# AC 2009-655: INSTRUCTOR-FRIENDLY INTRODUCTORY LABORATORY PROJECTS FOR USE IN 2 OR 4 YEAR COLLEGES

**John Krupczak, Hope College**
Professor of Engineering

**Kate Disney, Mission College**
Engineering Instructor

# Instructor-Friendly Introductory Laboratory Projects for Use in 2 or 4 Year Colleges

## Abstract

A group of educators from engineering programs at both four and two year colleges has developed laboratory modules with an emphasis on activities and perspectives shown to be successful in technological literacy courses for non-engineering students. To meet the needs of community college engineering programs, the logistical and commercial feasibility of shipping boxes or palettes of equipment was investigated. This will allow community colleges to borrow, rent, or lease rather than own the equipment. The laboratories were also developed to be completely self-contained so that all materials needed arrive in a single box in a ready-to-use condition. This was intended to minimize the preparation time for instructors in the two year college environment. These laboratories are suitable for use in either introduction to engineering or courses on engineering topics for non-engineers. The laboratories attempt to utilize insights from non-engineering students to determine themes that may enliven introduction to engineering courses. Technological literacy courses on a number of campuses have found that non-engineers respond positively to material that focuses on technology familiar to the students in their everyday life, use extensive verbal and graphical explanations, and include useful information that helps to establish a sense of empowerment regarding technology. Projects include building and testing common technological devices such as speakers, amplifiers, motors, and a photovoltaic battery charger. Eight laboratory projects will be created and tested both with non-engineering students and students enrolled in introduction to engineering classes in both two or four year schools. Results will be presented from testing done during the 2008-2009 academic year. The work was supported by the National Science Foundation under award: DUE-0633277.

## Introduction

The National Academy of Engineering is advocating that all Americans need to better understand all types of technology not just computers and information technology [1]. While not yet common, some engineering departments offer service courses for non-engineers [2]. Many of these technological literacy courses have become successful when measured by sustained student interest and long-term sustainability [2,3]. In attempting to enliven introduction to engineering courses, these successful technological literacy courses represent a potential source for themes or topics.

In addition to capturing the interest of first year 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 [4]. 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 [5].

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 through community colleges must contend with these challenges.

**Topics Cited as Appealing by Non-Engineering Students**

Based on experience from technological literacy courses for non-engineers [2,3,6-8], particular topics or characteristics have been found to attract the interest of the non-engineering student. These are summarized in Table 1.

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

| **Course Theme or Characteristic** |
|---|
| Relevance of topics to familiar technological devices. |
| Practical applications and skills. |
| Hands-on experiences with technology. |
| Avoidance of entirely mathematical explanations. |
| Development of a sense of empowerment in 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. While non-engineers are willing to pursue and even welcome developing in-depth understanding of technological principles, mathematical arguments alone are not sufficiently compelling in this regard. It should be possible to develop a self-contained explanation of the underlying principles of the device using only verbal descriptions and graphics. It might be noted that this is the approach followed in the popular “How Stuff Works” website [9], and the physics textbook [10].

Engineering educators might consider these preferences and priorities of non-engineering students as valuable data. Insights from non-engineers can help to identify the most compelling aspects of the field. The interests of first year engineering students may have more in common with their non-engineer peers than experienced working engineers. Themes borrowed from successful technological literacy course may help enliven the engineering curriculum.

## Laboratory Development Process

Work is underway to create eight laboratory projects that meet the criteria outlined in Table 1. These projects will be suitable for use in either a technological literacy class for non-engineering students or for introduction to engineering. The activities will be piloted in both two-year and four-year institutions to establish suitability across a range of academic environments.

To address the problem of obtaining equipment, the projects will be created in such a manner that they can be completely contained in a box of 20-100 pounds and can be shared between schools or rented from a commercial supplier

## Laboratory Projects Underdevelopment

**Electric Motor.** In this laboratory, students build a simple DC electric motor from basic components. The project makes deliberate use of general purpose materials and hardware rather than custom parts. Components include: wine cork, bamboo skewer, 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. To measure output power and torque a gearbox is constructed. The time needed to move a known weight through a fixed distance is measured. The motor and gearbox are shown in Figure 1.

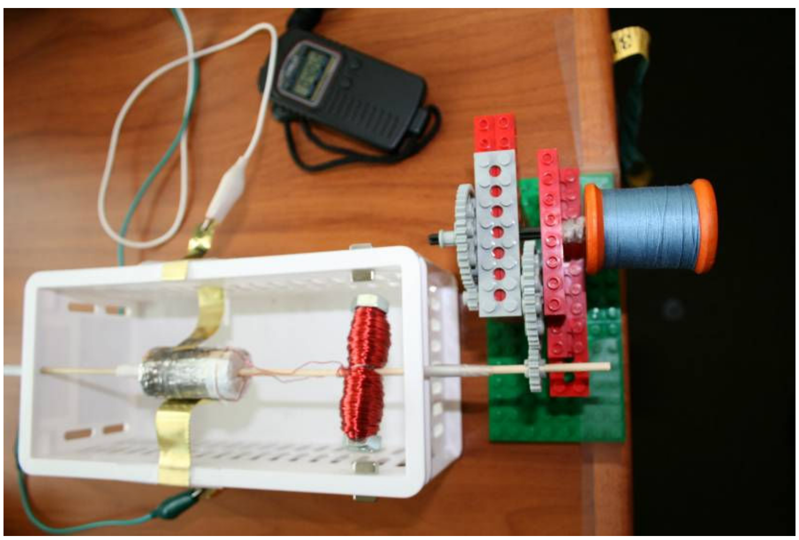


**Figure 1:** Electric Motor Made From Simple Components Producing Usable Torque.

**Speaker.** In this laboratory, a working electrodynamic loudspeaker is made using a magnet, coil of wire, a straw and a plastic drink cup. The speaker has 8 ohms impedance and produces a clear sound with volume exceeding 90 dB. The design is very simple, illustrating the key functional components of the speaker that allow the conversion of the electrical energy into sound energy. A view of the basic device is shown in Figure 2. Deliberate use is made of simple components to minimize costs while emphasizing basic function over specialized components. The only tools required are scissors and an optional glue gun. The speaker can be constructed by students in less than one hour and only a limited amount of work space is needed. Figure 2 shows speakers being built in a computer laboratory at a two-year college.

**Figure 2:** Simple Speaker Made From a Plastic Cup That Requires Limited Work Space.

**Simple Radio.** Each student builds the classic AM "crystal" radio. To facilitate the understanding of the basic principles at work, the radio design is extremely simple. This version forgoes tuning and utilizes only a coil wound around a cardboard tube, a germanium diode, an earphone and an antenna. The radios are kept by the students. The radio facilitates an understanding that electromagnetic waves carry energy and the principle of information encoding in the area of telecommunications. The basic radio is illustrated in Figure 3, along with students conducting a test of completed radios. The design is extremely robust and works well in areas where AM commercial radio signals are present.

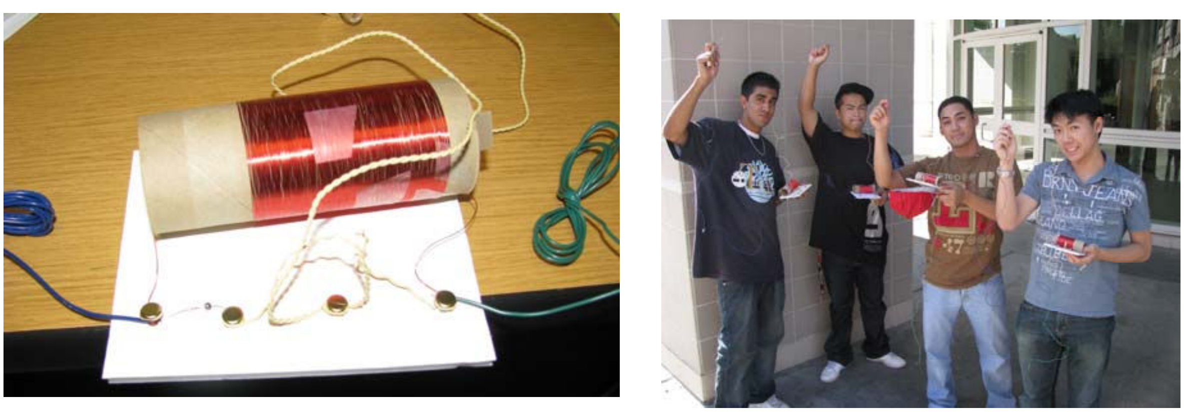
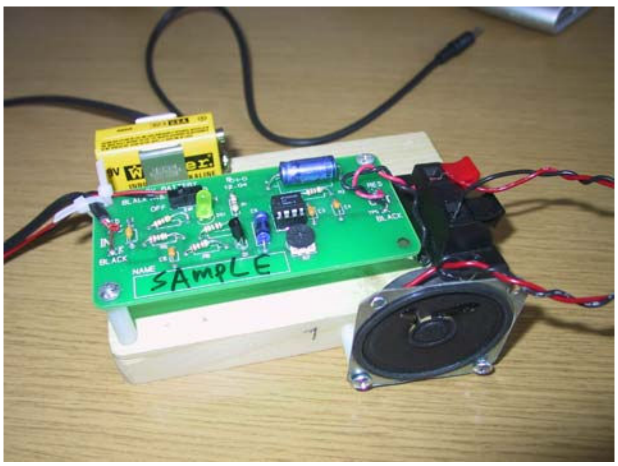


**Figure 3:** Modified Classic Crystal Radio and Students Testing Working Radios.

**Amplifier.** An amplifier is built consisting of a single-transistor preamp and an integrated circuit power amplifier. This amplifier makes it possible to hear the output of the crystal radio through the home-made speaker. Students do all of the assembly. Two versions have been created. One uses a custom-design printed circuit board. In the other, the amplifier is built onto a breadboard without soldering. The completed amplifiers are kept by the students. Using this amplifier it is also possible for students to connect a personal MP3 player to the homemade speaker described above. The soldered version of the amplifier is shown in Figure 4 along with students carrying out the construction.



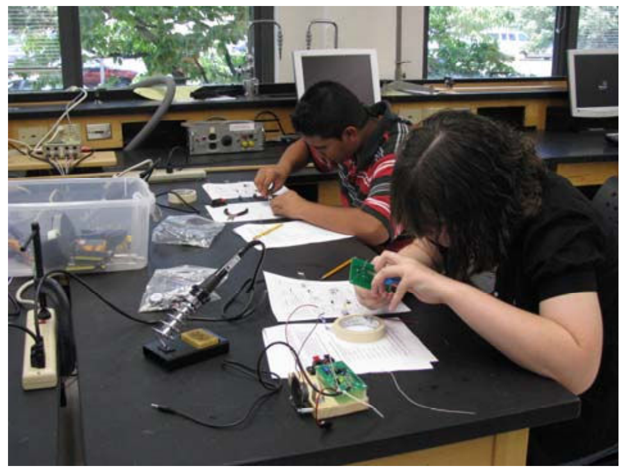
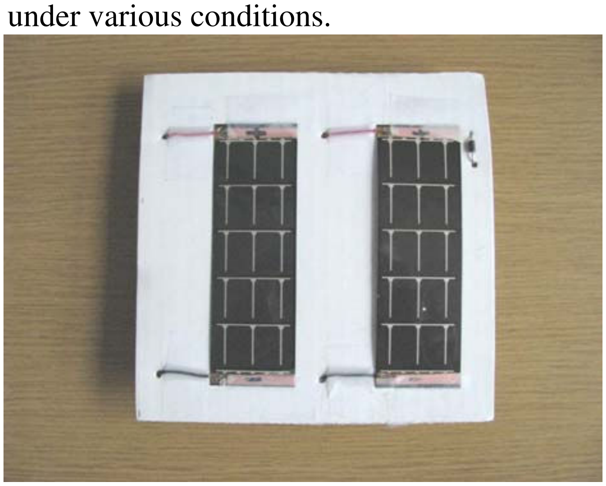



**Figure 4:** Audio Amplifiers Under Construction by Students and Final Product.

**Photovoltaic Battery Charger.** A photovoltaic battery charger was developed based on low cost thin-film photovoltaic cells. This device makes it possible to recharge two AA NiMH batteries. Students build the device and make measurements necessary to determine the recharging time under various conditions.



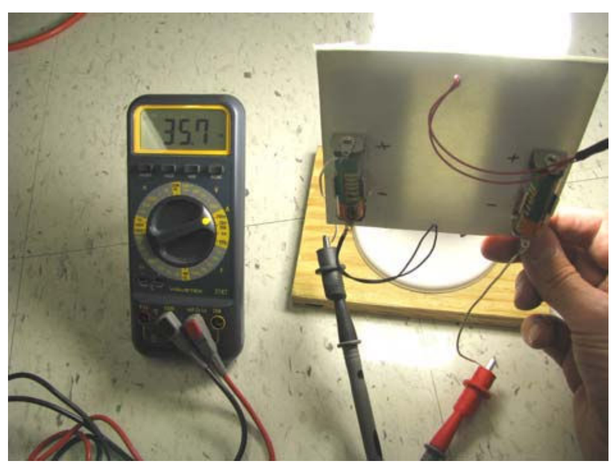



**Figure 5:** Photovoltaic Battery Charger Tested Indoors with a Compact Fluorescent Light.

Students are able to keep the battery charger. In either outdoor testing with the sun or indoor testing with a 200 W (equivalent) compact fluorescent light, the unit is able to recharge the two AA batteries to a usable level in 30 to 60 minutes. Complete recharging takes much longer, but the 30 minute charging time allows the project to be completed in the amount of time available for a typical laboratory session.

**Evaluation**

In addition to assessment of topic-specific content knowledge, several scales of the Motivated Strategies for Learning Questionnaire—MSLQ [11] will be used with each activity. Specifically, data will be collected using these scales:

- **Intrinsic Motivation:** Intrinsic motivation measures the extent to which students are inspired to learn because of curiosity about the topic, or the joy that comes from understanding complex material.
- **Extrinsic Motivation:** Extrinsic motivation measures the extent to which students are inspired to learn because of rewards such as grades.
- **Task Value:** Task value measures the extent to which students feel that what they are learning is relevant, useful and personally meaningful.
- **Self-Efficacy:** If students feel competent and empowered to succeed they will have high scores on self-efficacy.

These MSLQ scales have been used on hundreds of campuses. The psychometric properties are reliable and predict achievement [12].

Preliminary results from an initial test at Hope College are shown in Figure 6.
The results are highly encouraging—after completing just one series of the initial version of the laboratory activities in a technological literacy course for non-engineering majors, these students demonstrated increased intrinsic motivation, increased task value, and improved self-efficacy about science and technology. Self-efficacy increased by more than 10% and test anxiety about technological topics decreased by almost 15% in one semester. All results are statistically significant ($p<0.05$). These results are encouraging for the prospect of technological literacy for all Americans.

It is particularly notable that nearly 60% of the students taking the course at Hope College were women and 24% of the students were pre-service elementary teachers who will be teaching science in their classrooms. These results demonstrate that it is possible to lower anxiety, increase perceived value, and increase motivation for engineering and technology.

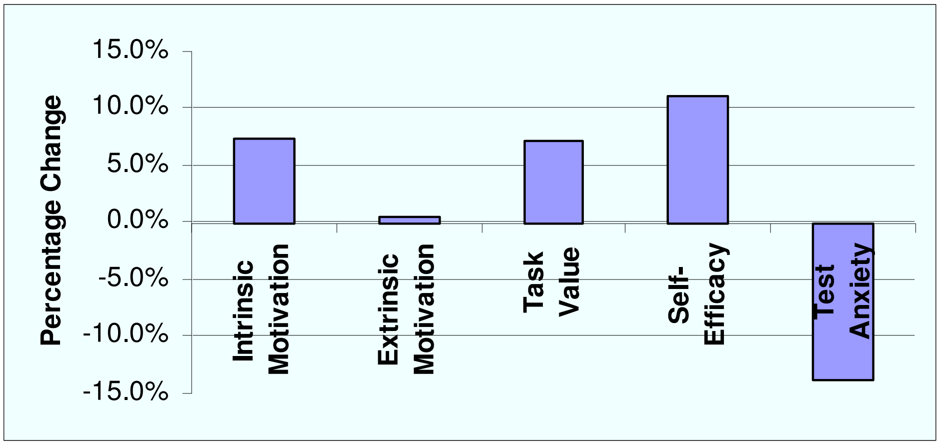



**Figure 6:** MSLQ Preliminary Results —48 Students, Spring 08.


## Acknowledgement

The work was supported by the National Science Foundation under award: DUE-0633277. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.


### Bibliography


1. Pearson G., and A.T. Young, editors, *Technically speaking: Why all Americans need to know more about technology*, National Academies Press, (2002).
2. Krupczak, J.J., D. Ollis, "Technological Literacy and Engineering for Non-Engineers: Lessons from Successful Courses," *Proceeding of the 2006 American Society for Engineering Education Annual Conference* (2006).
3. Kuc, R.," Teaching the non-science major: EE101 - The most popular course at Yale." *Proceedings of the 1997 American Society for Engineering Education Annual Conference* (1997).
4. National Science Foundation, Science and Engineering Indicators, http://www.nsf.gov/statistics/seind04/., Accessed March 15, 2008.
5. *Committee on Enhancing the Community College Pathway to Engineering Careers, National Academy of Engineering and National Research Council* "Educating America's Engineers: The Vital Role of Community Colleges," The National Academies in Focus, Vol 5, No 3 (2005).
6. Krupczak, J.J and C. Green "The Perspective of Non-Engineers on Technological Literacy," *Proceedings of the 1999 American Society for Engineering Education Annual Conference (1999).*
7. Sarfaraz, A.R., and T.A. Shraibati, "Responding to the Expectations of Non-Technical Students," *Proceedings of the 2004 American Society for Engineering Education Annual Conference (2004).*
8. Ollis, D. "Installing A New "Technology Literacy" Course: Trials and Tribulations," *Proceedings of the 2004 American Society for Engineering Education Annual Conference* (2004).
9. HowStuffWorks.com, One Capital City Plaza, 3350 Peachtree Road, Suite 1500,Atlanta, GA 30326, www.howstuffworks.com.
10. Bloomfield, L., *How Things Work: The Physics of Everyday Life*, 2nd Edition, Wiley, New York, (2001).
11. Pintrich, P.R., Smith, D., Garcia, T., and McKeachie, W. *A Manual for the Use of the Motivated Strategies for Learning Questionnaire.* Technical Report No. 91B-004. National Center for the Improvement of Postsecondary Teaching and Learning, (1991).

12. VanderStoep, S.W., Pintrich, P.R., and Fagerlin, Disciplinary differences in self-regulated learning in college students. *Contemporary Educational Psychology*, 21,(1996) p 345-362.