Laboratory Projects Appropriate for Non-Engineers and Freshman Engineering Students

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Introduction

The engineering departments at Hope College and Mission College both offer technological literacy courses targeted to non-science majoring students. These lab-based general education courses are designed with mechanical dissection and “make-and-take” lab projects that represent core technology.

These technological literacy courses are often referred to as “*How Stuff Works*” classes, because the focus is how and why core technology works as it does. Students are exposed to the scientific principles underlying the technology, and with this the students build or modify devices to work in a manner that satisfies a human desire, which is the engineering component.

Lab projects are constructed primarily with common, ordinary parts typically found in local retail stores. The use of simple parts helps to reduce abstraction and clarifies the underlying science of the technology. Engineering is explained primarily with natural language, demonstrations, teacher modeling, and hands-on lab projects. The lab projects either require students to take apart a device and analyze the functional parts (mechanical dissection) or build from scratch a new device (i.e. “make-and-take” projects).

Core Technology is defined as technology that is familiar to students as users. Core Technology is also technology that appears repeatedly in many engineered systems. Examples of Core Technologies are 1) a speaker, 2) a radio, 3) the LED, 4) the transistor, 4) the lever, 5) the internal combustion engine, 6) a DC motor, etc. These technologies are so familiar in everyday systems that students have a starting point from which to build their knowledge.

All people can and should understand the workings of common core technologies and have a basic understanding of the underlying science. With a “How Stuff Works” class, students are given a foundation that can be applied later to learning about other technologies not covered in the course. The benefits to having a technological foundation are clear – many important issues of our time have a technological component. With a proficient understanding of current technological issues, citizens could be more participatory and effective members of society.

Much work has been done through NSF funding to bring engineering, science, and technology to the public, but teacher materials for the college level are primarily available in electronic form. Support for faculty needs to extend beyond electronic file sharing to include supplying 'starter' kits that contain all the parts needed for students to build a project.

The Hope College – Mission College collaboration, with support from the National Science Foundation, is providing kits to faculty at other institutions and assessing if putting equipment and materials into hands of teachers is an effective means of getting more lab projects adopted into technological literacy and freshman engineering courses.

Why is Technological literacy important?

The National Academy of Engineering (NAE), as stated in *Technically Speaking,* describes "Tech Lit" as

> Technological literacy encompasses three interdependent dimensions – knowledge, ways of thinking and acting, and capabilities. [1]

Technology or the human-built environment is seen as encompassing four main content areas: Technology and Society, Design, Products and Systems, and Core Concepts and Connections.[2]

"How Stuff Works" classes falls into the *Core Concepts* category. The wide coverage of fundamental technologies makes these courses a starting point for college students who wish to have a better understanding of the broader technological world.

The NAE goes further to set the following goal:

> The goal of Technological literacy is to provide people with the tools to participate intelligently in the world around them. [1]

Technology has become more widespread and essential in our society now than ever in the past, and yet most people have a poor understanding of the technology they interact with. Devices are smaller and unserviceable, interfaces simplify and hide the technology so that users do not need to understand the technology in order to use it, and much of new technology today is happening at the microscopic level. All of these facts add separation between the end-user and the technology. The result is that collectively citizens are becoming less aware of technology but at the same time more dependent on it. This chasm between dependence and understanding needs to be addressed.

The NAE makes a strong case for greater public understanding of technology in *Technically Speaking* by stating

> Democratic principles imply that decisions affecting many people or the entire society should be made with as much public involvement as possible. As people gain confidence in their ability to ask questions and think critically about technological developments, they are likely to participate more in making decisions. [1]

The importance of an informed public on the health of the republic was stated numerous times by Thomas Jefferson. Jefferson was quoted as saying,

> "If a nation expects to be ignorant and free in a state of civilization, it expects what never was and never will be."

Technological literacy should be as important to our students as cultural literacy. A foundation of technological literacy not only helps explain the workings of technology but illustrates how fully integrated technology is into the fabric of society.

Technological literacy courses can serve as an educational bridge between the liberal arts and engineering. Samuel Florman [3] called for educational bridges to provide a route for engineers to access the arts. In the case of technological literacy courses, they are the bridge that gives the non-science student access to engineering and technology.

Types of Technological Literacy courses

Engineering departments on a number of campuses have begun to offer technological literacy courses for non-science majoring students [4]. There are four standard models of technological literacy courses as explained by John Krupczak and Dave Ollis: [5]

1. The Technology Survey course.
2. The Technology Focus Course that focuses on a particular technology area.
3. The Technology Creation Course (a course with design emphasis).
4. The Technology Course that Critiques, Assesses, Reflects, and/or Connects

Hope College and Mission College both offer Type-1, the Technology Survey Course designed for non-science majors.

Course Format and Lab Projects

Our Type-1 survey courses have two interconnected parts when covering new core technologies:

First, there is a lecture designed around small learning increments[6] about the science and technology specific to what students will build and see in the lab project. This is done so that students have a basic understanding of how and why the technology works before doing the lab. This is done through lecture and demonstrations.

Second, the students dissect or build a device. In doing this the students reinforce lecture information through observation and experimentation. Lab questions are designed to require students to experiment with the device by doing simple tests during the lab. After seeing something work, most students are more internally motivated to explain on their own the workings of the technology.

Direct instruction and lab parts must connect together. Connections can be made by reviewing a second time the lecture material during and after the lab.

The risk of not connecting lecture with lab is two-fold. Without direct instruction from the instructor, students will robotically assemble a device (i.e. this becomes the “cook-book” lab that has limited impact). Without the laboratory component the lecture runs the risk of being one-way and flat, and student learning becomes overly passive. Ensuring that lecture and lab fit together throughout the course gives students the connections linking the science to the technology.

Some of the labs being used in the Hope College and Mission College courses are:

	Dissection Lab Projects	Core Technology	Related Science
1.	Toy Car with Internal Flywheel	Energy Storage using Flywheel; Cams; Mechanical Advantage using Gear Reduction Box	Kinetic Energy; Rotational Inertia; Work; Friction; Torque
2.	Mechanical Alarm Clock	Escapement; Energy Storage using a Spring; Hair Spring and Balance; Gears; Portable Time Pieces	Periodic Motion; Spring Potential Energy; Frequency, Sound; Pendulum (comparison)
3.	Four Cylinder Internal Combustion Engine	Pistons; Valves; Crank Shaft; Cam Shaft; Timing Belt; Fuel Injection; Bearings; Engine Head and Block; Seals & Gaskets	Thermodynamics; Linear to Rotary Motion; Friction; Combustion; Efficiency
	"Make-and-Take" Lab Projects	Core Technology	Related Science
4.	Speaker	Speaker; Voice Coil; Diaphragm; Permanent Magnet	Electricity & Magnetism; Electromagnet; Sound Waves; Vibration
5.	DC Motor	Electric Motor; Rotor and Armature; Commutator; Brushes; Power Supply	Energy Conversion; Conductors & Insulators; Generators (comparison); Torque; RPM
6.	AM Radio	Radio; Antenna; Diode; Modulation methods; Tuner Circuits; Filters; Carrier Waves; Uses of the Electromagnetic Spectrum	Electromagnetic Waves; Electromagnetic Induction
7.	Audio Amplifier Circuit	Transistor	Semiconductors
8.	Battery Recharging Unit using Solar Cells	Photovoltaic Solar Cells; Batteries; Designs for Efficiency	Energy Capacity; Power; Voltaic Cell; Series and Parallel Circuits
9.	LED Book Light	Light Emitting Diode; Switches; Incandescent Bulb (comparison)	White Light vs. Colored Light; Electricity; Energy Conversion; Ohm's Law

Table 1

There are many other labs that would be appropriate for a Type-1 survey course. We chose those projects in Table 1 with the following goals in mind:

a) For items used in dissection, it is important to choose devices that will allow students to do functional decomposition. By taking the device apart the students can see the role of each sub-part and how it interacts with the other components. Functional Analysis helps students to transfer their understanding to other devices that utilize similar elements or core technologies.
b) Labs should be done individually. Each student constructs his/her own device. Although students are encouraged to help each other, individual projects usually means that all students are taking ownership in the project, especially if the lab project is something students will take home and keep.
c) Labs should require some manual work because learning and retention is enhanced when students do something with their hands.
d) Labs should be as simple as possible while still including all the fundamental components of a working device.
e) Create labs using simple, ordinary parts. Avoid using parts that are specially manufactured for a specific application as this will lead to a level of abstraction that is not necessary and may confuse some students.
f) Find labs that represent core technology – building block devices that are used repeatedly in other systems. Projects should be either real devices used for dissection or if it is a "make-and-take" project the device constructed should do something useful. Projects should not just verify a scientific theory.
g) Choose labs that can be connected together, either conceptually or literally. The speaker, radio, and audio amplifier are connected together so that students take away a complete AM radio.
h) Choose lab projects that can be analyzed and described mainly with natural language (i.e. minimal math).
i) Simplify labs and the directions such that every student who tries can complete the lab during the allotted time.
j) Use inexpensive parts.

Some Barriers to Offering Technological Literacy Labs

Aside from possible state level or institutional resistance to engineering as general education, there are other real barriers that may increase the effort of starting up a lab-based technological literacy course.

Budget constraints may limit lab projects. The semester cost for our technological literacy courses is approximately $55 per student. Currently there are only a few appropriate texts and even fewer lab manuals designed for a Type-1 technological literacy course. Due to the lack of instructional materials, faculty must develop their own labs and lectures. Lab development may be burdensome because:

a) Some trial and error is needed to fine tune lab projects and make labs affordable.

b) In order to achieve a breadth of labs covering a wide range of engineering, faculty must develop labs outside their discipline area.

c) Time may be limited because of heavy teaching loads, especially at small colleges.

d) It takes time to identify reliable parts vendors, such that a successful lab can be sustained.

e) Lab preparation is more intensive because of the individualized make-and-take model which demands more purchasing and organization. The lab technician may resist taking on different duties that do not fit the paradigm of existing science labs.

No one barrier is insurmountable, yet most faculty will encounter some aggregate of these barriers making course development challenging.

Despite the obstacles, the rewards for offering a technological survey course are great.
By doing something challenging (i.e. coming up with good labs), we offer our students a valuable course with a significant added value that is hard to replicate outside our networks. The experience of constructing a working device such as a radio, or hands-on contact with an actual car engine, provides students with an understanding of technology that cannot be replicated by clicking through an online virtual laboratory simulation. Doing this ultimately should give our students a competitive advantage in the global marketplace.

The Hope College – Mission College collaboration is investigating the viability of sharing lab materials in order to make it easier for faculty to start up technological literacy courses or to introduce these labs into their existing freshman engineering courses.

Lab Sharing

The internet has made materials in electronic format very easy to share   Lab equipment and lab projects cannot be shared in the same way. In order to adopt a lab, the teacher must acquire the materials and equipment, work through the project, and scale the lab to work in a setting of approximately 30 students. Often the “devil is in the details” and the devil is not seen until the lab project is sitting in the hands of the teacher. For this very reason equipment vendors set-up and demonstrate their products at trade shows or conventions. Pictures and videos do not “sell” equipment to consumers nor do they to teachers.

Recognizing this commits us to finding processes that will put materials and equipment into the hands of teachers.

The Hope College – Mission College collaboration is investigating the viability of sharing lab materials using our common shipping infrastructure, such as the US Postal Service and UPS. A sharing arrangement between colleges may be either on-going or temporary until new faculty become familiar enough with a lab project to prep the lab on their own.

We recognize that some labs are not cost-effective to share on an on-going basis (e.g. sharing a car engine). In such cases a one time share arrangement can be just enough to train the faculty and break the barrier of unknown. Having the actual equipment and using it in a lab setting gives faculty the “gestalt” needed to see the value of the lab. Having the lab equipment once also allows the faculty to better assess what is entailed in acquiring the lab equipment.

Hope College and Mission College have provided student kits for the following courses:

Computers, Networks, & Emerging Technologies: CNET 114 –
“How Technology Works” at Ohlone College, Fremont, CA

Engineering: ENGR 10 –
“Introduction to Engineering” at Las Positas College, Livermore, CA

General Engineering: ENGR 10 –
“Introduction to Engineering” at San Jose State University, San Jose, CA

Engineering: ENGR 5 –
“Engineering as a Profession” at Cabrillo College, Soquel, CA

Engineering: ENGR 01 –
“Introduction to Engineering” at Ventura College, Ventura, CA

Our lab sharing efforts have mostly focused on courses designed for freshman engineering students. This is because most community colleges do not yet have a technological literacy course. Our labs can be used in an introductory engineering course but probably these courses would not offer all of the labs.

As faculty build up a set of introductory core technology labs, the effort of starting up a new technological literacy course should be much less daunting. It is our hope that faculty who do not currently have a technological literacy course will consider creating one and folding these labs into such a course. Our labs at the very least can serve as a baseline from which to develop a technological literacy survey course.

Other Benefits to Lab Sharing

Every instructor has an area of expertise and yet the demand for understanding a wide range of technologies is great, especially in small engineering departments. Sharing labs puts into faculty's hands a lab they might otherwise never create themselves. This clearly can be seen as faculty development.

There is value in having someone (other than the person who created the lab) test a lab. The feedback allows for lab refinement. As labs are improved upon it is more likely that a set of canonical engineering labs will emerge. A refined set of labs is needed to validate the concept of technological literacy as general education, as well as to ease the efforts required for developing such courses. These labs could then be packaged into lab manuals and begin to help set a standard for technological literacy courses. A well developed repository of course materials is needed for a systemic shift towards accepting technological literacy as general education.

One of the most effective means of assisting faculty with new labs is to actually go and facilitate the lab with the faculty member. Although often infeasible, it is highly worthwhile as this real-time interaction helps build community among engineering faculty.

Lab sharing in no way should be one way. Faculty need to openly share their "secrets" – such as labs, teaching techniques, course materials, etc. if engineering is to mature into a discipline with a well defined role within general education. In order to identify and refine what it is we think all students should know, there needs to be some collective action so that our efforts take root and course materials represent what most faculty think are essential for technological literacy.

Conclusion

It is important that we consider strategies to make it easier for engineering faculty to teach technological literacy to non-science majoring students.

A first step in addressing the barriers to offering technological literacy lab-based courses is for faculty who teach these courses to share their lab materials.

Information and lecture content in electronic format is now easy to come by, yet a lecture-only course makes for "flat" curriculum that can exist anywhere. In order to give an added value to our students, we must do the more difficult task of providing an enriched, hands-on lab experience.

As more hands-on labs for technological literacy courses are used and made available, we should see a canonical set of lab projects emerge. With wide spread adoption of labs there is an economics of scale that makes supplying lab materials cost effective for equipment manufacturers. So what is a lot of work today (prepping labs and assembling kits for students) should be significantly less work later as the technological literacy concept takes root.

Non-science majoring students need access to “How Stuff Works” courses in order to gain a foundation in the workings of technology. If students are offered technological literacy courses we will be giving them an opportunity to acquire knowledge of fundamental science and core technologies. With this basic understanding one can continue to investigate the workings of the modern world, thus producing a greater sense of empowerment and comfort with technology.

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