AC 2011-1127: LABORATORY PROJECTS APPROPRIATE FOR NON-ENGINEERS AND INTRODUCTION TO ENGINEERING

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Abstract

Many engineering programs are facing unfamiliar challenges in the area of curriculum development and course offerings. Some engineering departments are working with a new constituency of students through newly offered courses on engineering and technological topics for non-engineering students. At the same time increased emphasis has been directed to the importance of a high quality first year engineering experience. Both of these changes have been motivated by several factors including calls for improved undergraduate education and increased technological literacy for all students. Another unfamiliar challenge is the increasing need for engineering departments to maintain stable levels of enrollment. Two year or community colleges are faced with additional demands to maintain an affordable and academically appropriate gateway into higher education and a viable means of transferring into four year programs. In achieving an effective engineering course, laboratory projects are universally identified as a key component. However creating and operating laboratories for large enrollment classes is a demanding task especially in the community college environment. To address these needs, this work investigates the feasibility of developing and shipping self-contained laboratories in a box. This will allow institutions to borrow, rent, or lease rather than own the equipment. The laboratories are intended to be completely self-contained so that all materials arrive in a single box in ready-to-use condition. This will minimize the preparation time for instructors. These laboratories are suitable for use in either introduction to engineering courses or courses on engineering topics for non-engineers. The laboratories attempt to utilize insights from non-engineering students to determine themes that help to make the laboratories appealing to both non-engineers and those students who have self-selected into engineering. Key themes include using material that focuses on technology familiar to the students in their everyday life, use of extensive verbal and graphical explanations, and inclusions of practical information that helps to establish a sense of empowerment regarding technology. Eight laboratory projects are being created and tested in both two or four year schools. Results will be presented from work done during the 2009-2010 academic year.

Introduction

The National Academy of Engineering has advocated that all Americans must develop a better understanding of the technology upon which our modern standard of living depends. This includes all types of technology and the products of the various engineering professions, not just computers and information technology.[1] While not yet common, some engineering departments offer service courses for non-engineers.[2-14] Many of these technological literacy courses have become successful when measured by sustained student interest and long-term sustainability.[2-14]

Initially it may appear that these engineering courses for non-engineers have little relation to the curriculum for an engineering degree. However, in attempting to enliven introduction to engineering courses, these successful technological literacy courses represent a potential source of themes or topics that capture the interest of undergraduate students.

Efforts to attract students to an engineering career must acknowledge that two-year institutions or community colleges represent the fastest growing segment of higher education.[15] Recent data shows that 40% of individuals earning bachelor or master's engineering degrees started higher education in a community college. The trend is higher in some states such as California for which more than 48% of graduates with science or engineering degrees started at a community college.[16]

Despite this contribution to the nation's engineering workforce, engineering education in a community college environment presents formidable challenges for both students and instructors. Most community colleges have small engineering programs with only a few faculty, often only one or two. Each instructor has high teaching loads of four or more courses per semester. Faculty have little time for course or laboratory development. There is limited laboratory support staff and budgets to buy and maintain equipment. While many community colleges exist, the relentless teaching demands on the faculty and geographic separation tend to result in community college engineering faculty working in a state of relative isolation. Any effort to attract students into engineering careers and promote technological literacy for non-engineers through community colleges must contend with these challenges.

Topics Cited as Appealing by Non-Engineering Students

Engineering faculty teaching technological literacy courses for non-engineers [2,3,17-19] have reported particular topics or themes that have been found to attract and retain the interest of the non-engineering student. A summary of these findings is listed in Table 1.

Table 1: Technological Themes Identified as Important to Non-Engineering Students.

Topics related to familiar technological devices
Development of practical applications and skills
Meaningful hands-on experiences with technology
Avoidance of over reliance on mathematical explanations
Developing an empowered relationship with technology

In learning engineering or technological topics, non-engineers place a high value on knowledge relevant to familiar technological devices, seek practical applications and skills, and aspire to a sense of empowerment in their relationship with technology. The non-engineering students enrolled in a general education engineering course have been found to identify relevance as an important characteristic of course topics and materials. This is consistent with the sense of immediacy or application that is characteristic of adult learners.[20]

Non-engineering students are interested in developing an understanding of technological principles. However, mathematical explanations are not generally effective with this group. Explanations of the underlying principles should make use of verbal descriptions, graphics, and other visual aids. This is consistent with the methods used in the popular “How Stuff Works” website[21], and a popular physics textbook developed for non-science students.[22]

Topics and themes from general education engineering courses may also prove successful in enlivening introductory engineering courses. The students who have self-selected as engineering majors may have many interests in common with their non-engineer peers. These non-engineering students may have inadvertently identified the most intriguing aspects of engineering.

Laboratory Development Process

Work is underway to create eight portable laboratory projects that meet the criteria outlined in Table 1. These projects are intended for use in a class for non-engineering students or for introduction to engineering. Pilot testing is taking place in both two-year and four-year institutions. This is intended to help establish the suitability of these projects across a range of academic environments. An initial stage of this work was reported earlier.[23,24] To address the problem of obtaining equipment, the projects can be completely contained in a box of 20-100 pounds and can be shared between schools or potentially obtained from a commercial supplier.

In addition to the criteria for project themes listed in Table 1, the projects will be developed to meet the characteristics outlined in Table 2. The overall goal is that each project results in a working device that the individual student can keep and take home. To meet the take-home characteristic each project must be relatively inexpensive. An overall average of five US dollars per project was established as a target. This would allow all eight intended projects to be completed for under fifty dollars. This was selected as a typical laboratory fee that might be charged to students taking a laboratory course. To facilitate use by a variety of faculty in two and four year engineering departments, the project should not require special facilities or expertise on the part of the instructor. All projects should require only common tools and readily available materials. Similarly the completed projects should be durable and robust and not demand sensitive tuning or delicate adjustments to function properly. A focus on particularly significant or core technologies was seen as important both for engaging student interest and insuring that most engineering faculty would be able to conduct the laboratory.

Table 2: Laboratory Project Characteristics

Each student takes his/her completed device home
Average cost of 5 US dollars each
No special parts - only simple commonly available components
No special facilities - construction requires only common tools
Focus on core technology - devices students have used themselves
Robust designs – not fragile & no excessive fine tuning
Can be taught by faculty from any engineering discipline
Devices should satisfy a human need or want

Laboratory Projects Under Development

Book light

In this project students construct a clip-on book light using a LED light. This is a basic series circuit with a switch, LED, and battery. Materials also include a large binder clip, and a section of tubing to serve as the neck of the clip-on book light. Samples of complete projects are shown in Figure 1. The project allows for creative embellishments and decorations of the final project. Many students respond positively to this creative aspect of the project.

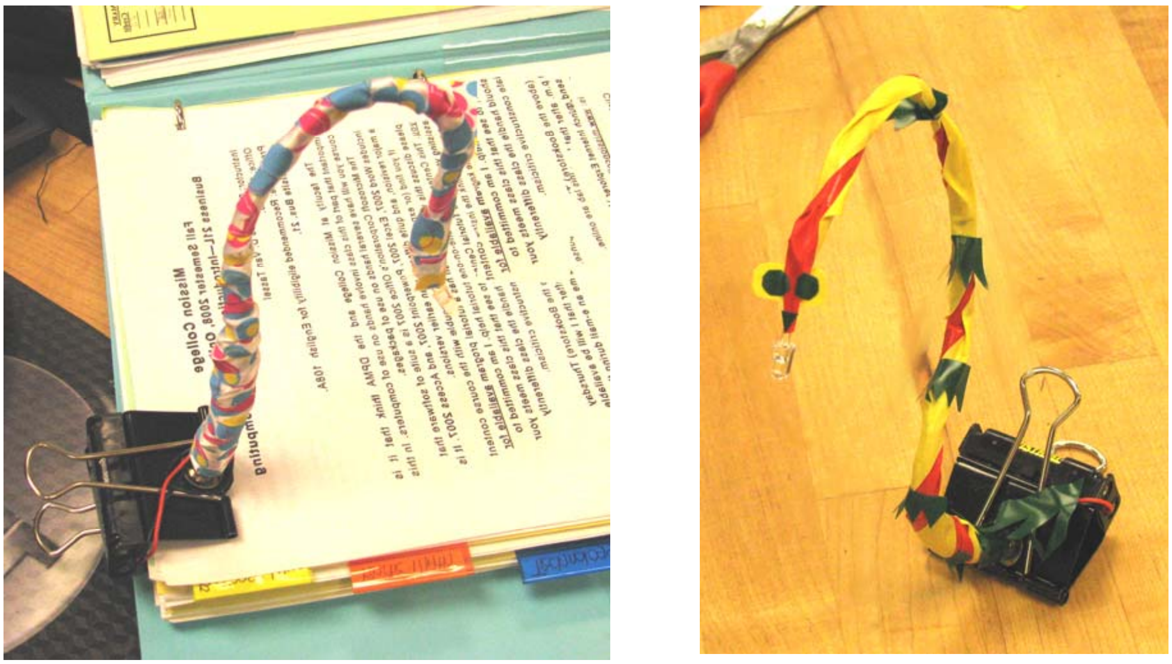

Figure 1: Examples of LED Book lights Constructed by Students

Electric Motor

In this activity, a simple DC electric motor is assembled from basic components. The project avoids any prefabricated parts and uses only general purpose materials and common hardware. Components include: wire, cork, bamboo skewer, brass strips, bolts, and a plastic tray. Construction requires that students wind the field and armature coils and assemble the component parts. Students keep the completed motors. A gearbox is constructed and used to measure output power and torque. The motor is shown in Figure 2.

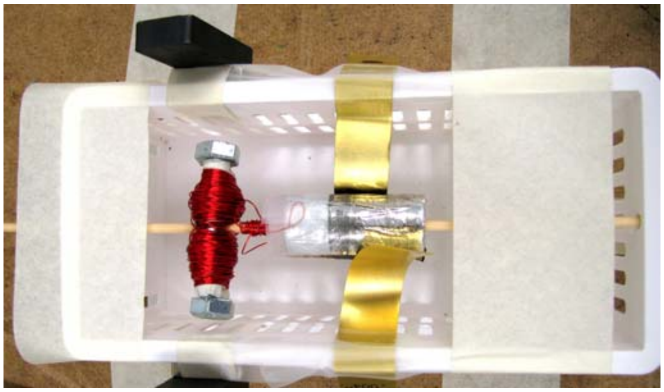

Figure 2: Electric Motor Made from Simple Components Producing Usable Torque.

Speaker

A simple loudspeaker has been developed that is made from a plastic drinking cup. The speaker has 8 ohms impedance and is compatible with typical consumer audio equipment. Despite the simplicity, the speaker produces a loud, clear sound and is capable of reaching 90 dB. The design is deliberately simple. The intent is to draw attention to the major functional components of the speaker. The only specialized component used is a standard audio speaker compression terminal to facilitate interconnection with consumer audio devices. Figure 3 shows a view of this speaker. With this simple design the speaker can be constructed in less than one hour. The only tools required are a pair of scissors. However a glue gun is a helpful option. Figure 3 also shows speakers being built at a two-year college in a laboratory with very limited table space.

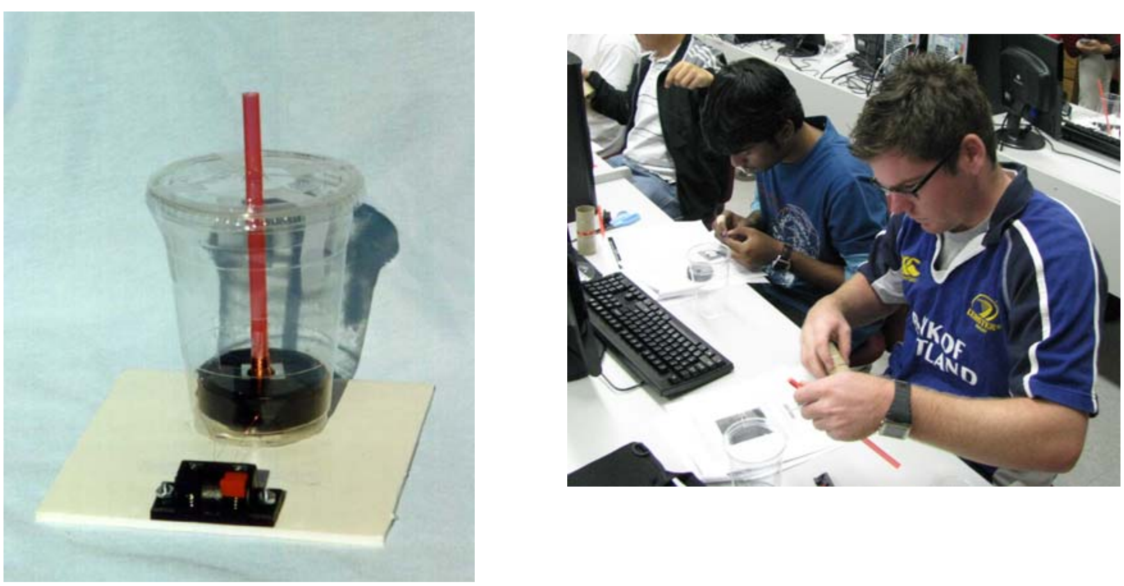

Figure 3: Electrodynamic Loudspeaker Constructed from a Plastic Cup.

Simple Radio

A variation on the well-known AM crystal radio has been developed. This radio is built from a coil wound around a common cardboard tube. Other than wire, the only components are a germanium diode and earphone. The design is extremely simple, but is also easy to construct and has been found to receive commercial AM broadcasts very well. Students keep the radios when they are done. A key principle conveyed is an understanding that electromagnetic waves actually carry energy as the radio produces audible sound without the aid of a battery or amplifier.

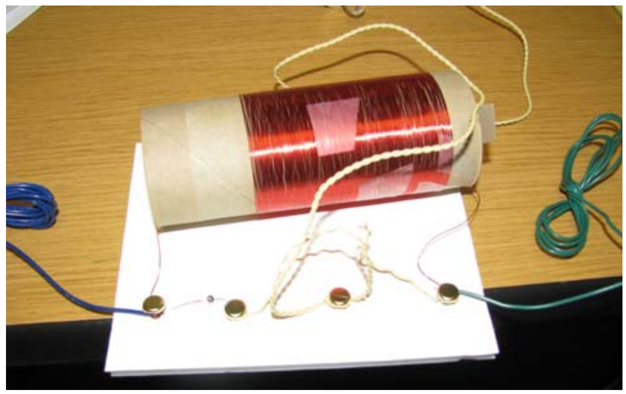

Figure 4: Modified Classic Crystal Radio and Students Testing Working Radios.

Amplifier

The transistor and the integrated circuit are routinely cited as among the most important inventions of the twentieth century. To help the students appreciate these devices, an amplifier project has been developed. In this project the use of simple components has been relaxed slightly to create a project of superior performance. Students construct an amplifier that uses a single transistor as a preamplifier and an integrated circuit power amplifier. With this device students are able to amplify the output of the crystal radio sufficiently to drive the homemade speaker.

Two versions of this project have been developed. One uses a custom-designed printed circuit board. The other versions uses a solderless breadboard. In either case students do all of the assembly and keep the completed device. In the solderless breadboard version no custom-designed parts are needed. Using the amplifier it is possible to listen to a personal MP3 player using the simple loudspeaker. Figure 5 shows the soldered circuit board version of the amplifier.

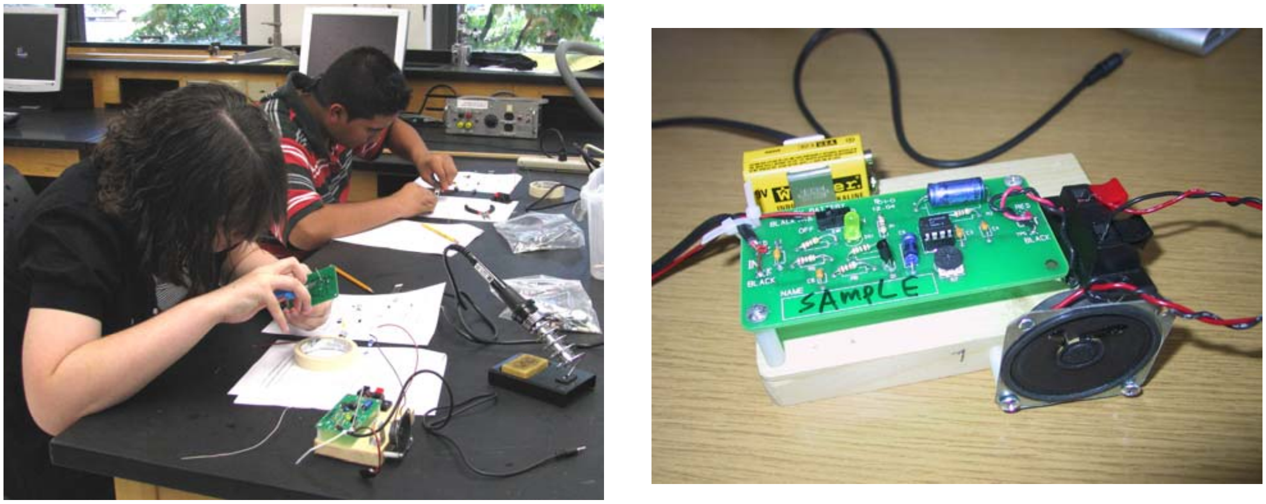

Figure 5: Audio Amplifiers under Construction by Students and Final Product

Photovoltaic Battery Charger

There is a high degree of interest in alternative energy among both engineering and non-engineering students. To support this interest a project using photovoltaics was developed. In this case thin-film photovoltaic cells are used to recharge two AA NiMH batteries. The device is intended to be used outdoors but will operate acceptably well using a 200 W (equivalent) compact fluorescent light. The device is amenable to having the students carry out a variety of measurements of current, voltage, and power. The photovoltaic project is shown in Figure 6.

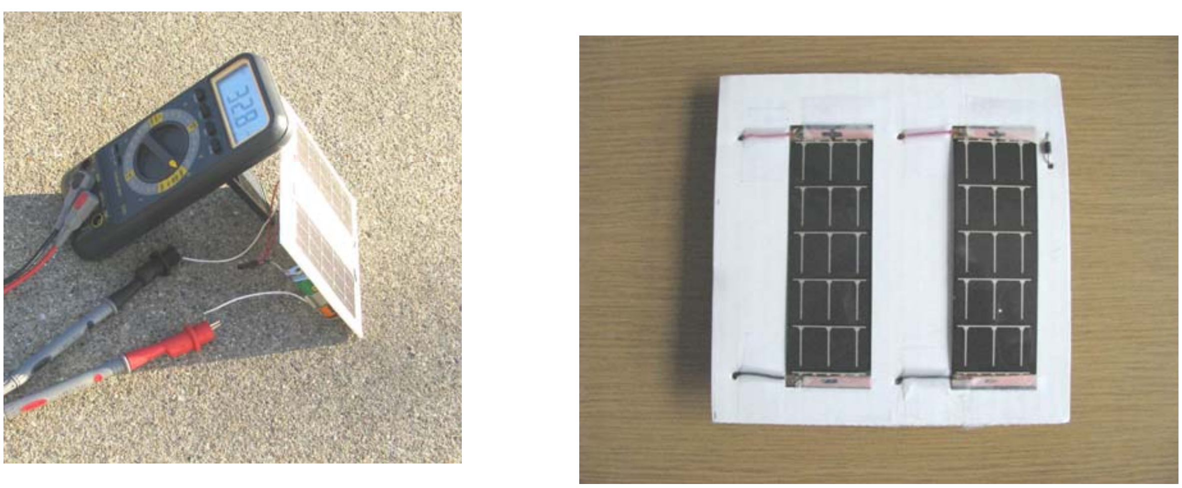

Figure 6: Photovoltaic Battery Charger Tested Indoors with a Compact Fluorescent Light.

Evaluation Methods

Evaluation is based on tests of student content knowledge before and after the laboratory. Student surveys about various aspects of the laboratory are also part of the evaluation process. Preliminary student data is currently available for four of the laboratories.

Content tests were based on the underlying principles involved as well as how the device works. The "how it works" questions addressed specific components in the device and the purpose or function of those components in the device operation.

Available content test results are summarized in Table 3. The content tests are based on a scale of 0 – 100 points, with 100 points being a perfect score. The result reported in the pre and post test for each laboratory is the average score of the students tested. All post-tests show statistically significant improvements over the pre-test scores ($p < 0.05$). For most of the laboratory projects, the average for the post-test is close to double the pre-test average.

Table 3: Subject Matter Content Test Pre and Post Laboratory Results.

Subject Content Tests	PreTest (max = 100)	Post - Test (max = 100)	Percent Change
LED Booklight	36	66	83%
Electric Motor	44	71	61%
Speaker	27	80	196%
Radio	62	84	35%
Average	**42**	**75**	**94%**

Also reported is an overall average for the entire set of four laboratory projects. This gives an approximate estimate of the effectiveness of the laboratory projects as a group. The pre-test average is 42 out of 100. This might be interpreted as a poor understanding of technology (technologically illiterate). The post-test overall average is 75 out of 100. This is a substantial improvement in content knowledge across these four areas. As a group the students could be considered to have improved from "failing" to understand technology to a "fair" degree of understanding.

Students were also surveyed about their opinion of the laboratory projects. The available results for four laboratories are summarized in Table 4. The questions were based on a 0 to 5 point scale with 1 being "strongly disagree" and 5 being "strongly agree." The students were asked to rate the laboratory as interesting, educationally useful, and whether or not they feel more competent about the course material as a result of the particular laboratory project.

The non-engineering students found all of the projects interesting. Results ranged from 4.6 to 4.9 on a 5.0 scale. The students also gave the projects high ratings in terms of being educationally useful. The four projects had an average rating of 4.5 on the 5.0 scale. The student rating was slightly lower for the question that asked students if they felt more competent about the course material after having completed the lab. It may be that students are more confident in assessing what interests them compared to estimating their degree of mastery of the course materials. Overall the laboratory projects were well-received by the students.

Table 4: Result of Student Evaluations of Laboratory Projects (1 – 5 point scale)

Average Student Rating (1-5 scale) 5.0 = highest	**Interesting**	**Educationally Useful**	**Improved My Competence in Course Material**
LED Book light	4.9	4.5	3.9
DC Motor	4.6	4.6	4.2
Speaker	4.6	4.4	4.0
Radio	4.7	4.6	4.0
Overall Average	**4.7**	**4.5**	**4.0**

The next stage of project will include similar content testing and survey data for the other laboratory projects under development.

Discussion

Initial tests of the portable laboratories show encouraging results. The students completing the projects demonstrated an increase in content knowledge in areas related to the project materials. Content knowledge increases are significant. The content knowledge average rose from a poor to a fair level of comprehension. The students themselves rate the projects as interesting and educationally useful. The students are learning and enjoying the process.

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