deeper love of coding, might have been electrical engineers. My students had an aptitude for computer science and no desire to pursue electrical engineering beyond getting through ELEN 2300, which was required for them to graduate. The course was unappealing because it targeted the wrong audience ("junior electrical engineers," rather than non-majors) and made unrealistic demands of the students by emphasizing depth as well as breadth. Radical changes in the philosophy and delivery of the course were needed.

I presumed that the purpose of ELEN 2300 was to help students learn basic problem solving skills and to give them a broad background in the theory and application of electrotechnology. Furthermore, the student should gain an appreciation for, and perhaps a mild working knowledge of the digital computer. Most important, this self-contained, terminal course in electrical engineering should teach future computer programmers about the capabilities and limitations of the hardware and circuits that will implement their programs. With this in mind, I adjusted the pace of the course, increased repetition, devoted more class time to review, and called upon "real life" examples frequently. The course schedule, shown in Table 1, was modified to establish a firm foundation, for instance with a discussion of basic electricity.

Because engineering is much more than book learning, theory is reinforced by laboratory exercises and simulations of analog circuits and digital electronic circuits. However, the synergy between lecture and laboratory is particularly strong in this non-majors course. In a course for electrical engineering majors, skills such as using a voltmeter, reading a logic diagram, understanding pin assignments, and wiring a circuit are prerequisite to performing the laboratory exercises. ELEN 2300 differs markedly in that these simple skills are a major course objective. Therefore, lecture material should reinforce the laboratory sessions. For instance, a lecture series on binary addition discusses operation and applications of adder circuits. In the laboratory, students use adder chips in circuits and verify their circuits by checking results with manual binary addition. Once the students are familiar with the use of circuits on chips, a lecture about sequential logic (with an emphasis on applications) can show students how to implement a circuit with a counter chip. Later, students will build such a circuit in the laboratory. Knowledge gained in the classroom is directly applied in the lab, and lab skills are used during lectures. Exams test both types of knowledge, for instance, by asking students to show how to "wire" a chip, as in Figure 1.

A Recipe for Success

Students are introduced to a new topic in lecture, starting with any necessary background in mathematics or physics, and leading through elementary concepts. Explanation of how the concepts relate to "real life" helps the students understand why they are studying this. A "practice" is assigned, one or two simple problems on a worksheet distributed at the end of class. The next lecture begins with a brief review, and then students are called to the blackboard to work a practice problem, with the instructor's guidance. After the blackboard work, a second handout provides detailed solutions. A collection of these handouts are valuable study guides.

In the laboratory, a circuit selected to demonstrate a particular concept is analyzed mathematically, synthesized physically, and implemented with simulation software. Three

Week	Lectures	Laboratory Exercise
1	Electricity, vector algebra	Micro-Cap software tutorial
2	Energy and power, Ohm's law	Ohm's law
3	DC circuits, Kirchhoff's laws	Kirchhoff's voltage law
4	Review and Exam	
5	Sinusoidal sources, passive elements	AC sources
6	Analog and digital signals, number systems	RC filter
7	Non-ideal waveforms, timing, data transfer	Digital waveforms
8	Boolean algebra, logic gates, binary arithmetic	Digital logic
9	Review and Exam	
10	Combinational logic, digital circuits, adders	4-bit binary adder
11	Comparators, decoders	7-segment decoder
12	Multiplexers, sequential logic	S-R latch
13	Latches, flip-flops, sequential logic applications	Gray code counter
14	Review and Exam	
15	Review and Final Exam	

Table 1. – Semester Schedule for Electrical Engineering 2300.

results—calculated, measured, and simulated—should be consistent. Students experience the same circuit three different ways, which I imagine they perceived as (respectively) mundane, novel, and familiar. The lab exercise reinforces lecture material and proficiency in "real world" aspects of electrical engineering. For instance, in order to build even the simplest digital circuit, students must learn to use manufacturers' technical data sheets for the logic circuit chips. Also, the use of actual measured values in place of nominal values yields different calculation results. This observation leads some students to question why this is the case, and for them, the laboratory exercise leads to discussions and a deeper understanding of the phenomenon.

Course exams lean heavily toward the practical application of skills, such as using technical data sheets. For instance, students are given a picture of a chip and asked to draw lines representing wires, in the correct configuration to build a circuit to implement a given logic scheme. Technical data sheets are provided with the exam. A typical exam problem is shown in Figure 1. To correctly answer the problem, the student must use higher-order thinking skills to analyze the data, design a solution with given components, and interpret detailed technical information to determine the correct wiring scheme. Generally, there is more than one correct solution, so the problem allows some latitude for students' individual style and imagination. By this instructor's observations, students who take an active role in the laboratory exercises score an average of 13 points higher on exams than the more passive lab partners. Lab is an important component of the course, and the skills gained therein are a major part of each student's grade.

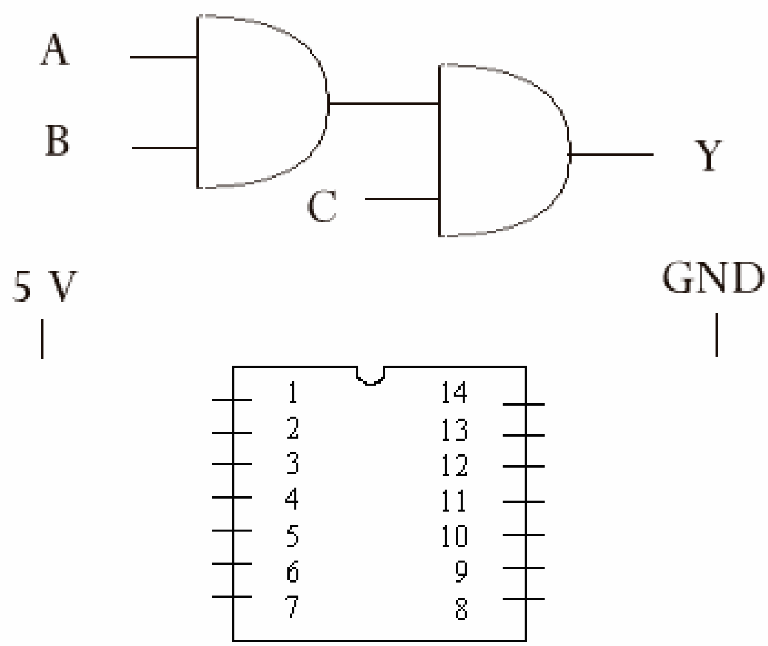

Figure 1. – Exam problem: "Using the manufacturer's technical data sheet provided, draw connector wires to the 7411 chip to implement the circuit shown."

Some Words about the Laboratory

Based on the experience of teaching ELEN 2300, I advocate providing separate laboratory instruments, components and supplies for lab courses for non-majors. Lack of separate laboratory facilities for the non-major courses lends the impression that the courses are an afterthought. The less experienced students work better with equipment, supplies, and procedures that are well organized and streamlined. Separate equipment and components specifically selected for the non-major lab exercises leads to better class preparation. It also discourages the situation of novice students finding burned-out components for their introductory labs and the situation of advanced students finding burned-out components for their design projects.

In the beginning of the course, my attempt to model the laboratory component after other engineering labs that I have taught resulted in much frustration for students and instructors. In this terminal course, students without prior lab experience do not seek to become laboratory experts. A laboratory for non-majors is not conducted the same way as a lab for electrical engineering students; accordingly, the following suggestions will help create the best possible learning experience in the lab:

- Prepare a lab assignment sheet clearly stating the objectives and detailed procedures.
- Limit the assignment to one, or at most, two simple tasks.
- Devote early lab periods exclusively to circuit simulation software exercises.
- Maintain a low student-to-instructor ratio, so that the teams will not be idle waiting for help.
- Encourage teams of two students. A partner is important to help work through difficulties, but more than two students per group prevents each from getting a fair share of the hands-on work.
- Communicate lab policies and due dates clearly and repetitiously.

The laboratory is an important part of this course, which emphasizes practical applications of concepts learned. There is still much room for improvement in course delivery, as explained in the following section.

Courseware

Repetition of concepts through multiple media cannot be emphasized enough. In addition to opening lectures with review, assigning a daily "practice," working through the problem in class, studying an applicable circuit in the laboratory, what else is there? Students were required to simulate and analyze laboratory circuits with Micro-Cap 6 software. This circuit simulation and analysis software package was selected because it offered a large component library, was simple to learn and use, and was available to students as an evaluation package, downloadable from the distributor's web site. The computer science students seemed comfortable with this aspect of the course, and it provided a good method for students to prepare for the physical laboratory. Some students worked beyond the course requirements in the simulation exercises.

The author believes that true multimedia courseware would be an effective means of enhancing instruction and learning in this course. Circuit simulation software is a starting point, but there is potential for improving the student's experience by using multimedia courseware modules. Further curriculum development should include migrating the department-issued laboratory manual to a CD-ROM format. This volume should include expanded tutorials, interactive exercises, and course hand-outs, distributed with circuit simulation software in a single integrated package. Such modules would extend the lesson beyond the lab and reinforce the link with lecture topics.

Conclusion

Electrical engineering for non-majors is not a watered-down version of courses required for engineering majors. Teaching a survey course in electrical engineering to a class with no prerequisite engineering knowledge except introductory calculus poses a considerable challenge for the instructor. The key to success in such a course is a strong laboratory component, which melds the familiar (computer simulation) with the novel (hands-on synthesis and analysis) and relates each activity to current lecture material. The future introduction of multimedia courseware will likely strengthen the synergy between theory and practice and stimulate students' interest in the course. At its best, this course brings a real-world perspective to the future computer science professional and aids the development of problem solving skills.

Postscript

The catalog description now reads,

"ELEN 2300: Analog/Digital Circuits and Logic. Credits: 3. Designed for non-electrical engineering majors. The course covers a broad range of analog and digital electrical engineering topics and is intended as an orientation and familiarization course as opposed to in-depth training for electrical engineering majors. The course is intended principally for Computer Science majors seeking familiarity with the hardware concepts associated with their career."

References

[1] Rainbow Software, distributor of Micro-Cap analog/digital electronic circuit analysis software. http://www.micro-cap.co.uk/.