Enhancement of an Introductory Computing Course with Experiential and Cooperative Learning

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Abstract

For the past seventeen years the University of Wyoming College of Engineering has had a freshman level computing and problem solving course in which freshmen were introduced problem solving strategies and computing to support those strategies. Several years ago it was observed that interest in the course could be increased if some physically based exercises could be introduced in the laboratory to give hands-on work done in the cooperative learning setting. The work reported here is the initial efforts toward implementation of those concepts.

1. Introduction

In addition to the usual calculus, chemistry, and English, first-year engineering students traditionally take an engineering course that focuses on technical subjects. For most of the last century, this first-year engineering course involved graphics, descriptive geometry and slide rule operation. Over the last two or three decades, graphics courses have largely been replaced by an offering that involves computing; however, there is no standard course content.

Goals for a first engineering course have been the subject of much discourse. Common themes for a first year course include aspects of appreciating engineering, participating in design projects, learning engineering problem-solving methodology, developing skill in computer programming, becoming familiar with various computer applications, and fostering teamwork in engineering contexts.

Several driving forces are responsible for these themes. NSF Engineering Coalitions[1] have sought to implement a new engineering paradigm characterized by active, project based learning; horizontal and vertical integration of subject matter; and the introduction of mathematical and scientific concepts in the context of application. Multiple reports[2, 3, 4] have recommended direct experience with the methods and processes of inquiry and with multidisciplinary curricula combined with effective pedagogical practices such as collaborative, active learning accounting for the varied learning styles of students.

New ABET accreditation criteria[5] identify student characteristics or attributes that institutions must address. Among the criteria are the abilities to design and conduct experiments as well as to interpret the data, to function on multidisciplinary teams, to identify, formulate and solve engineering problems, and a knowledge of and skill in the use of modern engineering tools.

Following national trends, we are enhancing our first-year introduction to computing and problem-solving course with experiential (hands-on) and cooperative components. Aided by support from the CCLI Program of NSF, course components are being developed to more actively engage students in exploring fundamental engineering principles and developing problem solving skills.

2. Background

Ten years ago, a course entitled Introduction to Engineering Computing was launched, which replaced a required course in FORTRAN programming. Based on the work of a faculty committee, the course was designed to introduce the basic productivity applications of spreadsheets, equation solvers, word processing, and graphics. Topics deemed useful include a discussion of units and dimensions, elementary statistics, curve fitting, engineering economics, and topics that lend to a treatment via the “engineering” problem-solving method. The course features applications that can be solved by hand and then by computer. As an example, data can be plotted by hand with a fitting derived by the method of selected points. Subsequently, the data can be plotted in a spreadsheet, using built-in curve fitting routines. The topics of material balance and elementary dc circuits support problem- solving methodology where students are expected to define the problem, supply a diagram, write equations based on the diagram, and to use selected software to solve the equations. In these contexts, the equations are most often a system of three or more simultaneous equations, linear in the case of circuits, and possibly nonlinear in the case of material balance problems.

At the implementation of the new course in 1991, the retention of engineering students between the freshman and sophomore years increased over 10% an increase that has subsequently been sustained. The addition of the active learning components is expected to produce an even further increase in the retention of engineering students.

The ten-year period has witnessed a marked improvement in students’ preparation in computer use. Word processing now requires very little attention, although formatting equations must be covered. Typical high school preparation in spreadsheet use is now adequate enough to proceed quickly to topics in statistics, curve fitting, and equation solvers. While computer graphics preparation ranges from nothing to two or three years of CAD, this has little bearing on the presentation graphics in our course.

At the same time incoming students seem to have less facility with the physical world. We find, for example, that few students are familiar with the use of a multimeter to measure voltage, resistance, or current. The increased computer understanding also comes with the loss of teaming skills that were developed through informal sharing of high school science laboratory equipment.

3. Course Enhancements

A recent grant from the NSF supports course modifications to actively engage students in classroom activities and the addition of cooperative learning techniques. The main idea is simple: Replace canned data with relevant physical data gathered by students. We are now in the process of developing laboratory exercises to include experiential components and have focused on topics in dc circuits for the first implementations. As a first step to support these hands-on activities, we have acquired an auto-ranging digital multimeter for each student.

3.1 Statistics of Central Tendency and Normal Probability Distribution

Prior to Fall 2000, a data file containing hundreds of numbers representing a physical quantity such as the diameter of parts produced by an automatic lathe would be provided on the server. The students are expected to (1) determine central tendency statistics such as mean and standard deviation, (2) sort the data to build a histogram, and (3) compare the data with a normal probability distribution curve. All these statistical procedures are easily accessed as built-in tools in Excel.

One of our new experiments involves batches of 500-1000 resistors all having the same nominal resistance. Students divide into small teams (two works well) measuring the resistances and entering the values into a file on the server. When the teams are finished, files are shared via the server and the accumulated data is used for the statistical analyses.

Interesting team interactions occur in the classes. In one case, all of the resistance values reported by one team were somewhat lower than the rest. Upon investigation, it was discovered that the person doing the measurements was holding the resistor in his hands, effectively adding the resistance of his body in parallel with that of the resistor.

3.2 Linear Regression Analysis

Circuit boards with a dry cell connected to a flashlight bulb in series with a potentiometer are provided to each of the teams of two or three students. Two multimeters afford the simultaneous measurement of current and voltage. As the students have not yet studied the material on dc circuits, they are instructed how to hook up the meters. Approximately ten values of current and voltage are recorded and analyzed with Excel. As shown in Fig. 1, linear regression is best for the battery and polynomial regression is best for the bulb.

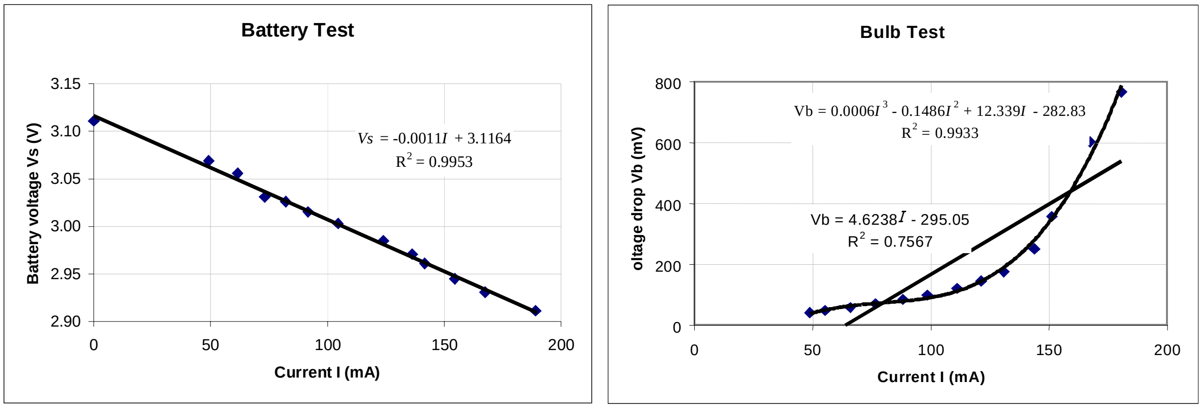

Figure 1. Typical Results Generated for Regression.

Later on, when covering the material on dc circuits, we point out that the slope of the current-voltage curve for the battery represents the internal resistance of the battery.

3.3 Series and Parallel Resistors

A board with eight separate resistors having values that differ over a small range is provided to students. Each resistor has terminals at its ends. The small teams are asked first to measure the value of each resistance. Next, they are to verify that the eight resistors connected in series, and then in parallel, provide a total resistance consistent with theory. Finally, students are asked to connect a circuit, such as the one in Fig. 2. The problem is posed to calculate resistances between specified nodes, with the results being compared by ohmmeter measurement.

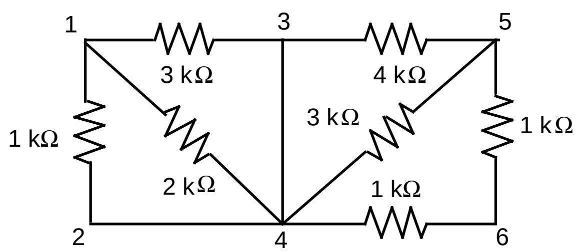

Figure 2. Circuit for Resistance Combination.

As an aside, it is an interesting challenge to make the connections for the circuit shown. Students are encouraged to share strategies for doing this.

3.4 Kirchhoff's Law Verification

A board with two loops, Fig. 3, is provided for students to compare the calculated loop currents with measured ones. While the concept of the internal resistance of the battery was subliminally introduced in a lab involving curve fitting, students are asked to figure out how to get R_{int} in this example.

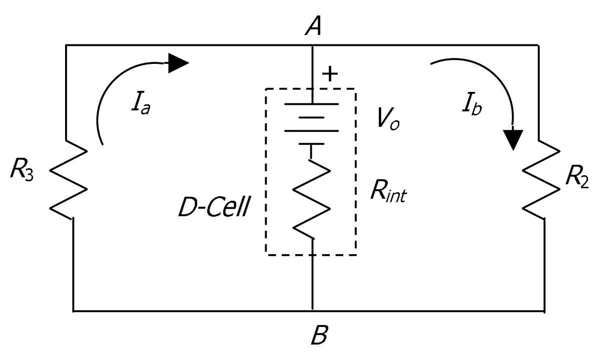

Figure 3. Kirchhoff's Law Board.

3.5 Maximum Power Transfer

An interesting application for an equation solver involves the concept of maximum power transfer to a load. The circuit of Fig. 4 involves a single AA cell, three fixed resistors, and a potentiometer that serves as a variable load. Students are asked to formulate a mesh equation model including an equation for the power in the load. This model is then entered into the equation solver and solved for a list of load resistances, in order to determine the load resistance that produces maximum power dissipation in the load. The students also make measurements of the fixed resistances, the load resistance and load voltage to calculate power as the load is varied. Experimental and computed results compare favorably so students gain confidence in the modeling process.

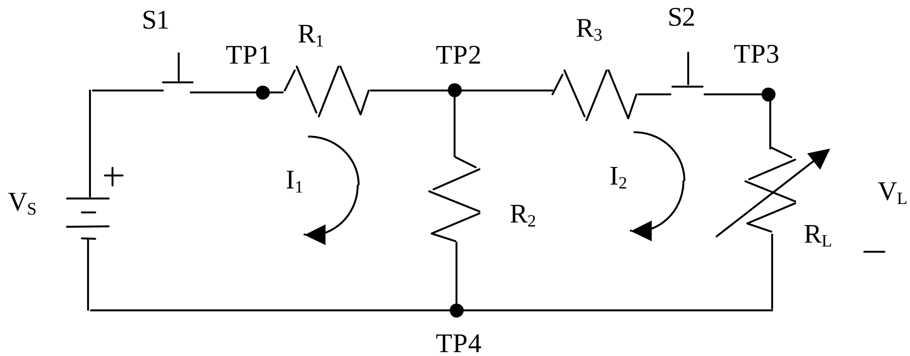

Figure 4. Board for Maximum Power Transfer Experiment

4. Future Projects

Projects in other areas of engineering, which contribute significantly to the experiential portion of the course, will be added to the course. The concept of variation in manufactured products can be illustrated by making measurements on machine parts (washers, nuts, bolts) or by making temperature measurements. A component involving material balance is planned as well. In order to devise an experiment that will not require a “wet” lab, a potential project will involve the use of colored plastic beads of different colors and different sizes. The composition of the mixture can be assessed automatically by application of Photoshop and the beads can be automatically sorted.

5. Discussion

Although the concept of students working together in labs is as old as engineering education itself, it is still quite effective. The change from individuals working at computers in isolation to working cooperatively to collect data, has spurred open communication in the classroom.

Prior to Fall 2000, the topic of dc circuits in this course was unpopular with students. Probably due to a lack of prior exposure to electrical concepts, the students were uncomfortable with the abstract concept of a phenomenon that cannot be seen, but can be observed by instruments. By measuring voltage, current, and resistance several times in several experiments during the semester, the students develop a deeper understanding of the circuits material. The team of instructors that taught this course Fall 2000 agrees that students did much better on the block involving dc circuits.

Details on the experiments are available from the authors on request.

6. Acknowledgment

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