TEKBOTS™: CREATING EXCITEMENT FOR ENGINEERING THROUGH COMMUNITY, INNOVATION AND TROUBLESHOOTING

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Abstract *¾ Attracting, educating and retaining new engineering students is a challenge. The creative aspirations and "can do" attitude spawned by the space race, Heathkits, and homemade crystal radios have been replaced with the passive satisfaction of video games, cell phones and throwaway electronic appliances.*

At Oregon State University we have made a fundamental change in our presentation of electrical engineering to freshmen by using a robot platform we call TekBots. We are emphasizing innovation, community building, and troubleshooting. Our aim is to put the fun and excitement back into electrical engineering and thus retain and inspire new students.

This ultimately will extend throughout the curriculum using the robot as a platform for learning. Rather than a single point project, the robot becomes the integration platform for learning and experimentation in almost every class for four years.

Index terms - Curriculum, Robot, Engineering Education, Innovation, Troubleshooting

INTRODUCTION

Why would a student enter an engineering program? Engineering is a difficult discipline that requires hard work and a significant commitment to succeed. While in the long run the pay off is great, the short-term benefits and "fun factor" sometimes elude undergraduate students. Historically, there was a "you can do it" attitude that existed in the general population spawned by the space race, Heathkits, and crystal radios [1]. This exposure to the tangible possibilities created excitement for the engineering discipline. In recent years, however, this excitement has waned while the demand for high qualified, creative engineers has risen. With this mismatch between the supply and demand, there is a need to create innovative engineering programs that attract and retain the best and the brightest.

At Oregon State University, we are addressing this need with a curriculum based on what we call *TekBots™* [2]. Beginning in the freshmen year, electrical and computer engineering students build a robot that they use as a *platform for learning* throughout their entire four-year curriculum. Using a common platform throughout the curriculum helps to integrate the material from seemingly disjointed courses. Students add capability to their individual TekBot based on the courses they are currently taking so that by the time they are seniors, they may have an internet-controlled wireless robot. This hands-on approach enhances the educational experience by creating excitement among the students for what they are learning and how they may apply that knowledge. A critical part of this program is that every student has their own individual TekBot that they customize as they progress through the program.

The focus of this paper is the first course in Electrical & Computer Engineering at Oregon State University, ECE 112. This is the first TekBots course in the curriculum and it is the key to establishing many of the principles that are emphasized throughout the following four years of the program.

To initially determine our key program values and outcomes, we surveyed our constituents including our alumni, the employers of our students, our graduating seniors and our faculty [3]. Like the ABET organization, our constituents believe *breadth*, *depth* and *professionalism* are vital to a successful engineering career. Additionally, our constituents also identified the following characteristics as important.

Trouble-shooting – Ability to troubleshoot engineering problems.

Community – Ability to lead, mentor, and/or contribute to the development of future engineers and on engineering teams.

Innovation – A fostered excitement of discovery and associated creativity.

Figure 1 summarizes the averaged responses from the industry, alumni, and faculty that said the outcomes are very important. Our constituents rated ability to trouble-shoot, recognition of community and innovative aptitude as high or higher than breadth, depth, and professionalism.

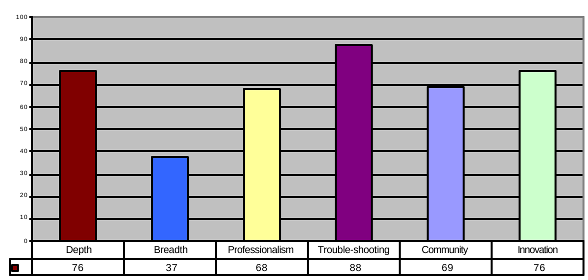

Fig. 1: Average (in percentage) of industry, faculty and alumni constituents that rated the educational objective as *very important.*

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Our goal is to use the development of the TekBots curriculum to enhance our students' sense of community, ability to trouble-shoot, and innovation aptitude.

DEVELOPMENT OF ECE 112

Possibly, the most important course in any engineering program is the freshman level orientation course. This course is the first exposure that a student has to engineering at a university. As such it should be the most dynamic and exciting course in the program, but it cannot be atypical of courses that the students will take during their college careers. If the orientation is too "good" then the students will not be happy with their decisions as they continue in their college careers.

From 1996 to 2000, ECE 112 at Oregon State University followed the freshmen course developed by Carnegie Mellon University [4]. There are also other examples in the literature of courses based on robots [6-10]. The initial challenge was to determine if a course created for a very selective private school could be adopted for a 200-250 freshmen class in a state university. The student response was very positive to this hands-on experience. This course has two components, a lecture portion and a lab portion. In the past, beginning lectures covered Ohm's law, Kirchoff's Laws, and other basic concepts. At the same time, the students started building their robots by constructing a zener diode voltage regulator. There was not a definite connection between the lecture and the lab. This made it difficult for the students to relate theory they were learning in class to the practical 'real world' systems that they were building in lab.

This is changed with the addition of TekBots to the curriculum. Instead of a disjointed lab and lecture, the experiments are carefully designed to reinforce what is being presented in the classroom. This level of integration is necessary in order to allow for students to connect theory to practice.

EVOLUTION OF THE TEKBOTS PLATFORM

Before describing the specific laboratories and their content, a brief summary of the evolution of this class and the Tekbot platform is given.

The robot platform is vital to how the course and laboratory inter-relate. Early versions of the robot were based on the Graymark robot [5]. In the spring of 2000, an informal course was created that followed the orientation class. In this class, students added a "layer" to the robot and then bread boarded whiskers, Fig. 2. Once completed, the robot would backup and turn when the whiskers contacted a wall or vertical surface. Approximately 50 students or one-fourth of the class voluntarily participated in this class because of their interest in doing more with the robot base. The students that got this working were really excited about what they accomplished. Thus, we extended this experience to all of our freshmen the following year by adding a pre-designed whiskers PC board to the Graymark robot as shown in Fig. 3.

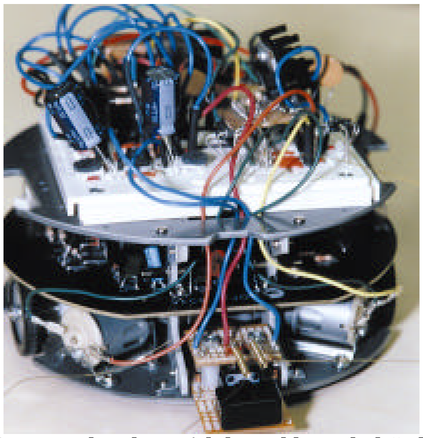

Fig. 2: Graymark robot with bread boarded "whiskers."

Fig. 3: Graymark robot with layered whiskers PC board.

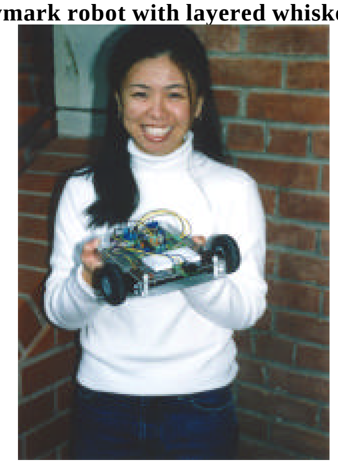

Fig. 4: TekBot robot platform with whiskers and add-on breadboard.

After experimenting with the idea of adding layers to the robot, we created a more rugged robot base that can be modified and added to over the course of the students undergraduate program as shown in Fig. 4. This base is very simple and includes the servomotors, batteries, whisker circuitry and the analog controller. We also included a breadboard on the base so that students can easily add features to their TekBot. An important consideration was the cost of the TekBot. We carefully balanced the need for long-term operation with cost. The current Tekbot is less than $80.

ECE 112 COURSE & LAB CONTENT

The lecture and the laboratory are tightly coupled in this course. Each lab reinforces what is presented in the lecture. For example, in Lab 2 students apply Ohm's law to the robot. They examine the current, voltage and resistance in the motor-battery circuit. As they increase the resistance, the current to the motor reduces, thus reducing the motor speed. In addition to coupling the lecture and laboratory material, there are also challenge problems provided in each lab. These challenge not only the very best students, but also entice the students who might be struggling to try a little harder. These generally build on the lab material but allow the students to push to very advanced levels. One other feature we exploit in the labs is taking students out of their comfort level. In Lab 1, the first thing the students must do is take the servo motors apart and modify them so that they are DC controlled rather than PWM controlled. This is very scary to many students who might feel uncomfortable with their technical ability at this point. It gets the students over the barrier that they might do something "wrong." Every effort is made to find fun and interesting lab experiments throughout the full 10-week term.

Table 1: Lecture and lab topics for ECE 112

Lecture Topics	Lab Experience	Lab Challenge
Week 1: •Concepts of Current, Voltage •Schematic diagrams Measuring voltage and current	•Modify servo motors •Soldering •Get dirty and greasy!	•N/A
Week 2: •Ohms law •Current and voltage sources •The power equation	•Read schematics •Apply Ohm's law to robot movement •Proper use of DMM	•Explore other ways than electrical of controlling motion
Week 3: •Kirchoff's Voltage Law •Test 1	•Power calculations •Create models of components	•Create a PWM circuit to control motor speed
Week 4: •Kirchoffs Voltage Law •Voltage dividers •Kirchoff's Current Law	•Verifying KVL •Compute efficiency of motor speed control •Dynomometer hill climb	•Explore why efficiency is important •Look at how to improve power consumption
Week 5: •Kirchoff's Current Law Resistor Networks Diodes and Transistors	•Verify KCL •Series/parallel component configurations	•Configuring motors and batteries for maximum efficiency
Week 6: •Test 2 •Digital logic principles •Designing with digital logic	•Transistors as switches and amplifiers •Motor control with transistors	•Examine motor noise with transistor noise amplifier. •Examine motor noise changes with loading.
Week 7: •A/D and D/A conversion •Comparators and OPAMP	•Make a light seeking robot (photovore)	•Make a dark seeking robot (photophobe). •Make a speed-controlled photovore.
Weeks 8, 9 and 10: •Discussion of TekBot circuits and debugging	•Assemble TekBot v1.0 system	•Customize/modify robot. •Tune for specific behavior

ENHANCING TROUBLE-SHOOTING, COMMUNITY AND INNOVATION

Troubleshooting - Students quickly learn that simple mathematics and concepts even though they may be 'perfectly' designed nearly never work when they are first done in lab. The students get a large amount of troubleshooting during their lab sessions simply from making small errors in design and implementation. The student then has to find and solve their problems. Ideally each student would be able to do this independently, but allowances are made since the students are freshman. A problem with only teaching students troubleshooting in this fashion is that often the student does not 'learn' from their mistakes, and may make it again at a later date, and a system of troubleshooting is not taught for solving later problems.

In the TekBots laboratory we use a systematic method of teaching troubleshooting to students. Along with their own errors that they make, we intentionally build some 'errors' into the labs. These 'instakes' (intentional mistakes) are then explained to the students and within the lab a system is given for troubleshooting and how the instake was found using the system. The hope is that this method directly demonstrates to the students that a trouble shooting method is not optional, it is necessary to any design.

Community - Since a sense of community is vital for students to stay interested and motivated, significant efforts were put into building community throughout the coursework and lab work.

Labs were staffed with junior and senior level students as lab assistants. Using lab assistants, who are only a year or two more senior, lowers the barrier to effective mentoring. Figure 6 shows one of our seniors mentoring a freshman at our open house demonstration.

Group exercises were also created for the lab experiments. These group labs required that students interact with each other in order to accomplish a goal. Group labs are intended to be low pressure placing emphasis on interaction and learning.

Fig. 5: Student in the freshmen laboratory working on troubleshooting part of the robot.

Competition is a driving force in nature and humans are no different. Athletes who compete against each other often feel a connection with all of the other athletes they compete against. A competition was introduced to the freshman course to be held at the end of the term. This competition is not mandatory but is instead purposely made to be a fun and challenging event for the students. While competition can be used to promote community, it can also create strife when competitors do not win. We reduced this by having a competition that consists of many smaller competitions that do not rely on each other. For example there is an event for individuals who want to add electrical modifications to their robot to compete in. At the same time there is a pageant so that less technically savvy students can decorate their robots and still receive adulation for their work. Throughout the term this competition is mentioned and excitement is created. By the end of the term nearly all of our students were taking active roles in creating robots that could compete in the competition.

The competition is open to the public. As shown in Fig. 7, future engineers enjoyed the display and competition as much as the college students.

Fig. 6: Upper class students mentor freshmen in ECE 112.

Fig. 7: Young kids find the robot competition fun and look forward to being engineers.

Innovation **-** Innovation is by far the hardest skill to teach. Some feel that it is impossible to teach innovation to a student. Using the TekBots platform, we have decomposed innovation into a few simple steps and then we teach these steps to the students.

Innovation needs a few things in order to exist or be used and learned. Innovation requires knowledge. For example, if a student has no awareness that a technique or item exists then they cannot use that to solve their problem. There must also be a reason to be innovative. If a student is given a particular task to do and provided all the detail of how to do it, why should they even consider another method? Innovation also needs to be practiced. If a student learns some information and has a problem, they will try to solve it. The more times they try this, the more times they will be successful and the more they will be comfortable with their own abilities to innovate and the more they will use them.

In the freshman orientation lab we use the same principle that has been used since the beginning of engineering education, the project. We assign simple projects to our students and give them a competition deadline. The projects are intended to teach the design/innovation process, not just the material being covered in class/lab. First it forces practice in innovating, but at the same time gives them a solution they can use to complete their assignment. Built into the project description itself is knowledge about the parts, tools, and concepts that they might need for their design while at the same time students are not forced to follow the solution given.

Another large and important method of sparking innovation is to challenge students. Many students need to be challenged before they will complete or even perform a task. Each of the labs has additional 'challenge' questions at the end of the lab. These questions are used to get students to 'test out' their abilities. The questions always relate to what they have learned from previous work. This is done so that the students will have the background knowledge needed to invent a solution to the challenge.

Figures 8 and 9 illustrate innovations by two of our freshmen. In Fig. 8, the student took his toy hovercraft and modified it to house the TekBot. In Fig. 9, the student created the BeaverBot. The school fight song is currently being programmed into the BeaverBot so that it will "sing" the fight song and synchronously dance to it.

Fig. 8: Freshmen student that converted his TekBot into a hovercraft.

Fig. 9: Freshmen student that invented the BeaverBot.

EXTENDING TEKBOTS BEYOND THE FRESHMAN LEVEL

The TekBot program is not intended to be a single course system, it is intended to be a platform for learning from the freshman level up through the senior level. To be successful it relies on several key concepts including

- Ownership – Each student owns their robot and is satisfied in knowing and seeing what they have accomplished.
- Continuity – The TekBots platform provides continuity throughout the entire program. It ties all the topics together.

- Context – The TekBots platform provides an application for many of the concepts the students learn about in class.
- Hands-on Learning – Students see theory into practice with this hands-on approach.
- Fun Factor – Through fun hands-on experiences students are inspired to learn more.

CONCLUSION

The freshmen course in Electrical & Computer Engineering tightly couples the Tekbots laboratory to the lecture. Each student is provided with guided experiments to help assimilate the lecture topics. Beyond the basic experiments however are "challenge" experiments used to push the students and to spark personal innovation. Upper class students serve as helpers in the lab rather than graduate students. This reduces the social barrier between the instructors and the students and promotes a "safe" learning community. This course re-institutes the forgotten art of troubleshooting. Some troubleshooting skills are developed through the use of carefully "broken" lab experiments. Through challenge experiments, we bait students into a problem of their own making resembling the real world where multiple correct and incorrect answers exist.

FURTHER WORK

To measure the success of the Tekbots program, a set of evaluations and assessments has begun as of early 2002. The preliminary results show that our students are enjoying there studies and seem to be 'flexing their creative muscles' by thinking of new features to design and add to their TekBots. The final assessment will be published at a later date.

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