AC 2010-1268: LIVING WITH THE LAB: SUSTAINABLE LAB EXPERIENCES FOR FRESHMAN ENGINEERING STUDENTS

Kelly Crittenden, Louisiana Tech University

David Hall, Louisiana Tech University

Patricia Brackin, Southeast Missouri State University

Living With the Lab: Sustainable Lab Experiences for Freshman Engineering Students

Abstract

In the United States, a movement toward project-based freshman engineering curricula began in the 1990's due in large part to the National Science Foundation's Engineering Education Coalitions. This movement continues at Universities across the country. At Louisiana Tech University, we began our own engineering curriculum reform in 1995. Through the support of the College and the National Science Foundation we have implemented and revised multiple Integrated Engineering Curricula.

One obstacle to implementing an active-learning, laboratory experience at the freshman level is the required infrastructure and setup time. These barriers can lead to either poorly implemented projects with no connection to the curricula or to time-intensive preparations by the faculty and staff. Through multiple iterations of our freshman curriculum, we have developed an active, hands-on lab-type experience at the freshman level that is both tightly integrated to the course content and does not require extensive set up and tear down time by the faculty.

This Living With the Lab curriculum relies on a student owned "lab". Freshman students purchase a commercially available microcontroller kit which is used throughout the year to introduce the fundamentals of engineering. Students gain hands-on experience collecting and analyzing data, designing and implementing real control systems, modeling and fabricating system components, and finally creating their own solution to an open-ended problem. This Living With the Lab curriculum is aligned with the outcomes suggested by the National Academy's Engineer of 2020, and with our own desire to instill a "can-do" spirit in our students.

This paper will describe the Living With the Lab curriculum while focusing on several of the lab experiences and how they connect to the curriculum. Data will be presented that show a marked increase (over our previous curriculum) in the number of times laboratory type, hands-on activities are performed by the students. We are tracking data points such as the number of times a student reports to have used a dial caliper, as well as a student's confidence in "locating specifications and prices for [supplies and materials] used in course projects . . ."

Motivation

Engineering faculty who are committed to educational reform have long since realized that passive lecture-based instruction should be replaced by active, integrative, project-based learning[1]. In the United States, the movement toward project-based freshman engineering curricula began in the 1990s due in large part to the National Science Foundation Engineering Education Coalitions[2-5]. This movement towards hands-on freshman engineering programs with a significant design component continues today at universities across the United States[6-8]. A vast body of literature on the subject clearly shows the benefits of incorporating project-based instruction with design early and often.

Over the past six years, the College of Engineering and Science at Louisiana Tech has taught a sequence of freshman engineering courses that we refer to as "Living With the Lab" (LWTL).

The goal of this course sequence is to provide the knowledge, skills and tools essential for boosting the confidence and creativity of freshman students while introducing them to the engineering disciplines. The core philosophy behind the LWTL concept is to create a learning environment that empowers students with a "can do" attitude. One of the essential ingredients to this environment is transitioning students from their previous learning mode to a more self-reliant mode of study. The LWTL curriculum encourages this transition through the use of a commercially available "lab" and real-world projects.

The LWTL curriculum was motivated through a combination of the following factors:

1. Our college vision of "being the best college in the world at integrating engineering and science in research and education"

2. A noticeable change in the type of students entering our College of Engineering and Science; particularly, students appeared to have less self-reliance and low exposure to working with their hands.

3. The National Academy's reports; "The Engineer of 2020[9]" was of particular interest.

4. A desire to incorporate more hands-on activity while simultaneously increasing the rigor

5. Student retention data that indicated our previous curriculum was not properly preparing our freshman for their future engineering courses

6. Evidence that indicates robotics curricula tend to attract students[10]

With these and other factors in our mind we began piloting various modifications to our existing Integrated Engineering Curriculum. Our current Living With the Lab curriculum evolved from these pilots with the assistance of the NSF through CCLI grant # 0618288.

Living With the Lab Curriculum

The "lab" used in the LWTL curriculum is the Parallax BOE-Bot (www.parallax.com). The BOE-Bot is a microcontroller kit complete with servos, mini protoboard, and various circuit elements. Upon first glance, it appears that LWTL is another "robotics" curriculum. A picture of the BOE-Bot kit can be seen in Figure 1. However, closer inspection of the curriculum will reveal that the BOE-Bot is used first as a hook to spark student interest, and later as a microcontroller in a full control system, and lastly as a platform on which students will build their own creations. The BOE-Bot content within the curriculum provides the perfect match for the project-based educational approach and greatly expands the types and complexity of projects that can be undertaken at the freshman level.

Figure 1. Contents of the BOE-Bot kit, www.Parallax.com.

Each freshman engineering student enrolled in the LWTL curriculum is required to purchase a laptop, the BOE-Bot kit, and an assortment of hand tools (note there is no textbook for the LWTL courses). Typically this represents approximately 500 students throughout the academic year. Each LWTL class consists of either 20 students in teams of two (honors sections) or 40 students in teams of four (non-honors sections). The students meet 20 times per quarter for one hour and fifty minutes each class, the students receive the equivalent of two semester credit hours per course. There are three courses in the LWTL freshman curriculum. In order to progress in the sequence, a student must receive a “C” or higher in both the LWTL engineering course and a “C” or higher in the corresponding Calculus course.

The LWTL courses are taught in our “Freshman Projects Lab”. This room contains ten tables with fours chairs each to accommodate the ten teams of students (there is a similar, but smaller classroom for the honors sections). Around the perimeter of the room are ten work stations with a milling machine, vice, and other tools. There are also two lathes and two large shear/brake/roll units in the room as well. The LWTL curriculum is designed to be very hands-on and there are essentially no class periods to do not contain at least one hands-on activity. A panoramic picture of the classroom can be seen in Figure 2.

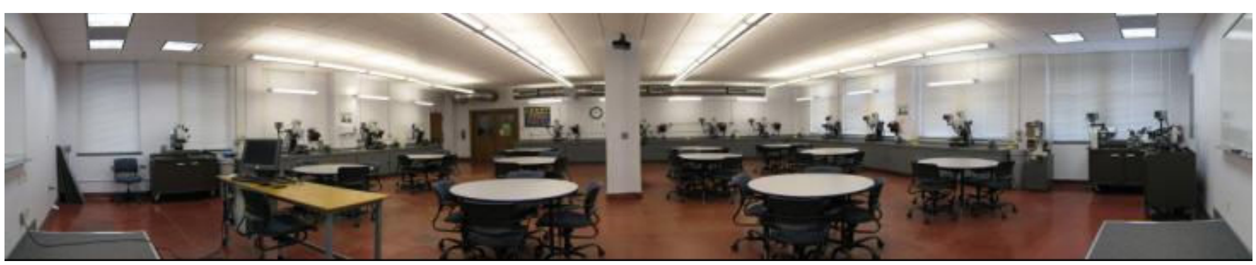

Figure 2. Panoramic view of the Freshman Projects Lab.

There is no textbook for the class, instead students print out partial notes from the LWTL website and during the lecture portion of the class a tablet PC is used by the instructor to fill in the missing portions during the course of the instruction. A typical class period has 20 to 30 minutes of lecture followed by an active exercise and possibly another short lecture to end the class. The student version of the course material can be found at www.LivingWithTheLab.com, for the instructor version of the course material email Dr David Hall at dhall@latech.edu requesting access to the site.

Selected Projects from LWTL

One of the key components of this curriculum is the concept of threaded material. There are seven threads that run throughout LWTL. These threads are shown in Table 1.

Table 1. Seven threads of the LWTL curriculum.

SYSTEMS

- fabricate, test and evaluate the efficiency of an engineering system
- fabricate and test an engineering system where two physical parameters are controlled
- conceive, design, and fabricate a prototype utilizing a controller, sensors and actuators

FUNDAMENTALS

- apply concepts of electricity and DC electric circuits
- apply basic statistics to quantify and model experimental data
- 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

ELECTROMECHANICAL

- utilize a programmable controller that interfaces with selected sensors and actuators
- implement functional circuits on a solderless breadboard for sensing and control applications
- utilize multimeters to troubleshoot circuits and to determine the power usage of a device
- describe the specifications, operating procedures, and underlying physics for the hardware utilized

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

SOFTWARE

- utilize Excel, Mathcad and Solid Works to assist in engineering analysis and design
- formulate and implement sequential computer programs for sensing and control applications

COMMUNICATION

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

BROADENING ACTIVITIES

- 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

This section of the paper will focus on the robotic elements of the “Electromechanical” thread of LWTL. Several papers have been published covering various aspects of other threads in the curriculum[11-24] and can be found at www.LivingWithTheLab.com.

Engineering 120

Engineering 120 is the first course in the LWTL sequence. The students are required to acquire their BOE-Bot by the third class meeting (2nd week) of the quarter. The students are also required to have a multimeter, wire strippers/cutters, and solder by this class period. We give guidelines for the type of tools that they need to purchase, but we do not specify exact model numbers. The reason for this openness is two-fold. First, it allows students to purchase tools at prices they are comfortable with, and second we want the students to become familiar with the concept of “speccing out” items and finding potential sources for these items.

The first in-class “electromechanical” exercise for the students occurs during class 3. The activity is to assemble a circuit and write a BOE-Bot program to cause an LED to blink in a certain pattern. It is worth mentioning that the previous class periods were spent discussing Ohm’ law as well as an atomic level view of resistance and current. For homework the students are asked to bring their BOE-Bot to the next class with a different pattern of flashing LEDs. Students complete this activity in pairs.

The next activity in this thread occurs on class 6. After discussing the concept of servo motors and dissecting one, students are given the “Around the Pencil” challenge. Students have previously learned how to use dead reckoning to drive the BOE-Bot in a straight line. The students are then given the task of navigating the BOE-Bot around a pencil in the center of their table and back to its starting point. Students are also introduced to the concept of subroutines as part of this exercise. For homework, students are asked to make the BOE-Bot accelerate and decelerate (ramping). A diagram of the pencil exercise can be seen in Figure 3. This activity is also completed in pairs.

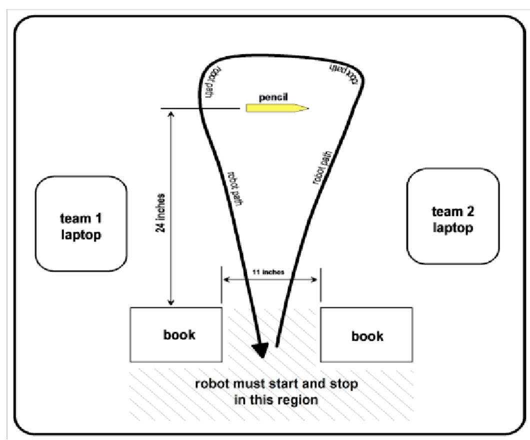

Figure 3. "Around the Pencil" BOE-Bot navigation challenge.

The third in-class exercise in this sequence occurs during class 9. The students are given an audio file of a “wolf whistle” and asked to make the BOE-Bot reproduce this sound. The students have recently learned about incremental step sizes in a loop and use this technique to reproduce the sound. This activity is either done solo or in pairs.

The next activity occurs during classes 13 and 14. As part of this activity students are taught to solder. There is regular lecture type instruction as well as short video modules that the students can watch for more detail. Students solder longer leads onto their photoresistors. Students use the photoresistors to explore the RCTIME command. If time permits, students use the photoresistors with the longer leads to navigate a small maze. In honors classes, this occurs after the students have navigated the maze by dead reckoning. The soldering is done as individuals, while the navigation is done in teams of four.

Figure 4. Parts given to students for fabricating their pumps.

Throughout classes 14 to 17 students are busy fabricating a centrifugal pump using the milling machines. This project is not robotic in nature, but it is worth mentioning. The students will later use this same pump as part of a larger control system in the subsequent course. This quarter the students will design the pump impeller in SolidWorks and print it on a Dimension 1200 EST 3D printer. The students will fabricate the pump housing from PVC stock and assemble the pump. The parts given to the students can be seen in Figure 4.

The students then test the pumps to determine their efficiency by calculating the amount of fluid work done over a certain time period versus the amount of electrical energy input. Typical numbers for the pump efficiency do not exceed 5%, but they are capable of pumping about 1L/min. Figure 4 shows the pump parts as the students receive them. The pumps are built in teams of two. This concludes the "robotic" portion of the first course in the LWTL freshman sequence. The students have been learning a variety of other things along the way as well. Those students earning a "C" or better in this course and in the corresponding Calculus I course will move on to Engineering 121 (ENGR 121).

Engineering 121

Engineering 121 revolves around the "fish tank". This fish tank is a closed-loop control system in which students program their BOE-Bot to measure the temperature and salinity of a small volume of water and to maintain both within prescribed ranges. Almost the entire fish tank and control system are built from scratch, only the solenoid valves used to control the flow of salty and deionized water are store bought (along with various circuit elements).

The first electromechanical activity of ENGR 121introduces the students to an integrated circuit – the 555 timer. This introduction occurs in class 3 after the students have built a conductivity sensor and learned some basic mass balance during the first two classes. The students go through a thorough lecture on the workings of the 555 timer and the BOE-Bot's COUNT command. This command counts the number of hi/low/hi cycles in a given time interval. Also, the operation and construction of capacitors are more clearly defined. Pairs of students are asked to implement the 555 timer with their photoresistor in order to become familiar with circuit.

During class 5 the student pairs replace the photoresistor with their recently fabricated conductivity sensor, and calibrate the sensor by building the fish tanks flow circuit. The flow circuit consists of the pump from ENGR 120, and the fish tank and conductivity sensor both from ENGR 121. Students record the output from their 555 timer and COUNT command at

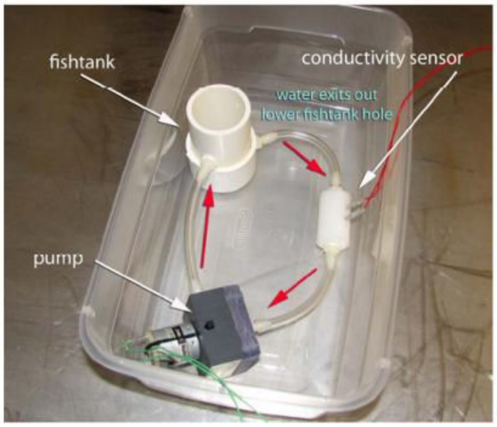

Figure 5. Flow circuit used for calibration of the salinity sensor.

various known concentrations of salt water and use this data in MS Excel to determine a calibration equation for their salinity sensor. A picture of the flow circuit can be seen in Figure 5. The next step is to use this data to control the opening and closing of solenoid valves connected to deionized and salty water tanks.

During classes 7 and 8 the students are introduced to transistors, relays, and solenoid valves by building a cascading switch controlled by their BOE-Bot. This is typically the first time the students think of the BOE-Bot as something other than a robot and begin to see it as a microcontroller. The students are first given an atomic level introducing to semi-conductors, doping, diodes, and transistors. In class 8, the students look inside a typical relay and learn to use the BOE-Bot to switch a transistor connected to a relay controlling a solenoid valve. Now the students have enough information to be able to regulate the salinity of the water in their fish tank. These activities are done in pairs, but the fish tank control will be done in teams of four.

Class 9 in a big step in the LWTL curriculum. During this class, the student teams bring their fish tank to class and demonstrate their ability to maintain the salinity of their water within a given range. The teams stabilize their systems and let the professor know they are ready to be tested. The professor will add either salty or fresh water to their tank and observe the response of their system. Their system should display the current salinity and status of each solenoid valve. Also, and most importantly their system should be able to restore the water to the correct range of salinity. A typical output panel of this process can be seen in Figure 6.

```
Salinity of Water in Tank:                        Valve Status:
    Lower Limit (0.08%) =      2013                  Salty Valve = off
    Current Salinity =         3513                  Fresh Valve = on
    Upper Limit (0.12%)=       3013
```

Figure 6. Output panel for salinity control of the fish tank.

This achievement marks a milestone in the course, but it is only half of the fish tank control system. Beginning in class 12, the students learn to control the temperature of the water. Students are formally introduced to the RCTIME command and the concept of an RC circuit. Students may have seen this in ENGR 120 if time allowed for their class to explore the photoresistor deeper. However, not all classes have time for that so the RCTIME command is covered during this class. Students build a small RC circuit using their photoresistor as the variable resistor and use it to distinguish dark and bright light levels. This activity is done in pairs.

Classes 13 and 14 have the students in teams of four fabricate a resistance temperature detector or RTD. The students learn the major steps of photolithography and create a mask, spin on photoresist, bake, expose, and develop their RTD patterns on a nickel coated glass slide. The slides are then sent off to our nanofabrication lab for etching. The students receive their etched RTDs on class 15 and complete their fabrication by soldering leads onto the RTDs and sealing them against water. Representative photos of the RTD fabrication can be seen in Figure 7.

Figure 7. Fabrication of an RTD using photolithography.

Class 16 requires the student teams to calibrate their RTD, this is done in groups of four. The student teams use the RCTIME command to measure the resistance of the RTD in various known temperatures of water. Using the same approach as the calibration of the salinity sensor, the students calibrate their RTD. The students have also been given a small resistive heater to use to heat the water in the fish tank. Now all of the elements for controlling both the temperature and salinity of their fish tank are present.

On class 17 the student teams follow much the same procedure as when the salinity control system was tested, only with the added challenge of regulating temperature as well. The students must demonstrate to the professor the ability of their system to recover from both a change in temperature and a change in salinity. For instance, the professor may add cold, salty water and observe the response of their system. Ideally, the system will manage to raise the temperature to the set point as well as stabilize the salinity within the prescribed range. Typically 8 or 9 of the 10 teams in a class will be able to achieve both of these requirements. During the following class, the student teams are asked to give a short presentation of their results and conclusions concerning their control system.

This is the last major activity of Engineering 121. This is a very intense quarter and the successful students mature very quickly during this process. Students earning a “C” or higher in both ENGR 121 and Calculus II are allowed to move on to the third course in the LWTL sequence, ENGR 122.

Engineering 122

The focus of Engineering 120 is to help students begin to make the transition from high school to college at a steady, but reasonable pace. There are more guided activities in this first course than in the second and third. At the same time, there are engaging fabrication projects. Engineering 121 has a much faster pace with much more autonomy given to the students. The fish tank project is still well constrained and guided, but the pace is almost frantic. This demanding pace is on purpose, as the accomplishment of the seemingly impossible begins to instill the “can-do” attitude in the students that we are seeking. Where the first two courses are well defined and more or less guided, Engineering 122 is very open ended and allows the creative side of the students to really begin to blossom.

Engineering 122 has at its core the "Freshman Projects Exposition". This event is held at the end of the quarter where students showcase products they have designed and built during the course of ENGR 122. The "Electromechanical" thread continues through ENGR 122 in the form of several short modules demonstrating a variety of sensors and mechanical devices as shown in Table 2. Additionally, the students are given several homework assignments where they are to research additional sensors on their own. Parallax has an extensive list of sensors that are designed to work with the BOE-Bot.

Table 2. Engineering 122 electromechanical modules.

Electronic Sensors	Mechanical Devices
Ultrasonic	**Linkages**
RFID	**Gears**
GPS	**Rivets**
Accelerometer	**Sheet metal tools**
RF transmitter/receiver	**Worm screws**

The student design projects are very open ended and allow the students to create a product based a problem that they have identified themselves. It is required that the students incorporate some level of control system in their product. Other papers[12,13] have been written that discuss the freshman design projects in more detail. The products relate to this paper in that they are electromechanical in nature. Examples of previous design projects are given in Table 3.

Table 3. Project titles from previous Freshman Design Expos.

Freshman Project Titles
1. Self-Leveling System for Trailers
2. Electronically Assisted Trailer Hitching
3. Portable Themed Pinball Machines
4. Robotic Lawn Mower
5. High Efficiency Escalator
6. Air Cannon Deer Feeder
7. Eco Friendly Lighting System

Sustainability

The LWTL curriculum requires a good deal of prep time to continue to flow smoothly. Weekly faculty meetings are held by the LWTL faculty (typically there are seven faculty and three graduate students). These meetings last approximately one hours and are necessary to stay ahead of any potential problems. We found that our curriculum tends to drift apart without these weekly meetings.

A larger portion of the day-to-day maintenance of the classroom and supplies is handled by our “Help Desk” workers. 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. The Help Desk is open Sunday through Thursday night of each week from 6 p.m. until 8 p.m. 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.

Figure 8. Vending machine for electronic components.

The operational costs of the projects are handled through a student lab fee, but are relatively small on a per student basis. Since most of the projects either use the BOE-Bot kit (which is student purchased) or fabricated from bulk material, the supply cost per student is not large. There are a few expensive items such as the solenoid valves in ENGR 121 and some of the more exotic sensors that students may use in ENGR 122, but these items are recovered at the end of the quarter and reused. Additionally, if students loose a transistor or relay, or if they simply want an extra one for whatever reason, we have converted a vending machine to dispense a variety of electronic components. A picture of the machine can be seen in Figure 8.

Data and Assessment

The Living With the Lab curriculum has greatly increased the hands-on activity of our freshman students. Preliminary data also indicates that students are being retained at an equal or higher rate than our previous (much less rigorous) freshman curriculum. There is no graduation data to report yet. This section will report the relevant data for these claims. Full annual reports are available at www.LivingWithTheLab.com.

Assessment data is collected through a variety of sources. There are end-of-quarter surveys for each of the LWTL courses, these surveys are administered through BlackBoard © www.blackboard.com. Retention data is collected through the University's student records and compiled and analyzed using MSExcel. Additionally, focus groups are conducted

Increased Hands-on Activity

One of the major assumptions of the "Living with the Lab" is that students' ownership and maintenance will result in students obtaining more hands-on practice. This assumption is dramatically demonstrated by examining Tables 6, 9, 12 and 16. The data from those tables, which indicates the "hands-on" application by class, is used to produce a visual demonstration of significance. The yellow shading indicates that the "Living with the Lab" is more than 3 times *greater than the "Old" curriculum* for all sections. The black shading indicates that the old curriculum is greater than all sections of the "Living with the Lab" curriculum. This only occurred with the sawing operation in ENGR 120. The blue shading indicates that the "Living with the Lab" sections are greater than the "Old" curriculum but not 3 times greater for all sections. The red shading indicates that the results are inconsistent. In some cases the new curriculum is greater and in some cases the new curriculum is smaller than the old curriculum. In Table 19, the "Living with the Lab" curriculum is more than 3 times greater than the "Old" curriculum 29 out of 45 opportunities. The "Living with the Lab" curriculum is greater than the "Old" curriculum 37 out of 45 opportunities. In only one instance, is the "Old" curriculum consistently less than the "Living with the Lab" curriculum. The results in Table 4 demonstrate that students' ownership and maintenance does result in students obtaining more hands-on practice. Also, the raw data can be seen in Table 5. In addition to evidence provided by student surveys, students in focus groups and in the Design Expo indicated that they spent a significant portion of their time in "hands-on" practice.

Table 4. Shaded Representation of More Hands-On Practice in 120 and 121.

Item	120 "Old"	120 "LWL"	121 "Old"	121 "LWL"	122 "Old"	122 "LWL"
	A	B	C	D		
Assembly						
Bending						
Cutting internal or external threads						
Drilling						
Implementing circuits on a breadboard						
Layout						
Milling						
Rapid Prototyping						
Sawing						
Soldering						
Using a dial indicator						
Using a lathe						
Using a multimeter						
Using a scale						
Writing PBASIC programs						

Table 5. Raw data for times during the quarter a student performed a given operation.

Item	ENGR 120 Old	ENGR 120 New	ENGR 121 Old	ENGR 121 New	ENGR 122 Old	ENGR 122 New
Assembly	2.15	2.69	.55	7.84	3.10	11.11
Bending	1.04	0.70	.18	1.88	4.77	7.05
Cutting internal or external threads	.23	1.21	.02	6.01	.55	3.89
Drilling	1.81	2.33	.55	8.54	4.29	10.95
Implementing circuits on a breadboard	.04	11.49	.49	14.36	.62	15.84
Layout	1.35	1.77	.63	7.55	2.24	13.00
Milling	.34	1.87	.00	4.14	.09	3.73
Rapid Prototyping	.21	0.68	.00	0.91	.71	2.25
Sawing	1.52	0.31	.15	0.91	2.05	6.82
Soldering	.14	1.28	.05	4.14	2.17	5.71
Using a dial indicator	.07	3.83	.02	5.85	.17	6.22
Using a lathe	.24	0.45	.02	1.68	.06	1.42
Using a multimeter	.26	6.63	.33	6.72	2.28	6.38
Using a scale	4.12	2.37	1.06	8.53	3.59	15.71
Writing PBASIC programs	.00	15.64	.05	12.41	.02	11.89

The surveys from ENGR 120, ENGR121, and ENGR 122 also demonstrated dramatic difference between the confidence and frequency of performance between students in the old curriculum and the new curriculum. For ENGR 120, there were 23 items where the "Living with the Lab" students reported a statistically greater confidence than the students in the old curriculum and 21 items where they reported a statistically greater frequency of performance than students in the old curriculum. For ENGR 121, there were 16 items where the "Living with the Lab" students reported a statistically greater confidence and 21 items where they reported a statistically greater frequency of performance than students in the old curriculum. Finally, in ENGR 122 there were 13 items where the students in "Living with the Lab" reported a statistically greater confidence than students in the old curriculum and 13 items where they reported frequency of performance was statistically higher.

The preponderance of evidence indicates that the "Living with the Lab" curriculum is successful in increasing confidence and frequency of performance when compared with the old curriculum.

The relationship between confidence and frequency of performance is not clear. There is definitely a link, but it is possible to perform an activity frequently and still not feel confident and it is also possible to feel confident without having to perform an activity. This relationship should be explored further as more data becomes available.

Student Retention Data

We are in the process of collecting retention data for the LWTL curriculum. Data from our previous curriculum showed at freshman to sophomore retention rate of approximately 62% with a graduation rate of only 35% of the original cohort. These numbers indicated to us that though students were passing the freshman curriculum at a relatively high rate, they were not being successful in the following courses. In an attempt to better prepare engineering students for the upper level courses, the LWTL curriculum was designed to be more rigrous while maintaining a high level of hands-on activity. The most recent data show that the freshman to sophomore retention rate for the LWTL curriculum is around 68%. Also, the incomplete data for the current year, shows a similar retention rate. No analysis on student performance in the upper level courses is available at this time.

The retention data seem to indicate that although the LWTL curriculum is more challenging, that students are being retained at a slightly higher rate than versus the previous curriculum. More thorough analysis of the retention data is needed to determine if there is a significant difference in the retention numbers between the two curricula. The consensus among the LWTL faculty is that the tougher curriculum forces students to choose to either change from engineering sooner or choose to change their work habits in order to be successful.

Conclusion and Future Work

The Living With the Lab curriculum at Louisiana Tech University has been successfully implemented and has shown a marked increase in hands-on activity in the freshman year versus our previous curriculum. Future work in this analysis requires similar questions to be asked of freshman students in other engineering programs. The data also show the LWTL curriculum to have the potential to increase student retention, while simultaneously increasing the rigor of the course content. Longitudinal studies are needed in order to determine if the LWTL curriculum can affect graduation rates.

Future work for the curriculum itself includes a planned revision for the Fall Quarter of 2010. During this quarter an honors section of freshman engineering students will pilot the use of a different microcontroller in the LWTL curriculum. Two of the major limitations of the BOE-Bot is the absence of floating-point calculations and the lack of analog inputs. It is envisioned that next year's pilot will overcome these two limitations and also increase the level of fabrication in Engineering 120. Students will use SolidWorks to model a chassis for their microcontroller and cut the pattern using our OMAX waterjet cutting system. Other ongoing modifications to the curriculum include tighter integration of content between the engineering, calculus, and science classes of the freshman year.

Bibliography

1. Splitt, F.G., "Systemic Engineering Education Reform: A Grand Challenge." The Bent of Tau Beta Pi, Spring 2003.
2. Sheppard, S. and Jenison, R., "Examples of Freshman Design Education." International Journal of Engineering Education, 13 (4), 1997, 248-261.
3. Weggel, R.J., Arms, V., Makufka, M. and Mitchell, J., "Engineering Design for Freshmen." prepared for Drexel University and the Gateway Coalition, February 1998. http://www.gatewaycoalition.org/files/Engrg_Design_for_Freshmen.pdf

4. Richardson, J., Corleto, C., Froyd, J., Imbrie, P.K. Parker, J. and Roedel, R., “Freshman Design Projects in the Foundation Coalition.” 1998 Frontiers in Education Conference, Tempe, Arizona, Nov. 1998.
5. Hanesian, D. and Perna, A.J., “An Evolving Freshman Engineering Design Program – The NJIT Experience.” 29th ASEE/IEEE Frontiers in Education Conference, 1999.
6. Carlson, L.E. and Sullivan, J.F., “Hands-on Engineering: Learning by Doing in the Integrated Teaching and Learning Program.” International Journal of Engineering Education, 15 (1), 1999, 20-31.
7. Carlson, L., Sullivan, J. Poole, S. and Picket-May, M., “Engineers as Entrepreneurs: Invention and Innovation in Design and Build Courses.” 29th ASEE/IEEE Frontiers in Education Conference, San Juan, Puerto Rico, 1999.
8. Hein, G.L. and Sorby, S.A., “Engineering Explorations: Introducing First-Year Students to Engineering.” 31st ASEE/IEEE Frontiers in Education Conference, Reno, Nevada, October 2001.
9. National Academy of Engineering, “The Engineer of 2020.” The National Academies Press, Washington DC, 2004. www.nap.edu
10. Pomalaza-Ráez, C. and Groff, B.H., “Retention 101: Where Robots Go . . . Students Follow.” Journal of Engineering Education, January 2003, pages 85-90.
11. Swanbom, M., Harbour, D., Hegab, H., Eddy, D. Microprocessor-Based Control System for Integrated Freshman Curriculum. American Society for Engineering Education Annual Conference and Exposition, June 2009.
12. Hall, D., Barker, M., Nelson, J. Living with the Lab: Update on the Second Year of Full Implementation for Over 400 First-Year Engineering Students. American Society for Engineering Education Annual Conference and Exposition, June 2009.
13. Crittenden, K., Hall, D., Barker, M., Brackin, P. First-Year Design Experience: Assembling the "Big Picture" Through Innovative Product Design. American Society for Engineering Education Annual Conference and Exposition, June 2009.
14. Hall, D., Cronk, S., Nelson, J., Brackin, P. The Facilitation of Lifelong Learning Skills through a Project-Based Freshman Engineering Curriculum. American Society for Engineering Education Annual Conference and Exposition, June 2009.
15. Cronk, S., Hall, D., Nelson, J. Living with the Lab: A Project-Based Curriculum for First-Year Engineering Students. American Society for Engineering Education Gulf Southwest Division Annual Conference. Waco, TX. March 2009 (12 pages).
16. Hall, D.E., Hegab, H.E., Nelson, J.D. Living WITH the Lab - A Freshman Curriculum to Boost Hands-on Learning, Student Confidence and Innovation, 38th ASEE/IEEE Frontiers in Education Conference, October 2008 (6 pages).
17. Hegab, H.E., Hall, D.E. Microfabrication of a Resistance Temperature Detector, 38th ASEE/IEEE Frontiers in Education Conference, October 2008 (6 pages).
18. Swanbom, M.E., Hall, D.E., Crittenden, K.B. Centrifugal Pump Design, Fabrication and Characterization: A Project-Driven Freshman Experience, American Society for Engineering Education Annual Conference and Exposition, June 2008. (16 pages).
19. Hall, D.E., Cronk, S.R., Brackin, P.D., Barker, J.M., Crittenden, K.B. Living with the Lab: A Curriculum to Prepare Freshman Studets to Meet the Attributes of "The Engineer of 2020," American Society for Engineering Education Annual Conference and Exposition, June 2008 (17 pages). 2nd Place Best Paper Award, Freshman Program Division; this paper was also invited for presentation and publication at the 63rd ASEE EDGD Midyear Conference held January 4-7 in Berkeley, California
20. Reed, A., Creekbaum, T.M., Matthew, E.D., Hall, D.E., Harbour, W.D. Utilizing Robotics to Facilitate Project-Based Learning: A Student Perspective, American Society for Engineering Education Annual Conference and Exposition, June 2008 (14 pages). This paper was invited for publication in the Computers in Education Journal, Vol. XVIIII No. 1, January - March 2009 pages 2 - 11.
21. Hall, D.E., Barker, J.M., Nelson, J.D., Living with the Lab: Expanding a Project-Based Freshman Curriculum to Over 350 Students, American Society for Engineering Education Annual Conference and Exposition, June 2008 (POSTER ONLY).
22. Hegab, H.E., Hall, D.E. Increasing Experiential Learning in Freshman Engineering through a Microfabrication Project, ASME International Mechanical Engineering Congress and Exposition, 2007 (5 pages).
23. Hall, D., Barker, M. Living with the Lab – Boosting Experiential Learning and Creativity in 1st Year Engineering Students, Intelligent Automation and Soft Computing, **13** (1), 2007, 3-18.
24. Barker, M., Hall, D. Teaching Innovative Product Development Skills to Freshman Engineering Students, American Society for Engineering Education Annual Conference and Exposition, June 2004 (10 pages).