AC 2009-1280: LIVING WITH THE LAB: UPDATE ON THE SECOND YEAR OF FULL IMPLEMENTATION FOR OVER 400 FIRST-YEAR ENGINEERING STUDENTS

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Living with the Lab: Update on the Second Year of Full Implementation for Over 400 First-Year Engineering Students

Abstract

Two years ago a robotics-centered sequence of three first-year engineering courses was expanded to include all beginning engineering students as part of an NSF CCLI grant. The objective of this course sequence is to immerse students in a skill-based, project-driven curriculum that builds creativity and a can-do spirit. Students purchase a Parallax BASIC Stamp controller, sensors, servos, and software to provide the basis for a mobile laboratory and design platform; this mobile platform, which is owned and maintained by the students, provides a mechanism for boosting experiential learning to a level that would be difficult to achieve using university-owned equipment and supplies. We call our educational approach "Living with the Lab."

The curriculum seeks to weave together topics from engineering systems, electromechanical devices, fabrication of prototypes, specification and acquisition of parts and supplies, software, fundamental engineering concepts, communication, and broadening activities. The project-focus starts by utilizing the Boe-Bot kit early in the year and then moves away from the "kit" as students develop a system to provide closed-loop control of the temperature and salinity of a small volume of water. The final project is an open-ended design project where students conceive, design, fabricate, test and present a "smart product" that utilizes the hardware employed throughout the year.

An update on our efforts to expand the curriculum from a pilot group of approximately 40 students to 433 students in the fall of 2009 is provided, including our efforts to train a team of faculty to teach the courses, purchasing supplies and equipment to facilitate the projects, and preparing course materials available to students via the web.

Introduction

The College of Engineering and Science at Louisiana Tech University has implemented a project-intensive first-year experience for all engineering students. The new curriculum seeks to provide a major boost in experiential learning by putting the maintenance and ownership of the laboratory in the hands of the students. Each student is required to purchase a laptop, a robot kit, several software packages, and a tool kit to provide a standard platform for laboratory and design activities. Student ownership of the laboratory expands the scope of hands-on activities that can be undertaken; we call this new curriculum "*Living with the Lab*." Coupling technology, including computer modeling, programming, control, measurement and fabrication, with engineering fundamentals provides a rich first-year experience that builds a strong technical foundation while fostering a creative and innovative spirit in our students. This paper describes our first-year experience and discusses some of the challenges of scaling the curriculum up from 40 to 433 students.

Overview of Curriculum

In 1998 the College of Engineering and Science moved to an integrated engineering curriculum based on the educational practices of the National Science Foundation Educational Coalitions [1]. Along with our freshman engineering course sequence, our freshman integrated curriculum includes differential and integral calculus courses, basic chemistry lecture and laboratory courses, and a calculus-based physics course, as summarized in Table 1; students also typically enroll in several non-technical courses during the freshman year. The freshman integrated courses are taken in “blocks” so that classes of 40 students share the same sections of each mathematics, science and engineering course during each quarter. The topics presented in the mathematics and science courses are coordinated to some degree with the topics presented in the engineering courses to motivate student learning and to provide for content overlap.

Table 1 – Technical courses of the freshman engineering curriculum.

Fall Quarter		**Winter Quarter**		**Spring Quarter**	
Course	*Credits*	*Course*	*Credits*	*Course*	*Credits*
ENGR 120	2	ENGR 121	2	ENGR 122	2
MATH 240	3	MATH 241	3	MATH 242	3
CHEM 100	2	CHEM 101/103	2/1	PHYSICS 201*	3

* Some disciplines take physics and some take additional chemistry

The “original” ENGR 12X freshman engineering course sequence between 1998 and the spring of 2007 included engineering fundamentals (circuits, materials balance, and statics), computer applications (Excel, Mathcad, and Solid Edge), statistics, engineering economics, teamwork, communication skills, and a design project. The students did most of their work in teams, including homework problems, laboratory activities, and presentations. The year culminated in a design competition between the ENGR 122 teams.

With seed money provided by the university to purchase course supplies, we began what would eventually become the *Living with the Lab* freshman course sequence in 2002 with a group of 21 students who volunteered to participate in the new courses. The new courses were much like the original ENGR 12X courses, only with a much stronger project focus. These robotics-centered courses were offered on a pilot basis to 40 students in 2003-2004. Beginning in the fall of 2004 and continuing for the next three academic years, the new courses were offered to two groups of 20 honors engineering students each year. Funding from an NSF Course, Curriculum and Laboratory Improvement grant allowed us to extend the curriculum to over 433 students in the fall of 2008.

The “*Living WITH the Lab*” curriculum seeks to immerse students in a skill-based, project-driven curriculum that builds creativity and a can-do spirit. Curriculum objectives are divided into seven threads that run concurrently throughout the year, as shown in Figure 1. Each of the objectives is mapped to one or more of the ten attributes of “The Engineer of 2020” [2] which serves as a set of guideposts for the curriculum. The content timing and delivery has been structured so that the knowledge, skills and attitudes associated with each of the seven threads are built progressively.

Aspects of each of the seven threads are included in all three of the ENGR 12X courses to provide continuity.

1. SYSTEMS
- fabricate, test and evaluate the efficiency of an engineering system
- fabricate and test an engineering system where two parameters are controlled
- conceive, design and fabricate a prototype using a controller, sensors & actuators

2. ELECTROMECHANICAL
- interface a programmable controller with selected sensors and actuators
- implement circuits on a solderless breadboard for sensing / control applications
- utilize multimeters for troubleshooting and to determine electrical power usage
- describe the specifications, operating procedures, and underlying physics for the hardware utilized

3. FABRICATION AND ACQUISITION
- fabricate parts using a wide range of conventional manufacturing processes
- design and fabricate an RTD sensor using microfabrication processes
- locate materials, supplies and components in stores and from online suppliers
- specify and purchase materials, supplies or components for projects

4. SOFTWARE
- utilize Excel, Mathcad and Solid Edge in engineering analysis and design
- formulate and implement computer programs for sensing and control applications

5. FUNDAMENTALS
- apply concepts of electricity and DC electric circuits
- apply conservation of energy to engineering systems
- apply basic chemistry and electrochemistry to salt water mixtures
- apply conservation of mass to engineering systems
- apply least squares fitting to calibrate sensors
- apply concepts of statics to engineering systems
- apply engineering economics to solve time value of money problems

6. COMMUNICATION
- utilize the specified engineering problem solving approach
- properly present technical information in tables and graphs
- communicate the results of investigations and projects both orally and in writing

7. BROADENING ACTIVITES
- assess potential impacts of selected global and societal forces on our planet and its inhabitants
- regularly attend professional society meetings and other student-led functions
- work individually and collaboratively to complete course assignments
- apply creative problem solving techniques for product design
- manage time and resources during the development of an innovative product

Figure 1 – The seven threads that define the first-year experience

The three classes (ENGR 120, 121 and 122) meet twice per week for 110 minutes, often switching between lecture, laboratory and fabrication activities in a single class period. Two special purpose classrooms were prepared to support the curriculum. The classrooms are equipped with round tables, rolling chairs, ample storage space for supplies, and equipment to facilitate project work. One of our 16 workstations is shown in Figure 2.

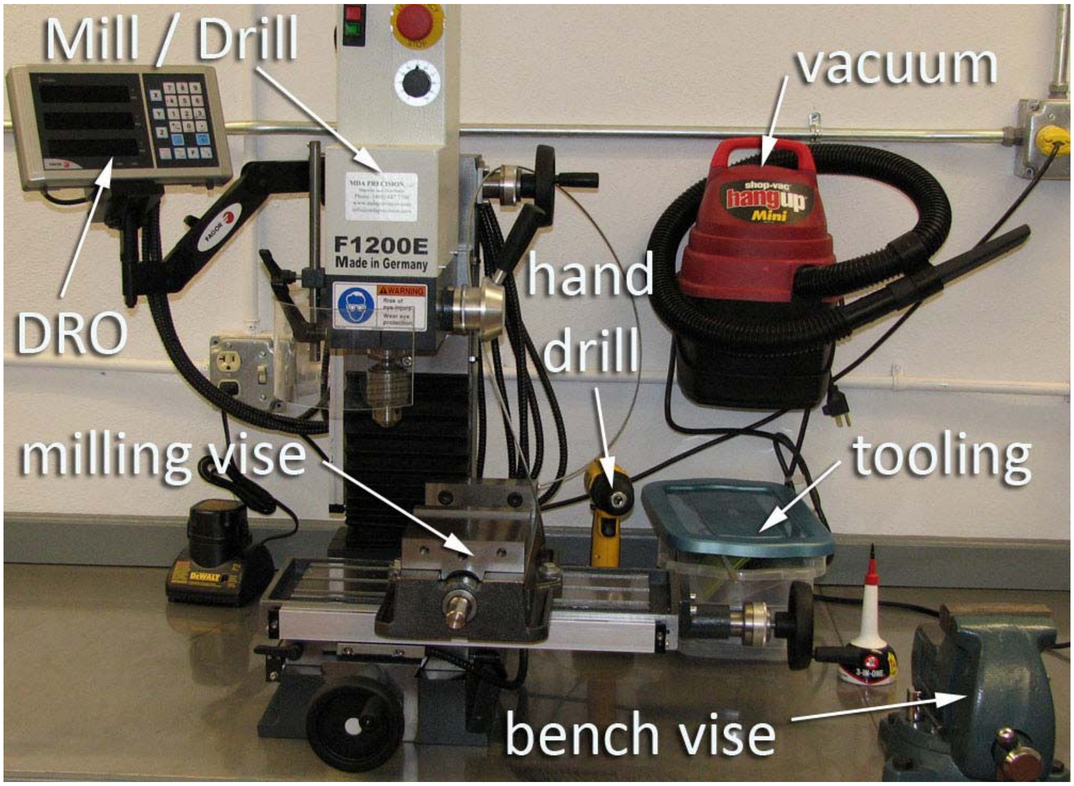


Figure 2 – One of 16 workstations in the freshman projects laboratories

As many as 14 course sections of the ENGR courses are offered simultaneously by 8 faculty members to service the 400+ students. Students in the different sections complete the same homework assignments and take the same evening exams. Common assignments and exams provide a uniform first-year experience for the students. Students complete approximately one homework assignment per class, one to three short quizzes, and two exams during each course.

Content of the Three ENGR Courses

ENGR 120 is the first engineering course. Students entering this course are required to purchase the items shown in Figure 3 as well as a few other supplies to support the projects. The course focuses on introducing students to electricity and basic DC circuits, linear regression and conservation of energy. Hands-on exposure to electricity and circuits is made possible using the Boe-Bot [3], the robot kit utilized in this curriculum. Students learn to use their multimeters while building and testing the following circuits on the breadboard of the Boe-Bot:

- DC circuits with resistors in series (to demonstrate Kirchoff's Voltage Law)
- DC circuits with resistors in parallel (to demonstrate Kirchoff's Current Law)
- Circuits with LEDs whose brightness is set by a resistor in series
- Circuits utilizing LEDs and buzzers that are controlled by the microprocessor
- A whisker circuit that allows the Boe-Bot to sense contact

Figure 3 – Students purchase a standard technology platform to facilitate projects

The major project in ENGR 120 is the pump project, as shown in Figure 4. Students fabricate a centrifugal pump using a series of drilling operations. Students gain experience in solid modeling by drawing the pump assembly and the impeller; the impeller is rendered on a rapid prototyping machine from ABS plastic. Students test the pumps to determine their efficiency as a function of pump head, utilizing their multimeters to measure the electrical power input to the pump. Students use linear regression to fit a curve that defines the performance of their pump. These pumps are made by groups of two students, and the cost per pump is approximately $5.

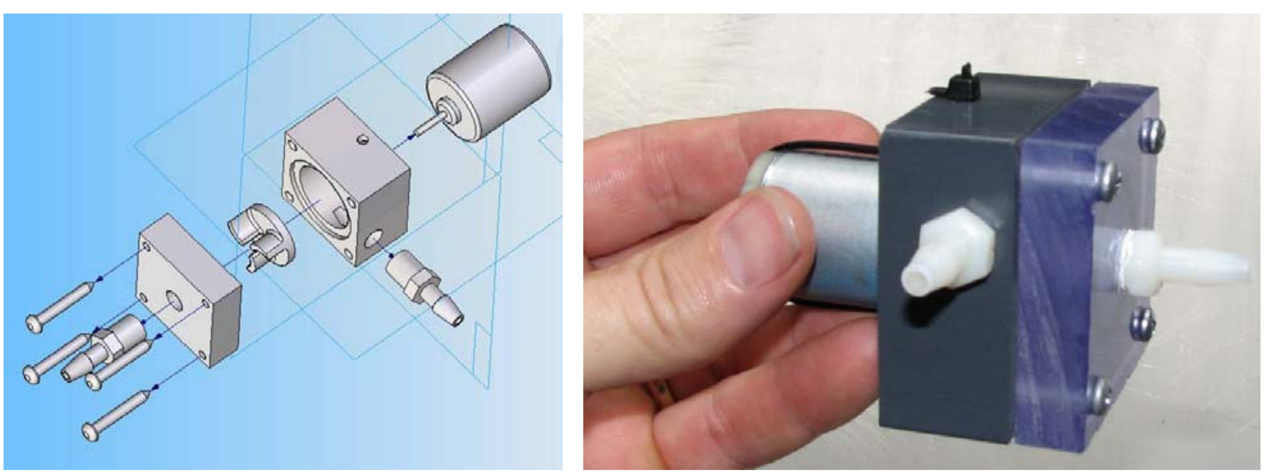


Figure 4 – The centrifugal pump fabricated and tested in ENGR 120

ENGR 121 is the second engineering course. This course is driven by the "fishtank" project where students build a system capable of providing closed-loop control of the temperature and salinity of a small volume of water. The fishtank project is composed of a number of smaller projects:

- Fabrication of a water chamber
- Fabrication and calibration of a conductivity sensor
- Microfabrication and calibration of a resistance temperature detector (RTD)
- Fabrication of a wooden platform for mounting components
- Wiring and testing of transistor / relay circuits for switching solenoid valves and a heater
- System programming, troubleshooting and testing

A partially completed fishtank system is shown in Figure 5. The pumps that the students build in ENGR 120 are again utilized in a flow circuit in ENGR 121. This is a complex project that is challenging for students; most student teams are able to build a system that can provide stable control of temperature and salinity. Success in a complex project like this builds student confidence.

Figure 5 – A student team with a partially assembled fishtank system

This project continues to build student understanding of electric circuits and electronics. The project also provides an opportunity to introduce mass balance problems, as students balance incoming salty and fresh water to achieve the target salinity in their tank. Salt water chemistry is also discussed, and the first-law of thermodynamics is presented to allow students to compute the time required for their heater to increase the temperature of the water in the tank by a specified amount (the heater is an 18 ohm resistor powered by a 12 VDC power supply).

ENGR 122 is the third and final first-year course. This course is designed to allow student to utilize the technical skills gained earlier to complete an open-ended design project resulting in a working prototype of a smart product. Examples of design projects are provided in Figure 6. During this project, teams participate in a variety of activities:

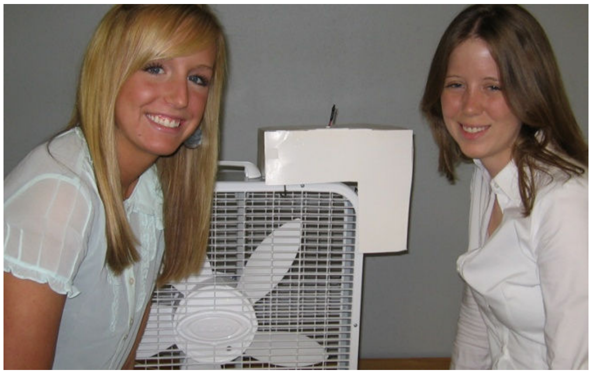
- the creation of a "bug" list to generate potential project ideas
- a review of the "10 Faces of Innovation" based on Tom Kelley's book The Ten Faces of Innovation [4] which is designed to encourage students to appreciate the skills of others and realize that every person has something unique to contribute to the team
- an IDEO video [5, 6] which demonstrates an effectively functioning team
- formal brainstorming training which covers team-relevant topics such as listening to others' ideas, as well as the fact that it is essential that ideas flow freely without passing judgment

The course includes descriptions of a wide variety of sensors and includes a project where students evaluate the performance of their robot servos. Students are also introduced to statics and engineering economics.

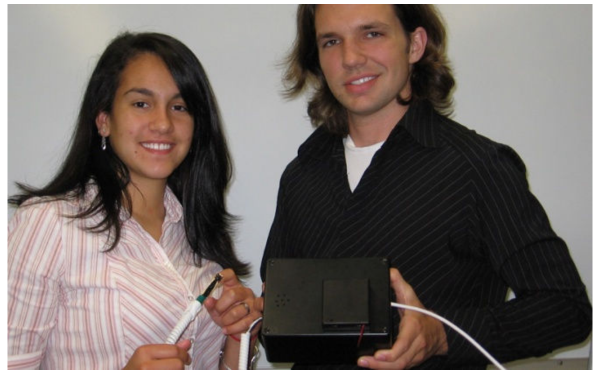
Faculty Training

Much of the effort to scale the curriculum from 40 to over 400 students involved faculty training. The two faculty members who developed the early version of the curriculum offered two week long summer training workshops to new faculty members to prepare them for teaching the curriculum. The workshop participants completed the major course projects and were provided with their own Boe-Bots and toolkits. Workshop participants were also provided with a copy of the course notes. The faculty team (workshop instructors and participants) spent time going through the course notes, resulting in numerous improvements to the curriculum.

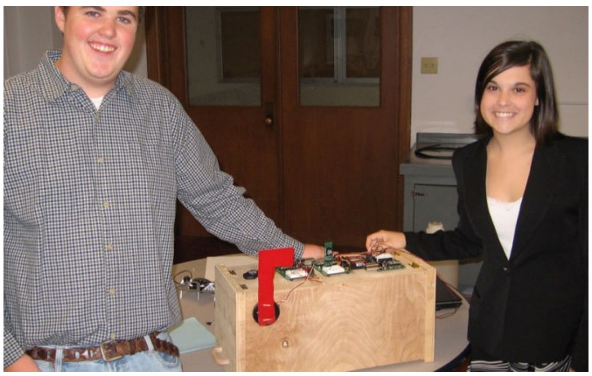
During the fall of 2007, the curriculum was implemented for the first time for all entering first-year engineering students. The course notes and assignments were distributed to the students and faculty members on the web, with separate student and instructor web sites. The faculty began to meet each week to discuss what was and was not working well, and adjustments in content and scheduling were made to improve the experience for the students. The faculty members continue to meet, and course modifications are made almost on a weekly basis. These faculty meetings are essential for building the faculty team; all faculty members have ownership of the curriculum content.



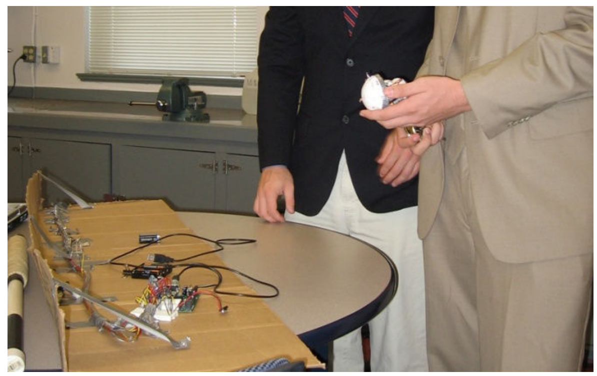
smart fan – comes on when it gets hot



device to check for slowing pulse to prevent auto accidents



smart mailbox

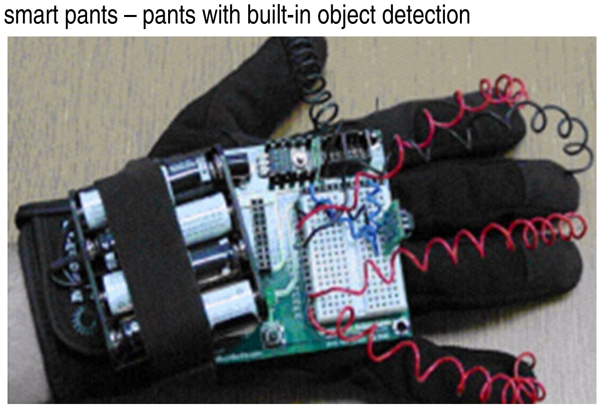


electronics to detect if a baseball goes foul

automated Easter egg painter

smart pants – pants with built-in object detection

automatic floor mopping robot – random motion



rapid surf – finger activated TV remote control

Figure 6 – Example projects from ENGR 122

Facilitating Projects

Even with a student-owned laboratory platform, implementing a curriculum that includes a large number of projects can still be demanding on the faculty. To help shelter the faculty from this load, we have implemented a student help-desk that meets Sunday through Thursday night of each week from 6 p.m. until 8 p.m. The help desk is staffed by two or three student workers who assist students with technical issues and who prepare the classrooms for the projects. Some the activities completed by the helpdesk include:

- helping students with software installation
- helping students with technical issues (Boe-Bot and projects)
- helping students with homework problems
- cleaning the classrooms
- preparing the classrooms for upcoming activities
- checking the workstations in the laboratory and fixing problems
- preparing project kits
- rapid prototyping pump impellers and other parts
- assisting with RTD fabrication (etching of Ni RTD with acid offline)

Without the assistance of these student assistants, it would be difficult to sustain the first-year experience.

Conclusions

A project-intensive first-year engineering curriculum has been implemented for over 400 students. The curriculum utilizes a common platform consisting of a laptop, a robot kit, a software suite, and tool kit to facilitate project work both inside and outside of class. The curriculum has resulted in a huge boost in hands-on learning. Implementation of the curriculum involved significant initial faculty training as well as continued faculty meetings. A student help desk was implemented that improves the experience for student participants and reduces faculty workload. The curriculum has been very well received by both students and faculty.

Acknowledgement and Disclaimer

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