University of Massachusetts Lowell "Laboratory in a Box" For First Year ECE Students

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Abstract - **This paper describes the first year Introduction to ECE program at University of Massachusetts Lowell. The goals of the program for 2nd semester ECE students are to excite the students about ECE through hands on activities, to equalize out the gaps between students who have hands on experience and those who do not, and to stress problem solving, programming and analytical skills required for success in the ECE curriculum. The hands-on gap exists especially between male and female students and between students from affluent versus non affluent high schools. The first year experience is based on our version of the "Lab in a box" which is a complete electronics workbench that can be taken home and used anywhere there is a computer. Students work on their own rather than with lab partners insuring that everyone gets the hands on experience. This paper describes both the "Lab in the Box", as well as a sample first year curriculum based on using the equipment and includes open ended design projects. Use of "Lab in a Box" is currently being extended to 2nd and 3rd year students.**

Index Terms – First Year Engineering Education, Lab in the Box.

INTRODUCTION

University of Massachusetts Lowell located northwest of Boston is the second largest university in the University of Massachusetts System. It is best known for its professional programs in engineering, management, nursing, and health sciences. The College of Engineering runs a common first semester Introduction to Engineering Design for all its first year students. The second semester students take department specific Introduction to Engineering Courses. The initial survey at the start of the second semester ECE specific course (summarized in Figure 1) at University of Massachusetts Lowell showed that only 35% of the incoming first year ECE class (140 students) had any formal programming experience in High School, and less than 40% of the students had ever constructed an electronic project prior to arriving on campus. The students that have this experience are primarily male, and primarily from more affluent suburban High Schools. The students entering ECE with both programming and hands on experience are at clear advantage, and this gap only widens as they move into the later years. Based on surveys of students leaving the ECE program without graduating, and with a desire to address the gap in hands on experience going into the Sophomore year, we took a look at ways of providing a hands on experience to 140 (going on 200) students each year. Unfortunately in past years, resource requirements to run hands-on design program both in terms of lab space, test equipment, and TA support made an individualized hands-on program impractical.

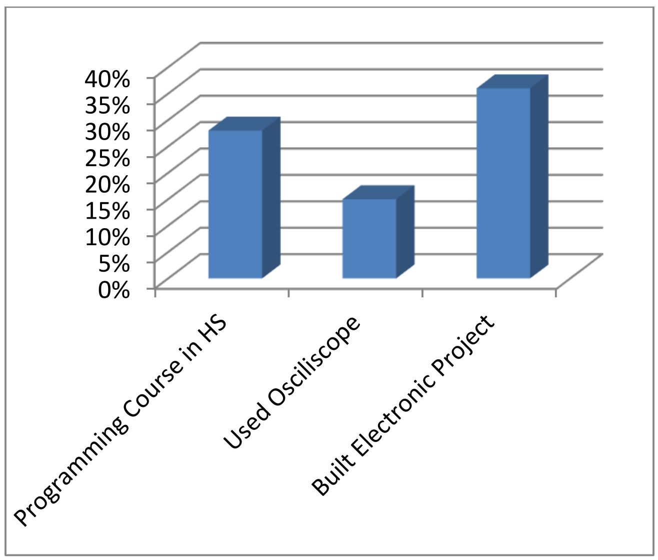

FIGURE 1
EXPERIENCE OF INCOMING FIRST YEAR ECE STUDENTS.

University of Massachusetts Lowell, working with nearby Analog Devices and Digilent is experimenting with approaches to get students excited to be an Electrical or Computer Engineer by allowing them to work on both formal labs and open ended design projects on their terms: in their dorms, in the cafeteria, in the student lounge. The approach is to give all first year students our version of the "Lab in a Box". While the "Lab in a Box" concept is not totally new [1, 2], our version is different in both the contents and how it will be used. Our goal is to furnish a complete electronics lab that can be used anywhere there is a computer. One of our key goals is to stress programming and use of sophisticated test equipment early in the program. It consists of a parts kit, wire kit, the Parallax "Board of Education" microcontroller with proto board (to teach programming), and the Digilent/Analog Devices "Discovery Kit" (a complete test bench). The Analog Devices Discovery module is a complete electronics test system consisting of 2 Channel Digital Oscilloscope, Function generator, Digital Logic Analyzer, voltmeter, and power supply. Software development environments for the "Board of Education" and the "Discovery Kit" are provided to the students. Together these elements shown in Figure 2 represent a complete electronics lab that stresses our priorities in engineering education.

FIGURE 2
COMPONENTS OF THE UML FIRST YEAR "LAB IN A BOX"

In the first half of the semester, students learn application programming skills using Matlab. By mid semester, they are ready to tackle a series of hardware/software projects, including open ended design projects. They learn how to use a digital oscilloscope, waveform generator, and logic analyzer. Figure 3 shows the setup of the lab with one of the Authors working with a student to complete their experiment.

The plan is for students to purchase the "Riverhawk Lab in the Box" at the beginning of their first year and use it for their entire 4 years and their capstone project. This paper describes the design of the curriculum, and presents data from previous first year classes showing that this approach does improve retention, excite the students, better prepare the students for their sophomore year, and improve overall success.

TOP LEVEL GOALS FOR OUR FIRST YEAR COURSE

Many "baby boom" generation engineers still remember their first hands on electronics experience as teenagers. Many built radios from either tubes or discrete transistors, were amateur radio operators, or built their stereo systems and other projects from kits such as Heathkit. Today, most engineering students generally do not have access to the kinds of hands-on experiences as previous generations. The number of amateur radio operators under 30 is significantly down. The goals of the "Lab in a Box" curriculum designed initially for first year students and expanding to 2nd and 3rd year is to provide individualized hands on experience to students to try to make up for the lack of hands on experiences as teenagers. This section describes our top level requirements for the first year curriculum to go along with our "Lab in a Box".

Goal Number 1: Everybody gets Hands-on Experience: Many generations of engineers remember as students working in labs in teams of 2 or 3 students sharing a test setup. Often the top student of the group did the work; the others either watched or did other things. Today doing other things means checking e-mail, texting, or playing games on cell phones. Only one student gets the real hands on experience, and this is probably the one that least needs it. This observation leads to the first goal of the curriculum design: Everybody needs access to a set of test equipment and needs to do each experiment by themselves. They can get help if they need it, but each student needs to do each experiment.

Goal Number 2: Scalability and Cost: The first year electrical engineering class at University of Massachusetts Lowell is increasing in size by over 10% per year. We expect to be at about 200 first year ECE students in the next few years. Our target size for laboratory classes is no more than 19 students per section. For a class of 200 students with 19 students per section (11 sections and 11 Teaching Assistants), and 2 hours formal lab per week, per section, this requires availability of a laboratory with 19 sets of equipment for a minimum of 22 hours per week just for this class. Working with real test equipment, the classic model for laboratories does not scale if the goal is to have everybody to work by themselves. There is not enough equipment or laboratory space to satisfy goal number 1.

In the current curriculum model, we created 35 of the kits and students check them out each week. After the curriculum is fully developed, students will purchase their individual kits in the first year and use them throughout the 4 years. The goal is for the complete laboratory kit to be on the order of about $200.00, which is approximately the cost of an engineering text book. Students furnish their own computer to work at home or use computers in a generic computer lab on campus.

Using the “Lab in a Box” model, instead of a fully functioning lab with 19 equipment stations, we require only a computer room with 19 computer stations. The savings in test equipment is on the order of 50,000 to $100,000. There is also significant savings on equipment maintenance. Students are responsible for the care and maintenance of their equipment.

Because students can and probably would prefer to work at home, we will change from 2 hours of lab with the TA to 1 hour in which the students bring in their work to show their TA and get help if they need it. This addresses the space issues and reduces TA cost issues. We are also experimenting with access via Instant Messenger or Skype so students can ask questions of a TA.

Goal Number 3: Enhance Open Ended Design and Innovation Experience: Our industrial advisory board has for years been concerned about both the lack of student exposure to state of the art test equipment and test procedures, and the lack of open ended design experiences prior to their senior capstone experience. As the University moves towards a formalized co-op experience as part of the curriculum, getting the students more hands on experience earlier in their studies is increasingly important.

Based on input from our industrial advisory board, the third requirement for the curriculum design is that there are open ended design experiences for first year students in which we give a set of requirements and have them figure out a solution, rather than classic “wire by number” step by step laboratory approaches. In the ECE Hardware Module using the “Laboratory in the Box”, there should be 2 to 3 open ended projects.

When students have their own electronics workbench in a box and can work at home, they can work on more advanced and individualized projects on their own. Since many students work odd hours, and find it hard to schedule time when the laboratory is open, this provides incentive for students to innovate and explore.

Goal Number 4: Stress Programming, Test Automation, and Analytical Thinking

Many engineering students find that programming is one of the hardest things to learn, and the low rate of success of engineering students in programming classes requires that students get as much experience in this class in preparation. Students learn both classic high level application programming using Matlab, and microcontroller programming using the “basic stamp” board. The students also learn how to take outputs from test instruments and analyze the data.

A 7 WEEK MODULE FOR FIRST YEAR STUDENTS USING THE “LAB IN THE BOX”

In this section we describe the curriculum for the 7 week module incorporating hardware and software using the “Laboratory in the box” concept. The current format of the class consists of one hour of lecture per week with the entire class and two hours for formal lab time per week led by a Teaching Assistant, with a maximum of 19 students per lab section. Grades are based on the labs and projects and are given jointly by the TA and the professor. The lectures are video captured and posted for students to view. All laboratory materials are posted on the course website. The module was designed to be scaled to the entire college first year class and to be run as blended (online/in class) course.

Week 1: Learning how to use the digital oscilloscope, and building a digital “Blinker”. In this first laboratory, students learn the function of resistors and light emitting diodes (LED’s). They use the voltmeter function of the Discovery Kit to measure the voltage drop across the LED’s. They write a simple program on the microcontroller to make an LED blink. They use the digital oscilloscope to look at the waveform at the output of the microcontroller. They then make a second LED blink alternatively, and look at both waveforms. They then change the duty cycles and blinking rates and look at the waveforms on the oscilloscope.

Week 2: Reading the status of switches: In the second week they learn how to read the value of a push button switch using the microcontroller and have the light blink when the switch is depressed. They look at switch bounce using the oscilloscope. At the end of week 2, they have to start their first open ended design project which is to design a traffic light controller for a 4 way intersection given a set of specifications.

Week 3: Controlling a servo motor. In this laboratory they learn how to use Pulse Width Modulation to control a servo from the microprocessor. As they do so they observe the waveforms using the digital oscilloscope. We introduce the concept of the capacitor as a filtering or smoothing device.

Week 4: RC time constants: In the fourth week they learn about charging and discharging of capacitors and the filtering of waveforms. They use the oscilloscope to measure the RC time constants after calculating it theoretically. They start open ended design project 2: using the servo motor to design a pair of windshield wipers.

Week 5; Sound and frequency: In this laboratory they use the FFT capability of the digital oscilloscope to break down the spectral content of several different waveforms. They use the microcontroller to write a simple ring tone. This also secretly teaches concepts of pointers and memory management.

Week 6: Transistors and Photo Resistors: In week 6 students learn how a transistor and photo resistor works, using the microcontroller to control a transistor and read the values of light sensitive resistors.

Week 7: Operational Amplifiers: In the final week students learn how an operational amplifier works by using the function generator and the oscilloscope to build and measure the gain and frequency response.

FIGURE 3
LAB SETUP SHOWING STUDENTS USING THE ANALOG DEVICES DISCOVERY KIT TO MEASURE WAVEFORMS ON THE MICROCONTROLLER

CONCLUSIONS

This is the first semester using the "Laboratory in the Box". It is believed that this approach will turn out to be a disruptive change in ECE education. The "Laboratory in a Box" based on the Analog Devices Discovery Kit allows all students to have an individualized hands-on experience with state of the art test equipment early in the curriculum, on their own terms. It allows students to explore, innovate and learn where and when it is best for them. It also changes the economics and scalability of providing hands on experience with modern equipment to large numbers of students. In the first semester of the new curriculum, 91% of the students who started the course completed the course, versus 83% when the course was run the previous years. The curriculum teaches core skills required for every ECE student to succeed: design, programming, analytical thinking, engineering measurements.

We have several observations based on the first running of the course.

What Worked:

1) In the first semester of the new curriculum, 91% of the students who started the course completed the course, versus 83% when the course was run the previous years.
2) The end of semester Survey showed that almost all students enjoyed and had fun doing the projects.
3) Several Students reported that the hands on experience gained in this class helped them to land internship or summer jobs.
4) This class is prerequisite for several of the sophomore year classes including circuits, logic design and applications programming, and it will be seen whether student performance in the next year improves because of this class.

What Needs Improvement:

1) Based on observation, we estimate that about 60% of the students are capable of doing the experiments on their own. However, about 25% of the students, due to gaps in their backgrounds, require significant TA support. As we try to structure how to run the lab in terms of how many TA's, how many hours the lab needs to be staffed etc. this will have to be taken into consideration.
2) Each "Lab in The Box" kit was shared in effect by 9 students per week. While the main kit held up fairly well, by the end of the semester, the parts boxes were in bad shape. Having students responsible for their own kits would greatly minimize costs of maintaining the kits.
3) The end of semester survey showed that students still find learning to program a challenge. Trying to make it fun by having them do open ended projects helps, only up to a point.

We plan to move quickly to a model where students purchase their own lab kits and begin where appropriate to work independently. Our conclusion is that this lab in the box concept is disruptive in terms of changing the accessibility of engineering students to state of the art test equipment.

At the beginning of the first year ECE class only 15% of the incoming students had used an oscilloscope. Now at the end of the class 100% of the class has made measurements using state of the art test equipment, programmed a microcontroller, and built electronic projects.

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