INTEGRATING COMPUTER ENGINEERING EDUCATION WITH A PLATFORM FOR LEARNING

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Abstract *- Computer engineering is predominately taught in a way that separates topics into seemingly unrelated islands of information, where each island is the class in which the topic is presented. When viewed across classes, the topics seem to have little relation to each other. The way topics are presented ignores the need for connection and for integration, which should be at the core of an engineering education [2].*

Using a platform for learning across the entire computer engineering curriculum, topics in different classes which seem disconnected can be placed into a unifying framework under which all the topics can be blended into a coherent whole. The platform acts as the consistent reference point that connects the spectrum of topics throughout the curriculum.

In the spring of 2002, a new platform for learning, called a Tekbot was integrated into the computer engineering curriculum at Oregon State University. This paper describes how the integration of topics has improved the curriculum and paints a roadmap of how the platform will be used across the computer engineering curriculum.

Index Terms – TekBots, Platform for Learning, Digital Logic, Engineering Education, robot, innovation, depth, breadth, community

I. INTRODUCTION

It is essential to begin by defining a platform for learning. Although a number of definitions are valid, a platform for learning in the most general sense is a contextual framework (or umbrella) for learning that provides relevance between topics within a curriculum. It also becomes an engaging "proving ground" where new abstract concepts are applied to a real world problem.

The initial platform for learning in the computer engineering curriculum at OSU is referred to as the Tekbot. The basic Tekbot consists of a simple aluminum frame with two independent, DC servo motors for locomotion. In its most basic embodiment, it has two main circuit boards which are mounted above the motors. One contains a discrete H-Bridge and the other, the bump switch steering logic, fig. 1. This entire assembly is constructed in their freshman introduction to computer engineering course.

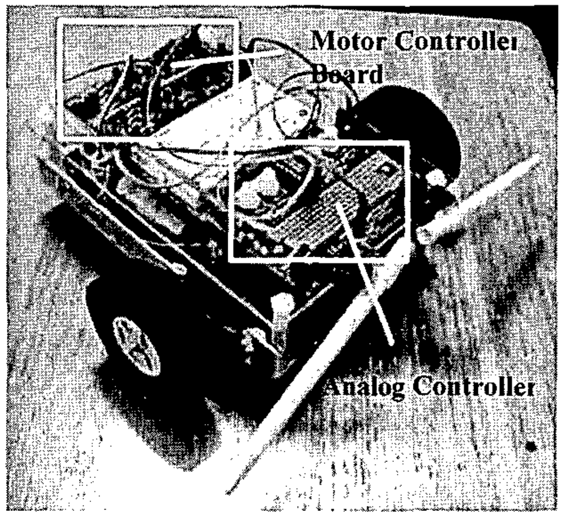

FIGURE 1
AN ENTRY LEVEL TEKBOTS PLATFORM

The basic Tekbot platform was designed with flexibility and expansion as key features. As the student progresses through the curriculum, the basic mechanical platform stays relatively unchanged. However, new circuit boards or functionality are added to integrate the new topics with those already applied to the platform. Each class may add a new function, or replace some feature with an improved implementation of the same feature.

It should be noted that a very large number of equally useful platforms for learning could be conceived that provide the aforementioned benefits. The Tekbot robot platform is just one of many possibilities. In the future, the platform could become a boat, an airplane or a submarine.

There are several key characteristics that we have found that are vital to a platform for learning as shown in Fig. 2. They include:

- Personal Ownership. It is well documented that a person who feels a sense of ownership for something will invest more time and effort into making it the best it can be [4]. A platform for learning must encourage a student to take ownership of it.

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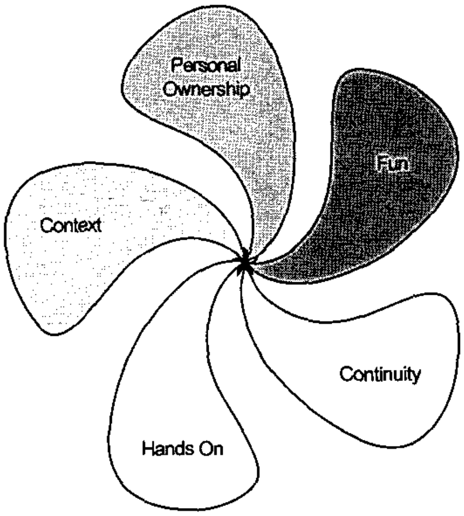

FIGURE 2
CHARACTERISTICS OF A PLATFORM FOR LEARNING

- Curriculum Continuity. In education where the quid pro quo is to have courses with independent grading and instruction, courses can naturally begin to seem disjoint and unrelated to each other. This can occur even if the courses are very similar [3]. A platform for learning must bring these connections out and make them obvious to students to add relevance to a student's knowledge and build from what the student already understands.
- Context. When people have the ability to form connections between pieces of knowledge they can 'synthesize' a deeper and longer lasting understanding of what they have learned [2,3]. When teaching with a platform for learning, it is vital that things taught in lecture are reinforced in lab, and things experienced in lab are taught in lecture.
- Fun. It is common sense that students want to do things that they find fun. A platform for learning must leverage this to keep students engaged and interested in learning.
- Hands-On/Interactive. Many studies have shown that when people are allowed to interact and 'play' with an idea or concept that they remember and appreciate it more [5]. A platform for learning must have this quality of flexibility and involvement so that students are allowed to play.

II. TEKBOTS: AN ECE PLATFORM FOR LEARNING

The TekBots platform serves as the primary teaching tool for the first freshmen class in ECE. It includes a motor controller board, an analog controller board, a charger board and a prototype board. Each of the elements of the TekBot help to reinforce the material covered in lecture. For example, the motor controller board is used to explore correct biasing of transistors and simple digital logic for control.

The TekBot becomes the foundation for several other courses in the Computer Engineering curriculum. As students progress through the four year curriculum, they build on the basic TekBot. Using this common platform, the lecture topics are reinforced in the laboratory and topics from one class are connected with topics from other classes. The development of the platform for learning in the four year computer engineering curriculum is shown in Fig. 3. The core computer engineering curriculum is indicated at the top of the figure. After their first introduction class, freshmen take the first class in digital design. In this class, students remove the analog controller board and replace it with a digital controller containing a programmable logic device. By the end of the term, students design a digital controller that performs the same function as the analog controller. From this experience, they develop a concrete understanding of differences and tradeoffs between an analog and a digital controller.

At the end of the sophomore year, students take the first class in computer architecture. As shown in Fig. 4, a microcontroller board is added to the basic robot allowing it to be a tool for teaching the course objectives for computer architecture.

The microcontroller board is designed using an 'AVR' RISC microcontroller, from the Atmel Corporation, with significant onboard peripherals. This is coupled with some expanded memory, an LCD display, input and output switches, and LEDs.

Using this microcontroller board and a TekBots platform we can significantly enhance this first course in computer architectures. For example when students are learning about timers in a microcontroller, they are asked to design a TekBots platform that can 'record' its own actions and play them back at a later time. In another lab, students learn about interrupts and service routines. Here they are asked to design a system that allows the TekBots platform to instantly react to an impact while at the same time it can navigate an area.

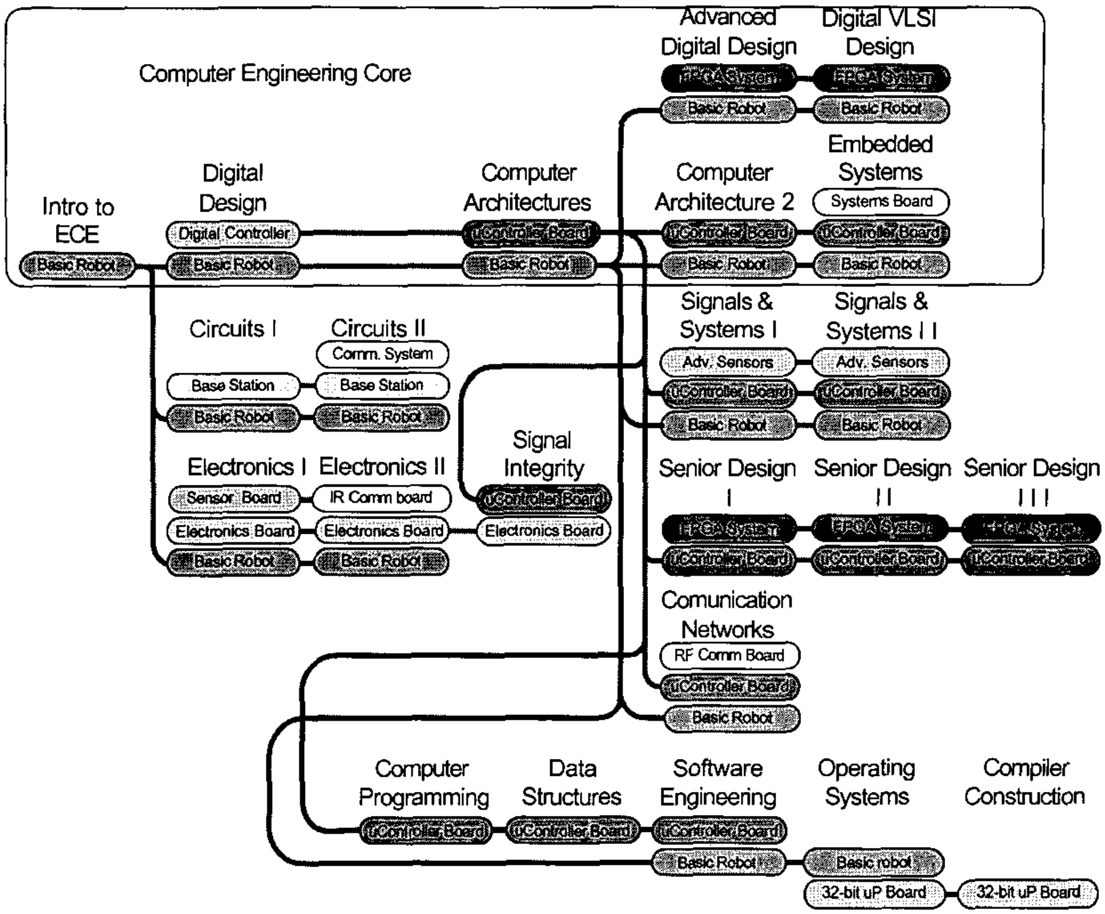

FIGURE 3
ELECTRICAL AND COMPUTER ENGINEERING CURRICULUM WITH THE COMPUTER ENGINEERING SECTIONS HIGHLIGHTED

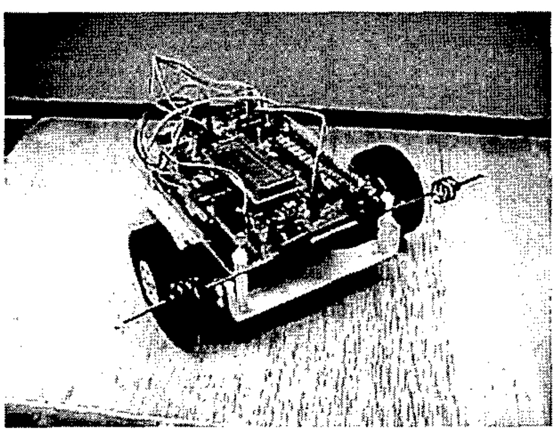

FIGURE 4
A MICROCONTROLLER ENABLED TEKBOTS ROBOT

This same board is used in the second computer architecture class offered in the junior or senior years. This course focuses tightly on the processing unit and 5-stage pipeline of many processors. It explores how instruction set architectures effect processor design and how things such as pipelining, write after read (WAR) hazards, Read after Write (RAW) hazards and context switching are done in a RISC processing unit. Using their own microcontrollers, students are asked to calculate efficiency and timing for their microcontrollers as well as write code that reduces the number of incorrect branches, improving efficiency.

In the junior/senior embedded systems course, students learn how to interface different systems and devices to each other so that useful tasks can be performed. Topics like address IO mapping, serial, I2C, Bluetooth, coding theory, address decoding, clock distribution, and power distribution are discussed. In the lab all of the systems from the previous computer engineering courses are brought together with some new systems and the students are asked to make them all interface. For example, the microcontroller board might be connected with the cPLD board and then to a large and varying amount of memory and IO. The cPLD then is used to connect everything together, acting as an address decoder, buffer, and possible watchdog timer.

The last two senior courses in the computer engineering curriculum are the advanced digital design and VLSI design course. These courses combine much of the previous knowledge to teach advanced topics. In the digital design course, topics like efficient state encoding, bit-slice processing, design for test, and timing considerations are taught. VLSI teaches the process of taking a design from idea through partitioning to HDL description and synthesis. Important topics like back-annotation, synthesis constraints, and accurate testing are covered as well.

For both of these courses, a large size FPGA is used. The FPGA that was chosen is a Spartan-II product from Xilinx. This FPGA has plenty of resources to use for these two courses and can be easily interfaced with the TekBots platform. The FPGA is used in the advanced digital logic course to hold a student designed processor that meets a set of requirements. These requirements include maximum operating frequency, minimum cycles per instruction average, size, functionality, and others. This new processor is then used to control the operation of the students TekBots platform

In the VLSI course, again multiple systems are brought together and used. Here the students design a coprocessor that they must connect to their microcontroller board. They get to choose the interface and method of processing as long as they can perform the required actions. Examples of coprocessors are cryptographic, UART, DMA, and network interfaces. Using a network interface, students can interact with their TekBots from a local area network, or wide area network.

With this background on the progression of the platform for learning, the next section will expand on the digital logic class in the freshmen year. In this section, we will show that the platform for learning enhances the educational experience and learning over a traditional lab or conventional lecture.

III. ENHANCING LEARNING IN DIGITAL DESIGN

The first course in Digital Logic begins with simple description of binary and other number systems and proceeds through truth tables, logic gates, Boolean algebra, Karnaugh maps, asynchronous logic, synchronous logic, and state machines. As part of the course there is a required weekly three hour lab.

A complex logic device (cPLD) is incorporated onto the digital logic board. A Lattice Semiconductor mach4 series device was chosen that has both large number of product terms and input/output pins and it is relatively inexpensive. To keep the hardware small for integration with the robot and yet keep it versatile with numerous inputs and outputs, two printed circuit boards were developed.

The programming hardware and cPLD are on one board and the inputs and outputs on another with the two connected by cables. The design had to use simple tools available free to students that can be used on their personal computer and the boards are easily mounted onto the TekBot as shown in Fig. 5.

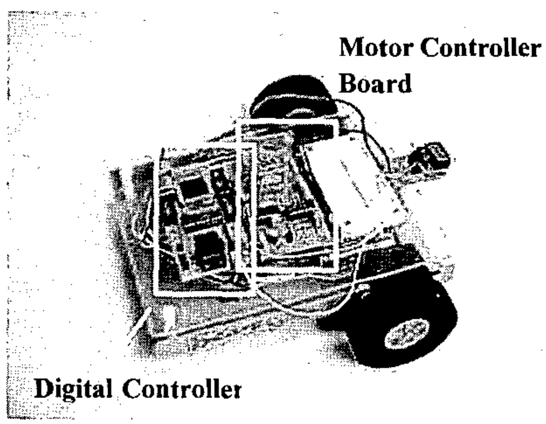

FIGURE 5
A TEKBOTS ROBOT USED IN DIGITAL LOGIC

With this new hardware, the TekBots base revisions were made to the lab and lecture material. One of the first steps was to explore how the labs and lecture topics related to each other. Were they in context and did they support each other in how and what they were teaching. We found that the present lecture and lab topics worked well together with lecture topics being covered in lab the week after they were taught in lecture. Since the labs and lecture were in context, the content was changed only slightly to reflect the platform for learning philosophies.

TABLE 1
DIGITAL LOGIC LABS WITH LECTURE TOPICS AND LAB EXPERIENCES

LAB TITLE	LECTURE TOPICS	TEKBOTS EXPERIENCES
SIMPLE COMBINATIONAL SYSTEMS	TRUTH TABLES SOFTWARE TOOLS LOGIC GATES	STUDENTS ARE ASKED TO CREATE SEVERAL SIMPLE COMBINATIONAL CIRCUITS AND DEMONSTRATE THEIR FUNCTION
REMOTELY OPERATED VEHICLE	LOGIC REDUCTION BOOLEAN ALGEBRA KARNAUGH MAPS ENCODERS/MULTIPLEXERS	STUDENTS DESIGN A COMBINATIONAL LOGIC FOR CONTROLLING THEIR ROBOT WITH A WIRE PUSH BUTTON REMOTE CONTROL.
SIMPLE SEQUENTIAL SYSTEMS	LATCHES CLOCKED GATES ACTION TABLES TIMING DIAGRAMS	STUDENT TEST OUT SEVERAL DIFFERENT SEQUENTIAL GATES AND VERIFY THEIR OPERATION.
STATE MACHINES	STATE TABLES STATE DIAGRAMS MOORE VS. MEALY	A 'BROKEN' STATE MACHINE USED IN A VENDING MACHINE IS GIVEN TO THE STUDENTS. THEY EXAMINE AND REPAIR THE STATE MACHINE.
AUTONOMOUS ROVING	STATE ENCODING CLOCK DIVISION	STUDENTS COMPLETELY DESIGN AND TEST THEIR OWN STATE MACHINE FOR HAVING THEIR TEKBOT ROAM AND AVOID OBJECTS.

To keep the learning experience fun, great care was put into making the lab work and lectures challenging but not so difficult as to prevent students from completing them. The concepts and activities were designed to be novel and fun as well. For example in lab, each student builds their own remote controlled robot, fixes a vending machine that is dispensing free soda pop, and works with very basic artificial intelligence by designing a state machine to control the TekBot autonomously

With such large scale revisions and improvements assessment is vital to ensure that everything is going as planned and that the changes are yield the result that are expected. In this first digital logic course significant effort was put into assessing the changes from TekBots.

IV. ASSESSMENT

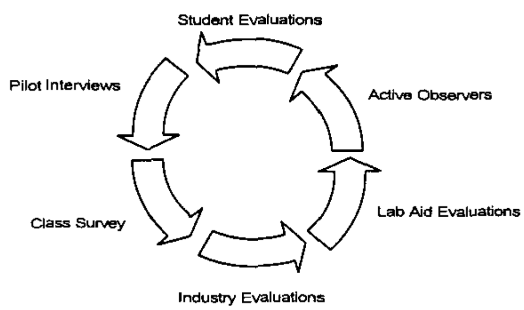

FIGURE 6
TYPES OF EVALUATIONS USED TO ASSESS DIGITAL LOGIC CLASS REVISIONS.

Figure 6 shows the organized set of evaluations that were performed to gauge the impact of the TekBots integration into the digital logic class. A single method can not completely measure all of the effects of the changes so this multi-faceted approach was used. The evaluations included student surveys, student evaluations, lab assistant evaluations, industry surveys, active observers and individual interviews.

A large scale survey was given to the class both at the beginning and end of the term. The survey was designed to measure whether innovation and community were enhanced with the platform for learning. A unique aspect of the digital design course is that there are both electrical and computer engineering students and computer science students enrolled in the class. The computer science students do not take the laboratory section of the course allowing for our assessment to have a control group.

Another method that was used to observe student perspective was the evaluation of the teaching assistants. This evaluation was used to gauge the students' sense of how the teaching assistants contributed to building a community. Students were asked to measure the amount of mentoring that they received from their TAs and how it was given.

One of the most insightful evaluation methods used was a series of pilot interviews with students. An impartial observer was asked to randomly pick a representative sample of students and conducted short interviews with them. The transcripts of these interviews have been invaluable in revising the course work to its latest form. There was information in the interviews that was unobtainable by any other method with students giving frank and complete opinions about their experiences in the coursework. The majority of responses were good, with the largest mentioned problem being that there was a large time commitment if the student wanted to excel in the coursework.

In Table 2 the results of the large scale survey is summarized. The table is based on the pre-survey and post-survey data on a student by student basis. The survey gathered information about various important aspects in innovation and community. The table is broken into five columns, the aspects under survey, the 'score' from the first survey, the 'score' from the second survey, the percent change between the scores, and the likelihood that the change was not a random occurrence and instead was a result of TekBots.

TABLE 2
RESULTS FROM THE ECE272 SURVEY

SUBSCALES AND SCALES	PRE SURVEY SCORE	POST SURVEY SCORE	PERCENT CHANGE	PROBABILITY THAT MEASURED QUALITY CHANGED FROM TEKBOTS
MENTORING	10.5 /20	12.2 /20	15.9%	99.87%
LEADERSHIP	9.8 /20	11.4 /20	16.1%	98.72%
TOTAL COMMUNITY	20.3 /40	23.6 /40	16.0%	99.8%
NOVEL IDEAS	11.3 /20	10.5 /20	2.7%	94.57%
MANY SOLUTIONS	10.5 /20	10.8 /20	1.5%	35.18%
TECHNICAL COMPETENCE	8.8 /20	10 /20	13.6%	84.66%
LIKES PROBLEMS	9.8 /20	10.3 /20	5.1%	58.7%
VALUABLE ANSWERS	8.7 /20	9.7 /20	11.4%	82.39%
TOTAL INNOVATION	49.1 /100	51.3 /100	2.4%	50.49%

For innovation we wanted to explore if TekBots helps the student come up with more novel ideas, see many different solutions, felt that they are technically competent, enjoyed problems, and if they felt could develop valuable answers. The survey contained several questions about each of these areas. The score for each section was created by tallying all of the questions for an area, with a smaller score being better. The survey could not show that the change in most of these areas was due to TekBots except for in the area of novel ideas. Here there was a 94.5% probability that the improvement we saw (11.3 becoming 10.5) was due to TekBots.

Community was also surveyed by considering if students felt they were mentored and if they felt they could mentor others. Under both of these categories we saw with certainty that TekBots enhanced their experience. Mentoring had a 10% (2 point) improvement while leadership had an 11% (2.2 point) improvement. For scoring community, a larger score is 'better' than a smaller score. Doing this helped us to see if students were just filling in the survey in a pattern, or actually answering the questions while giving thought to each question.

We can see in the data that there was a definite improvement in the community aspects that we tested, both with students feeling like they were mentored and feeling like they were able to mentor/lead others. While the overall improvement in innovation was not shown with this survey, there is noticeable improvement in the 'Novel ideas' section of the survey. Students who took TekBots in the lab felt that by the end of the course, they were producing more novel ideas and approaches.

ONGOING / FUTURE WORK

The ongoing work at OSU can be separated into three different categories; multidisciplinary expansions, adoption in other programs, and continuation to other courses.

We have begun the process of creating other platforms for learning with other schools and disciplines. At present we are working with the Mechanical Engineering, Computer Science, and Business departments at OSU to create new platforms for learning.

Through extensive assessment and validation we have been working to demonstrate the potential of Platforms for learning and specifically TekBots to other universities and colleges.

By the time of this writing several more courses will have been revised and improved.

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