A Manipulative Rich Approach to First Year Electrical Engineering Education

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***Abstract* - Instruction of innovative engineering design skills has been identified as an important goal for engineering educators. Some universities choose to delay the design content of their curriculum until the senior year, when the designers can utilize the engineering concepts learned in lectures. This delay is unnecessary as the skills needed for innovative designs can be learned independently from the engineering theories being implemented. The first year curriculum at OSU introduces three design courses, each with a manipulative rich laboratory provided by the TekBots program and staffed by freshman mentors. The three initial TekBots courses explore core topics to our incoming students, which include computer architecture, analog circuits, and digital circuits. Further enhancements to the first year electrical engineering course include curriculum development, increased collaboration with other departments, and development of a high school outreach program.**

Key Words- TekBots, Engineering Education, Freshman Year, Electrical Engineering, Platform for Learning

I. INTRODUCTION

The first year in an engineering program is the most important stage of engineering education. Incoming students are introduced to a completely new style of learning. This first year also sets a precedent for the remaining years as an engineering student. ABET requirements add another challenge to planning a first year curriculum. In her keynote speech at DesignCon 2007, Leah Jamieson brings attention to additional challenges for engineering educators. She describes a need to add other additional abilities and traits, such as innovation, leadership, decision making, and an ability to recognize and manage change [1]. An excerpt from her speech outlines an alternative approach to curriculum design.

> "An alternative proposal is to turn the curriculum inside out. The challenge is that we still need to teach engineering – technical and engineering skills – but now we need to teach this other stuff, and I contend that most of that "other stuff" is hard to teach in a traditional classroom. You do not envision a class on innovation; you do not envision a class on lifelong learning. So the question becomes, is there a way to turn the curriculum inside out; to integrate these other abilities so deeply that in fact they go along with the learning of the engineering? [1]"

II. PLATFORM FOR LEARNING

A platform for learning is defined as a common unifying object or experience that unites various classes into a curriculum sequence [2]. This comprehensive platform introduces incremental tasks and provides mastery experiences that improve self-efficacy. This program began in 2001 and has gone through iterations to improve the impact on self-efficacy. For instance, stress in the lab was reduced by switching the motor control board production to a manufacturer. Testing and hands on learning with the board still occurs in lab, but the students have more time to experiment and understand the circuit elements.

In 2000, Oregon State University began creating a solution to the need for more design, leadership, and innovation by creating a platform for learning called TekBots [2]. Inspiration for TekBots came from an intellectually substantive introductory ECE course to freshman used at Carnegie Mellon University. Their course used a simple robotic system to motivate and provide a tangible manipulative for understanding basic electrical engineering concepts [3]. Our changing needs motivated designing of a new platform for learning. All platforms for learning have several core concepts [4]:

Ownership—Each student has their own equipment and platform. This personal ownership helps the student take responsibility for their equipment and education.
Continuity—A platform provides continuity through the entire curriculum. It provides natural ties and comparisons to different topics.
Context—A platform provides an application for concepts in lecture to be given a context. Ideas have a common foundation while using a platform for learning.

Fun Factor—Through engaging hands-on experiences students are given opportunities to learn more.

Hands-on Learning—Students have an opportunity to test the theories learned in lecture and improve the implementation of these lessons within their platform.

III. EDUCATIONAL OBJECTIVES

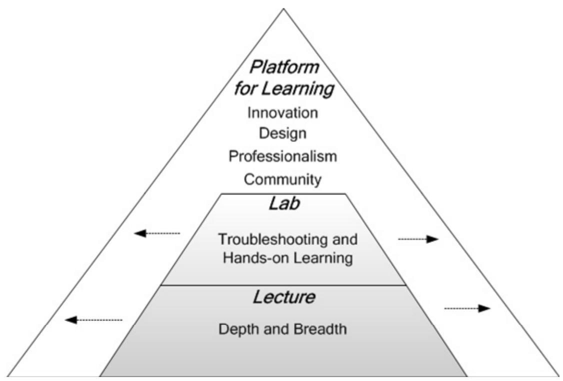

Figure 1: Model showing lecture and lab enhancement.

Figure 1 shows how a platform for learning addresses both ABET and requirements beyond ABET. Depth, breadth, and traditional engineering fundamentals required by ABET and are taught in lecture. Experiences in the lab provide opportunities for troubleshooting and hands-on learning. A platform encompasses both lab and lecture. This increases both intended effects, while also adding design, innovation, professionalism, and community [4]. The intended effect that this program has on each requirement needs to be clarified.

Depth—The ability to identify, formulate, analyze, and solve electrical and computer engineering problems by applying fundamental mathematics and engineering theory.

Breadth—A base of understanding at a systems level as well as at a component level. This includes comprehension of the global and local consequences that ECE solutions create.

Troubleshooting—A developed and practiced skill by which a student approaches the isolation, diagnosis, and resolution of engineering challenges.

Community—The ability to responsibly build relationships, learn from, teach, and lead teams of engineers.

Professionalism—The preparation for being able to effectively work in a modern workplace. This includes learning coherent communication, responsible teamwork, and an understanding of engineering ethics.

Innovation—A process by which ideas are created, experimented upon, and transformed into engineering products.

IV. FIRST YEAR PROGRAM

A. Overview

The first year of curriculum used at OSU consists of three courses and a freshman mentor program. Freshman mentors are a set of constant peer instructors that are only a year or two older than the incoming students. Mentors are employed through all three introductory courses. Each course provides a unique insight into the wide field of electrical and computer engineering. The introductory course, ECE 111, teaches engineering ethics, the basics of microcontrollers, and begins the formation of the design process. ECE 112, the second course in the series, covers a wide range of analog circuits, and allows for the transfer of microcontroller design skills to the design of analog circuits. The final course in the first year program, ECE 271, teaches digital logic and the tools needed to construct efficient blocks of logic. The lab for this course, ECE 272, gives students an opportunity to implement those designs using digital logic. Again, this lab provides a link to the designing tasks implemented in ECE 111 and ECE 112. This progression is shown in figure 2; note that the momentum gained in the first year program is utilized further in 10 future engineering courses that utilize the TekBots platform for learning.

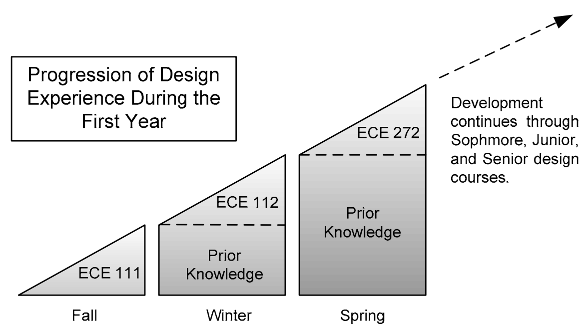

Figure 2: Model showing the progression of design knowledge

Material learned from the TekBots platform becomes a great resource for senior design projects. A high percentage of students at OSU voluntarily use a piece of the technology learned during their study of the TekBot platform for learning. An example of a senior project that most apparently used TekBot skills and hardware was a modified TekBot that found and sorted balls based upon color [5], figure 3.

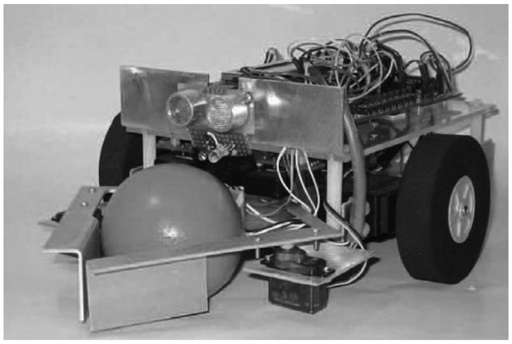

Figure 3: A senior project that used prior design knowledge

Results show that TekBots has been successful at improving the electrical engineering educational environment at Oregon State, but the platform has spread to other schools both near and far from Oregon. In Oregon, Linn Benton and Umpqua Community Colleges are using TekBots in their curriculums. George Fox University is using TekBots as a platform to base the development of system automation [6]. Outside of Oregon, the University of Nebraska [7], Texas A&M University, Rochester Institute of Technology [8], Iowa State University, and Fukuoka Institute of Technology in Japan have used and modified the TekBot platform for learning to help develop engineering curricula to meet their needs.

B. ECE 111

The initial course in electrical engineering, ECE 111, is composed of two primary components: lecture and lab. The lecture material covers ethics, student skills, and the basics of microcontroller usage, but not architecture, per se. When covering ethics, the traditional approach of case studies is used as well as ethical applications to the current student experience with discussions of academic dishonesty. Student skills include scheduling courses, interviewing practicing engineers, and developing a plan for graduation.

Lab for ECE 111 is taught by freshman mentors with groups of 25 students per section. These two hours provide students an opportunity to form community groups, build relationships with freshman mentors, and gain hands on learning with the manipulative for ECE 111. The microcontroller and PCB used are shown in Figure 4. The small size and cost of this manipulative make this a good tool to introduce electronics manufacturing without the risk of damaging expensive lab kits.

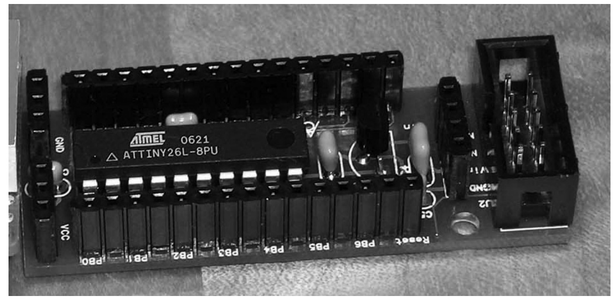

Figure 4: Microcontroller manipulative used in ECE 111

This manipulative also provides a platform to instruct peripheral skills towards actual construction of electrical engineering prototypes. These skills include component identification, soldering, bread boarding, troubleshooting, and perforated prototyping. Instruction is provided in written form, a freshman lab manual, which is used for the entire year. The freshman mentors also provide accessible support to the students while in lab.

The initial projects for the lab are structured and limited. Students calculate how to correctly limit LED current with assistance from their classmates and mentors. A microcontroller is then programmed to blink the LED at a certain rate, or to be controlled by a small switch. The last defined project uses prebuilt functions to read an analog-to-digital converter and control the number of LEDs that are lit.

About half way through the term, students are given a choice of four open ended final project ideas. Students are required to achieve certain minimums, but the maximum achievement is not set. The available project choices include building: A tachometer, a digital range finder, an inclinometer, or a project of their own choosing that gets instructor approval. Each project uses an input sensor. The tachometer counts how many magnets pass a reed switch in a given second and then outputs the result to a seven segment display. The digital range finder reads an analog signal from a sharp IR sensor to find the distance to the nearest object and then displays the result on a seven segment display. The inclinometer also reads an analog signal from an accelerometer to find the angle of an axis relative to gravity and display the result on a seven segment display. These projects are intended to be ambitious and difficult, which allows students to feel success towards engineering. A key component to being able to teach the lessons and skills needed for this resides in the training and coordination of the freshman mentors.

C. ECE 112

The second course in the platform for learning focuses on the core fundamental topics used in electrical computer engineering. Current and voltage are technically defined for the students. Their past experience with LED biasing allows them to grasp more of what the terms "current through the LED" and "voltage drop across the LED" really describe. The lecture contains an introduction to Kirchhoff's laws, circuit simulation in SPICE, diode and transistor circuits, simple logic gate formation with transistors, and logic minimization.

The lab for ECE 112 introduces the TekBot, shown in figure 5. The labs for the course are divided into four sections: Chassis and battery charger board assembly, experiments with theories, motors, and analog controller board assembly. Assembly of the charger board introduces the concept that functional blocks each perform a specific task. The bridge rectifier allows for three types of wall warts to be used: center pin positive, center pin negative, and AC. A voltage regulator enables the higher voltage wall warts to be used without damaging the operational amplifier. This introduces the students to a sound design and diagrams how a complex system can be understood by dividing it into comprehensible subsections.

This process of blocking a board is repeated with the motor controller board. A logic gate is introduced as current sequencer to an H-bridge. This current sequencer turns off both channels to the H-bridge to eliminate the switching current of the controller. Students are also taught how to troubleshoot and verify their board by using designed test pads on the circuits. This helps empower the student to fix problems as they arise.

The final board that is built in ECE 112 is the analog controller. A comparator is used to compare a voltage set by a potentiometer and a RC ramp generator. This provides timing control that is fed to the motor controller board and controller the time that the TekBot reverses and turns after bumping into an object.

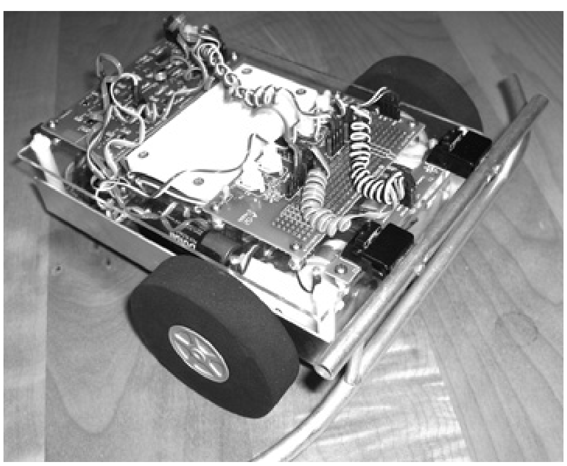

Figure 5: TekBot manipulative used in ECE 112

D. ECE 272

The final TekBots course in the first year program for TekBots is ECE 271. This course covers the analysis, minimization, and design of digital logic by introducing the following topics: Number systems, Boolean algebra, circuit minimization with Karnaugh maps, flip flops, counters and state machine design. The lab for this course, ECE 272, uses the cPLD shown in figure 6. This manipulative is used as a replacement for the analog controller used in ECE 112. The removal of the old board and installation of the digital logic board comes with a discussion that covers how an engineering problem has many solutions. Students begin to learn that their TekBot can be driven by multiple control boards, each with a different set of costs and benefits. A analog control board is less expensive. A digital logic board is more precise and can interface to infrared devices, such as a television remote.

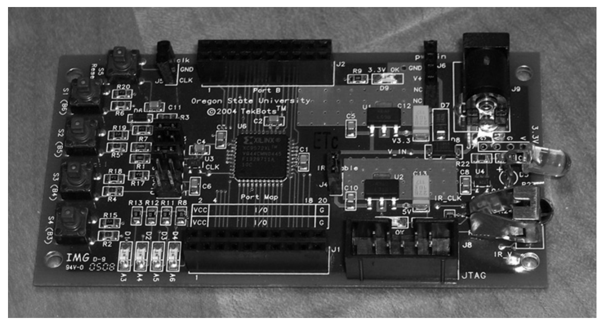

Figure 6: TekBot manipulative used in ECE 272

The ECE 272 lab begins with an overview of the new board being used on the TekBot. A quick scan of the schematic shows the students that they already have some common knowledge to leverage. There are 3.3 and 5.0 volt regulators and LEDs that have been used in ECE 111 and ECE 112. The first lab begins with using buttons to control switches, just as in ECE 111. Following labs mirror the lecture topics and give students an opportunity to gain hands on experience and increase their depth of the knowledge. The last lab gives students two options for their final project. The first is to building an IR controlled TekBot. The second option is to combine previous designs and make a tethered TekBot that automatically reacts to walls and displays the current action with a seven segment display controller.

V. Results

A voluntary survey is given multiple times a year, at least once a term. Questions pertain to different aspects of self efficacy. All questions are rated between 0 and 100 with a higher score correlating to a stronger agreement with the survey question.

Table I. Survey Results for Freshman Year Program			
Question	ECE111 Pre	ECE112 Pre	ECE112 Post
I do more than what is required in lab and create new projects with my lab materials.	42.9	58.6	61.2
I have a role model who helped me engineer something creative this term.	22.0	48.7	52.2
I have experienced success in doing engineering -related activities.	57.3	80.5	81.0

The first survey question tracks improvement in innovation within the lab. The ability to stretch the platform and their own skills beyond the original required level shows how students can be led to increasing their innovation experience.

The second survey question is used to find the level of effect that the laboratory assistants, the freshman mentor, have on the innovation that is learned in lab. Teaching creativity is difficult, but this shows that students believe they are becoming creative engineers.

The last question shows that the Platform for Learning increases the confidence by giving students early successes in engineering. Creating successful experiences in engineering are a valuable component to developing the incoming engineers.

VI. Conclusion

The engineers of the future that are currently enrolled have peripheral needs that surpass the ability of tidy math and engineering theories. Using a manipulative rich platform for learning introduces messy problems into a controlled lab setting, such as a syntax error, a defective connection, or a broken component. Working through schematics with classmates or mentors and then logically overcoming them fosters those extra skills that are becoming more important to engineers in industry.

The difficulty in teaching engineering design is the fact that it takes both confidence and familiarity with a concept, before a student can create new designs using the concept. The core concepts of a platform for learning, ownership, continuity, context, fun factor, and hands-on learning, combine to improve the delicate art of design.

VII. Future Work

Future goals for the TekBots platform for learning intend to increase learning while minimizing unnecessary difficulty. Block diagrams are going to become more a more important focus of design. Innovation will be encouraged by providing easier methods to achieve more results. The most notable change for next year will be a graphical programming environment for ECE 111. This will enable students to develop and understand sections of microcontroller programming, without the complexities that are inherent in a syntax specific programming language.

The TekBot platform for learning is in a constant process of improvement. Figure 7 shows how the forward movement of the platform is structured. Development of a course takes place during the summer by exceptional students that have first hand knowledge of the performance of the platform during the prior iteration. Students that worked on developing the course are then encouraged to assist in the implementation during the next course offering. New students and teaching assistants evaluate strengths and weaknesses of the platform, in order to focus development efforts that will happen during the next summer.

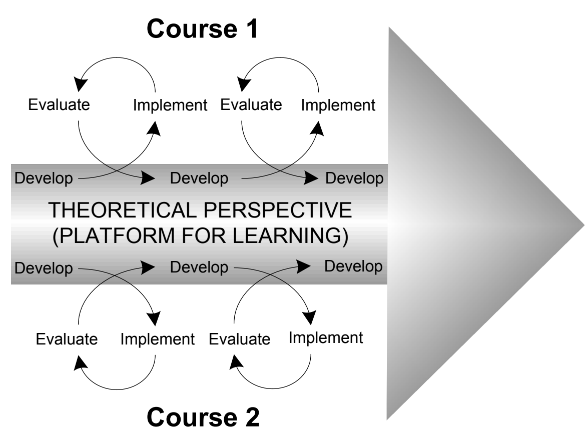

Figure 7: Procedure to improve the platform for learning.

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