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SAAST ROBOTICS - AN INTENSIVE THREE WEEK ROBOTICS PROGRAM FOR HIGH SCHOOL STUDENTS

David J. Cappelleri*, James F. Keller, Terry Kientz, Peter Szczesniak and Vijay Kumar

Department of Mechanical Engineering and Applied Mechanics

University of Pennsylvania

Philadelphia, PA 19104

Email: {dcappell, jfkeller, tkientz, peterszc, kumar}@seas.upenn.edu

ABSTRACT

We have designed an intensive, three-week robotics program for high school students that combines theory with hands-on practical experience in cutting edge technologies. Conventional approaches to engineering education are bottom-up. Students are first taught the basics and are then courses that build on the basics. Most students do not take coursework on engineering applications, particularly design and systems engineering, until the end of the curriculum. This has the disadvantage of not exposing students to the excitement in engineering until late in the curriculum. Our goal is to develop a top-down curriculum in which students are introduced first to the applications and systems concepts which then leads to the teaching of fundamentals. This approach has the potential to recruit and retain students in engineering while making the curriculum more relevant and rigorous.

INTRODUCTION

Most traditional engineering curricula are taught in a bottom-up fashion where often the student takes two years of coursework in science, math and engineering science before finally getting a glimpse of engineering problems and methodology [1]. One reason this is the modus operandi is because of the nature of engineering courses. It is difficult to teach, for example, attractive courses in aerospace engineering before students have had any exposure to fluid mechanics, which is in turn

taught after thermodynamics and therefore after a substantial exposure to physics and mathematics [2–5]. We report on a new short course that shows it is possible to teach design and robotics at the high school level. In this top-down approach to education, students are introduced first to the applications and systems concepts which then leads to the teaching of fundamentals. Engineering applications excite and attract young students. Therefore, simple experiments can be used to motivate technical discussions and concepts. Mechanical engineering and robotics are both very diverse fields so they have potential to generate interests in many different areas when students are exposed to them. Unlike other engineering disciplines, most mechanical engineering and robotic systems have components from the other disciplines incorporated in them. You can have purely electrical or computer systems but to operate or implement most mechanical or robotic systems, many systems need to be integrated together. Utilizing this top-down education style provides perspective to beginning students [6], who currently perceive that engineering consists only of theoretical physics and mathematics, and attracts students to the sciences and engineering.

RELATED WORK

While our broader agenda is teaching design and mechanical engineering, our goal here is to develop a top-down education curricula for teaching a robotics course to high-school level students and to evaluate its effectiveness. We therefore restrict the scope of our discussion to other attempts to develop coursework

*Address all correspondence to this author.

in this area.

There has been much work in robotics education focused on college-level interdisciplinary robotics courses [7], [8], [9], [10], [11], [12] including three workshops in recent years [13], [14], [15] as well as a special journal issue on trends in robotics education [16].

In [17], learning robotics through hands-on applications is discussed. In order to eventually study advanced robotic systems, the integration of existing technologies, including mechanical, and electrical engineering is crucial. The authors use this as a foundation for the "practical education" at their university. Further evidence of the efficacy of this approach is shown in [18], where the authors argue that the most efficient way of teaching true knowledge and understanding for robotic systems is to let the students to work on real systems instead of academic problems and to let them build and experience them. Examples of low-cost robotic platforms suitable for this type of hands-on robotics education can be found in [19].

Robot design competitions have been identified as a strategy to maximize the learning experience and promote intellectual development in courses [20] and to teach system integration schemes [21] at the university level. A competition can bolster to intellectual maturity of students who begin to accept that there may be more than one right answer to a problem. It also encourages the students to identify many problems, evaluate the solutions, work in a group, and directly apply knowledge.

Our main focus here is to develop a curricula that is appropriate for high school and freshman level students to learn the basics of robotics. There have been several efforts to educate high school and middle school students with robotic technologies. FIRST (For Inspiration and Recognition of Science and Technology) holds a yearly robotics competition for high school students [22]. Student teams are partnered with professional engineers who mentor the teams through the 6-week design and build cycle, with a provided kit of parts. Teams then compete head-to-head in regional and national competitions. FIRST also runs a Lego League [23] for middle school students. Here the participants use the LEGO[®] MindstormsTM Robotics Invention System [24] to construct and program their inventions. The LEGO[®] robots are a popular choice for undergraduate and high school robotics courses [25], [26], [27]. Botball is another program designed to pique the interests of high and middle school students about science, technology, engineering, and math [28, 29]. The students are given about seven weeks to design, build, and program a team of mobile, autonomous robots, construct a website documenting their process and compete head-to-head in regional tournaments. A division of the RoboCup [30] tournament has also started a junior division, called RoboCupJunior [31], to attract and educate younger students in science and engineering. A modular, reconfigurable robotic platform created at PARC is used to teach robotics to high school students in [32]. The students can create their own robot topology ranging from biomimetic to an-

thropomorphic robot structures and program them accordingly with module specific software. In a robotics day-camp held at the University of Minnesota, students in grades 5 through 8 learn hardware by building robots from Acronome's Palm Pilot Robot Kits and software by programming Sony AIBO robot dogs [33]. However, in all of these programs listed, there are no formal educational or teaching components. There is no significant exposure to theoretical concepts in these courses. In contrast, our three-week program introduces basic mathematical and engineering science concepts required for design and robotics.

This paper presents our intensive, three-week program in robotics for high school students that utilizes a top-down education model. It introduces students to the state-of-the-art in robotics, manufacturing, and automation and combines theory with hands-on practical experience. There is both the formal education and lab component to the program where the students acquire the technical skills they need to design build and robots capable of performing specific tasks, as well as a final group project.

In the formal classroom component, coursework covers the basics of mechanical design, sensing, actuation, control, and embedded programming. In the lab, students are introduced to both mechanical fabrication techniques and electronic system development. There is a fully-equipped machine shop available for the students use. The students are instructed on using both CNC and conventional machine tools. Sensors and actuators are introduced along with microcontroller interfacing and programming.

The final component is a group project consisting of a design competition in which each group designs and builds a mobile robot that is teleoperated. The mobile robot is based on a TXT-1 1/10 scale monster truck [34]. This challenging project requires each team to design and build the mobile robot, learn to drive it using a radio controller, and add sensors and a mechanism capable of acquiring and collecting target objects that are dispersed on an obstacle course.

Students are also exposed to various guest lectures on current robotics research areas throughout the course. They also go on 2-3 field trips to local companies utilizing robotic technology to help them gain insight to the field, as recommended in [35].

This paper describes all these components of the program in detail. The class format and syllabus is presented first, highlighting the lectures, labs, and manufacturing project. The final project is then described and is followed with the results and the conclusions.

CLASS FORMAT AND SYLLABUS

As stated previously, robotics merges together many different disciplines. The curriculum is designed to teach the students each of these by covering the basics of mechanical design, sensing, actuation and control, and embedded programming. Class was in session from 9am to 5pm, Monday thru Friday for 3

weeks. The general format for the day was lectures in the morning and lab time in the afternoon (Figure 1). Evening lab hours were also provided for the students to work on lab homework assignments and projects. The lab assignments were performed in groups, but they required individual lab reports. There were three electronics labs and two mechanical design labs. Three small homework assignments were assigned and done individually. A piston-cylinder manufacturing and assembly project was completed individually while the final project was done in groups of 3 students. The schedule was such that the lectures were front-loaded towards the first half of the program, leaving time in the second half for project work.

Lectures

The lectures were designed to provide the students with the necessary tools to understand and complete the assigned labs and to apply these technologies towards the final project and design competition.

The first lecture provides an overview of current robotics technology and is aimed at answering the basic question of what exactly defines a robot and as well as explaining robot components and design considerations. Topics touched on include basic robot topology, design requirements, math modeling concerns, sensor and actuator selection, process considerations, control design concepts and system integration.

A lecture on the design process, prototyping techniques, linkages and mechanisms follows. The students participate in a design game to help reinforce the design process lessons learned in the lecture - problem understanding, solution development, and solution delivery (Figure 2). Prototyping methods such as foam-core and laser cutting mock-ups are presented. Gruebler's equations for planar mechanisms are introduced and explained with examples. Specific examples of various mechanisms that are applicable to the final projects are showcased and analyzed.

There is a lecture introducing various types of sensors, measurement techniques and how to interface them with a robotic vehicle. Position and motion sensing modalities are emphasized along with a discussion on design and specification considerations for particular applications.

A lecture on the basics of electronics covers topics such as: What is electricity?; Voltage, Current, Resistance; Ohms Law; Capacitors and Inductors. This lecture is coupled with an introduction to the BASIC Stamp 2 micro-controller from Parallax [36]. Here, the chip capabilities, pin characteristics, sample programs, common commands, and operating instructions are presented.

A lecture on mechanical design elements introduces cams, gears, belts and chains. Again, various examples of each are defined and applications explained. An actuators, control and interfacing lecture explains what actuators are and why they are needed. It reviews the theory behind electric motors, servo-

Week 1				
Monday	Tuesday	Wednesday	Thursday	Friday
Welcome and Safety Workshop	Lecture: Design Process, Prototyping, & Linkages/Mechanisms	Lecture: Cams, Gears, Belts & Chains	Lecture: Actuators, Control and Interfacing	Special Topics: Industrial, Service and Personal Robots
Program Overview Tours of Engineering and Robotics labs Student Experience Survey	Lecture: Sensors, Measurements and Interfacing	Intro to Final Project Robot competition Assignment of Groups Distribute TXT Bases	Open lab/shop project time	Special Topics: Industrial, Service and Personal Robots - con't
Lecture: Introduction to Robotics	Lecture: Introduction to Electronics and the BASIC Stamp II Microprocessor	Open lab/shop project time	Open lab/shop project time	Master Lecture I
Lunch	Lunch	Lunch	Lunch	Lunch
Machine Shop Training Piston Project Introduction	Mechanical Design Lab #1 Electronics Lab #1	Mechanical Design Lab #2 Electronics Lab #2	Open lab/shop project time	Open lab/shop project time

(a) Week 1

Week 2				
Monday	Tuesday	Wednesday	Thursday	Friday
<i>Piston Project Parts Due for Anodizing</i> Design Review - Initial Concept of Robot Design	<i>Mechanical Design Lab #1 and Electronics Design Lab #1 Due</i> Open lab/shop project time	Special Topics: Robotic Air and Undersea Vehicles / US FIRST Competition	<i>Mechanical Design Lab #2 & Electronics Lab #2 Due</i> Open lab/shop project time	<i>Electronics Lab #3 Due</i> Design Review II - Prototypes and Progress Report
Special Topics: Walking robots	Field Trip 1	Open lab/shop project time	Open lab/shop project time	Design Review II - Prototypes and Progress Report - con't
Open lab/shop project time	Field Trip 1	Open lab/shop project time	Master Lecture II	Open lab/shop project time
Lunch	Lunch	Lunch	Lunch	Lunch
Electronics Lab #3	Field Trip 1	Mechanical Design Lab 2 Competition	Open lab/shop project time	Open lab/shop project time

(b) Week 2

Week 3				
Monday	Tuesday	Wednesday	Thursday	Friday
Open lab/shop project time	Open lab/shop project time	Special Topics: Sony Robot Dogs and RoboCup	Robotic Monster Truck Competition: Seeding Rounds	Robotic Monster Truck Competition: Final Competition
Presentation guidelines	Open lab/shop project time	Open lab/shop project time	Robotic Monster Truck Competition: Seeding Rounds	Robotic Monster Truck Competition: Final Competition
Field Trip 2	Open lab/shop project time	Open lab/shop project time	Robotic Monster Truck Competition: Seeding Rounds	Robotic Monster Truck Competition: Final Competition
Lunch	Lunch	Lunch	Lunch	Lunch
Field Trip 2	Open lab/shop project time	Open lab/shop project time	Open lab/shop project time	Project presentations

(c) Week 3

Figure 1. Class Format

motors, and mechanical, hydraulic and pneumatic actuators. Latency in control systems is also analyzed here.

The final lecture was on industrial, service, and personal robots. It reviewed the current state-of-the-art in each and presented the current and future challenges in automation, autonomy, and augmentation and what is needed to move from a personal computer to a personal robot.

The rest of the classroom instruction sessions were comprised of talks on special topics in current robotics research.



Figure 2. Lecture on design process - Design Game

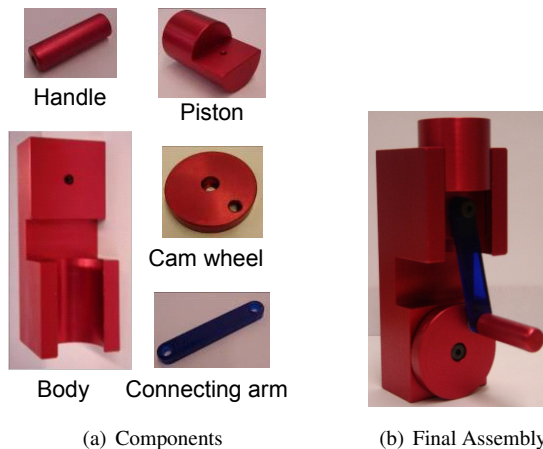


Figure 3. Piston-Cylinder Manufacturing and Assembly Project

These consisted of talks on robotic air and undersea unmanned vehicles, walking robots, and robot dogs.

Piston-Cylinder Manufacturing and Assembly Project

In order to acquaint the students with the equipment in the machine shop, they are tasked with a piston-cylinder manufacturing and assembly project. They need to manufacture all the parts (Figure 3(a)) necessary to build the assembly shown in Figure 3(b). They need to use a band saw, drill press, lathe and milling machine to manufacture the handle, cam wheel, piston and body parts of the assembly out of aluminum. They also need to tap holes in the piston and handle and use the laser cutter to manufacture the connecting arm out of acrylic. The complex features on the body are done on a CNC mill by the instructors, with the students observing. The finished parts are anodized and then engraved with the laser cutter. Each student then assembles the final parts and takes home the final assembly as a souvenir.

Electronics Labs

The electronics labs give the students a solid foundation for their final project by teaching them how to interface with and control all of the necessary components that they will utilize in their designs (Figure 4).



Figure 4. Lab stations for electronics labs

The first electronics lab is an introduction to the BASIC Stamp 2 (BS 2) microcontroller. The students learn how to program and interface the BS 2 with electronic input sensing devices. These devices consist of a push button switch, potentiometer, analog-to-digital converter, LED, and an ultrasonic range finder. Sample code to operate each device is provided to the students. They need to execute the code, record their observations and answer questions regarding the system performance. In some cases they may need to modify the code slightly to achieve the desired results.

In the second electronics lab, the students are introduced to interfacing actuators to the BS 2. This consists of having the BS 2 control a DC brushed motor, stepper motor, and radio-controlled (RC) servo motor via a potentiometer input. Again, sample code to operate the motors is provided, which requires slight modifications by the students to obtain the desired performance.

The final electronics lab deals with interfacing the BS 2 to an RC receiver. This teaches the students how to monitor a servo signals from the RC receiver and use this signal to perform various tasks with the BS 2 such as motor control/positioning.

Mechanical Design Labs

This first mechanical design lab introduces the students to three different lifting linkage mechanisms and prototyping techniques such as foam core mock-ups and laser cutting of acrylic parts. The students will need to design a lifting mechanism as part of their final project. This lab requires them to build a foam-core mock-up of one such device. A unique 4-member bottle opener linkage is also presented in this lab. The students must determine the appropriate link lengths, manufacture, and assemble them in order to successfully open an 8 oz bottle of soda. This part of the lab acquaints the students with the effects of forces exerted from lever arms, CAD drawings and manufacturing parts with the laser cutter. Figure 5(a) is an example of a lifting mechanism foam-core mockup and Figure 5(b) shows one of the bottle opener designs.

In the second mechanical design lab, the students are tasked to design and build a "truck" to transport as much payload as possible up an inclined plane. A 4-Speed Crank Axle Gearbox from



(a) Foam-core Mockup

(b) Bottle Opener Design

Figure 5. Mechanical Design Lab 1

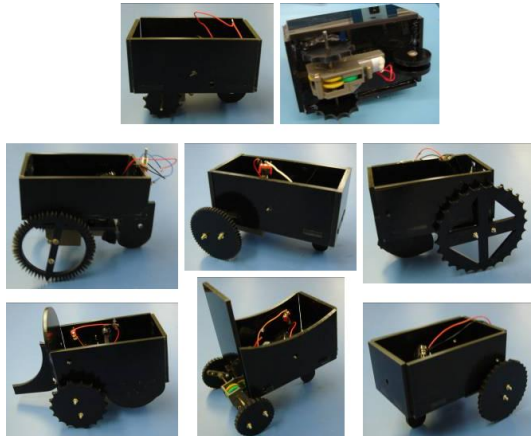


Figure 6. Mechanical Design Lab 2: World's Strongest Truck Designs

Tamiya USA (Part #:70110) [34] is provided to each group. The gearboxes can be assembled in 4 different speeds or gear ratios. The students must choose the appropriate ratio for this particular application and assemble it. This lab requires the calculations of the gear ratios for each of the gearbox configurations based on the gear ratio equations presented in the lecture.

The inside dimensions for the truck bed are restrained to be the same for all groups. The rest of the design is open for the students - wheel diameter, mounting, additional traction design, gearbox mounting, etc. An on/off switch and battery holder is also required to be mounted to each truck. Figure 6 shows the designs that some groups came up with for the lab.

All groups participated in a "World's Strongest Truck Competition" (Figure 7) at the end of the lab. Miscellaneous hardware (nuts, bolts, washers, etc.) was used as payload for the trucks. Each truck was loaded with as much payload as possible as it traversed up a carpeted inclined plane. The truck that could carry the most payload across the finish line was the winner.

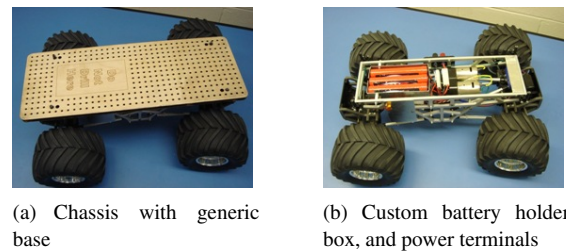
FINAL PROJECT

Description

The platform for the final project mobile robot is a modified version of the TXT-1 1/10 scale monster truck, (TXT-1 Tamiya



Figure 7. Mechanical Design Lab 2: World's Strongest Truck Competition



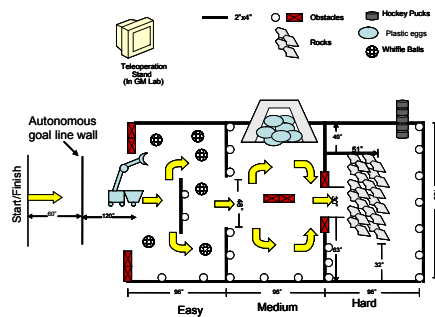
(a) Chassis with generic base

(b) Custom battery holder box, and power terminals

Figure 8. TXT Monster Truck Chassis

Xtreme Truck Chassis [34]). In the first year that this program was ran, the students had to build the TXT monster truck chassis out-of-the-box themselves by the end of the second week of class. The robot chassis from year 1 were re-used the following year. Reusing the chassis not only saves money but it allows for more instruction and lab time in the beginning of the program. As a result, the mechanical design labs were introduced in year 2 of the program. A generic removable base with through holes was added to each chassis for the students to build on. A custom-made battery holder and power terminals were also added to the chassis for easier use and interfacing. The modified, re-usable chassis is shown in Figure 8.

The goal of the final project is to be able to tele-operate the robot through an obstacle course (Figure 9) retrieving targets. The final project was inspired by the recently deployed Mars rovers that were tele-operated from Earth. The were used to explore the Martian surface and acquire interesting samples of various types of objects for testing and analysis. Each group of 3 students is given the following items: TXT-1 Monster Truck Chassis, Radio Control Kit, and Basic Stamp 2 micro-controller. Miscellaneous servo, stepper and DC motors, gears, chains, and sprockets are also available for use. Also provided are a color wireless camera and monitor. The robots have to be tele-operated and semi-autonomous once the robot is on the obstacle course. Teams do not have direct line of sight to their truck to maneuver through the obstacle course.



(a) Schematic



(b) Obstacle Course I

Figure 9. Obstacle course for final project

The Obstacle Course and Scoring Rules

As robots traverse the obstacle course, they can earn points in a variety of ways. The team with the most points at the end of the competition run is the winner. A schematic and picture of the actual obstacle course used in the year 1 of the program is shown in Figure 9. In year 2, two parallel courses were set up to enhance the competitiveness of the project, allowing for head-to-head play. Actual hard boiled eggs from year 1 were replaced with plastic easter eggs in year 2. The real eggs were crushed during the first few competition runs in year 1, not allowing an even playing field for other teams competing later on.

The following is the list of targets on each course for which points are awarded:

- 12 whiffle balls - 1 pt/each gathered; 2 pts/each carried back to the starting line
- 12 plastic eggs - 2 pts/each gathered; 4 pts/each carried back to the starting line
- 6 hockey pucks - 3 pts/each gathered; 6 pts/each carried back to the starting line

Points are deducted when course boundaries, marked (soda cans) and unmarked obstacles (bricks) are disturbed (2 pts/each one disturbed). Fifteen points are deducted for every human interaction (this includes manual restarts, manual repositioning of the robots, etc.) once the robot is on the obstacle course. Each group is awarded an additional 20 points for completing

the course and returning to the starting line in 10 minutes (5 minutes for seeding rounds) with at least one item gathered from the course. No points are awarded for a robot that does not attempt to traverse the obstacle course.

Each team has the option of participating in an autonomous mode of the competition. To score points during this phase, teams must get the chassis of their robots as close to a goal line wall as possible without knocking it over. There is a time limit of 30 seconds to complete this section. Points are awarded based on how close the robot chassis is to the wall, with no points being awarded for robots that knock the wall over.

Competition Results

Design reviews were held during the program to help keep the students on track with their designs. In year 1, the milestone of building and test-driving the chassis by the end of week 2 was established. A design review was then held the Monday morning of class in the last week, with each team presenting their ideas to the entire class for critiques and discussion. Many teams were pressed for time as the competition on the last day of class neared. In an effort to yield more time to work on the fabrication and debugging of the final projects, the initial concept design review was moved up in year 2 to the Monday of the second week and another design review was added to the Monday of week 3. The second design review was held with each group individually with all the instructors, rather than in front of the entire class.

In year 1 of the program there was only one day of competition, held on the last day of class. Most teams were working right up until the last minute to get a functioning robot onto the course. All seven teams came up with unique designs and were able to successfully tele-operate their robots through the obstacle course.

In order to try and alleviate the stress on the last day of class, an additional day of competition was added in year 2 on the Thursday of week 3. Here, shorter seeding rounds were planned to face-off teams against each other in head-to-head match-ups. Every team plays every other team one time. The win-loss records for the seeding competition are used for seeding in a single elimination bracketed playoff on the final day of class. Due to the added lecture time afforded by re-using the chassis from the previous year, more lectures on linkages and mechanisms were available to the students at the beginning of the program. This led to more unique and complicated designs in year 2, and unfortunately more problems getting fully functional robots. Only two robots were ready to navigate the course on the final Thursday so no seeding rounds were held. On the last day of class, there were only two fully operational robots that navigated the course. One that was ready on Thursday had been damaged during a test run that day making it in-operable on Friday. After the group presentations on their designs, three more were functional leaving just 2 that were not operational. Most of



Figure 10. Sample Final Project Designs



Figure 11. Robotic Monster Truck Competition

the problems encountered were due to the complexity of the designs, electronics issues (poor wiring), and underestimating the torque capabilities of the various motors.

The robots that did compete each year were able to successfully navigate the course, obtain the various targets and transport them back to the finish line. Figure 10 shows some sample final designs that teams came up with while Figure 11 shows some of the robots in action during the competitions. In both years, the simple designs worked out the best. These designs had simple scoops on the front that were actuated with one motor and in some cases flaps on the end of the scoop to push the balls into the scoop. Robots designed to pick up the eggs and wiffle balls and just went for the hockey pucks as a bonus worked the best. The teams that chose to just go for the hockey pucks (worth the most points) ran into the most trouble.

RESULTS

We have ran this program for the past two years with class sizes of 21 and 23 students. The students not only learned technical skills but also mechanics, electronics, and a programming language. They also learned a lot about teamwork and professionalism through their interactions with the technical staff, pro-

fessors, graduate students, and colleagues.

Student surveys were handed out at the end of the program for feedback. All the students enjoyed their experiences. Over 83% rated the experience as "Excellent" or "Outstanding". Most wished they had more time to work on the final projects. In spite of working an average of 10+ hours/day it was a meaningful experience. Students acknowledged the one-on-one attention and direction received from the instructors and staff as a great attribute of the program. Although evaluation of the effectiveness of the program would require tracking the students and surveying them after they entered a baccalaureate degree program, this preliminary data suggests our top-down approach is effective in engaging and motivating the students to work hard and learn.

It is also evident that the final project is quite hard. Time constraints implied that there was not much room for error. The team dynamics for such a diverse group of young students can be complex at times. Some maturity issues with students, (social and personal, not technical), led to difficulties with some of the teams. The students enjoyed the design and fabrication aspects of the program more than the in-class lectures. They found it difficult to connect the lecture materials to real-world applications and their final projects.

This program is educational for a number of reasons. Lectures covered the basics of robotics and the lab and homework assignments were designed to reinforce these topics. The submitted lab reports along with homework assignments were graded and returned to provide feedback throughout the course. Subsequent reports and assignments grades improved as students gained more experience. The final project ties together all that is learned in the three weeks. In order to get a functioning robot, the students need to have an understanding of the topics that were covered and be able to implement them successfully.

Ideally when teaching the design process, problems with large potential design spaces an many different solutions are used. In the mechanical design labs, some aspects of the design space were limited (i.e. choosing 1 of 4 gear ratios in mechanical design lab 2) but others were not in order to foster creativity (i.e. the wheel design, gear box mounting, truck body shape, weight placement, etc. for the same lab). In regards to the final project, the design space is large and there are many solutions to the problem. Two formal design reviews were held with each team throughout the course to help with the process as well as many informal reviews. Due to the time constraints, simulations of each design were not performed to address validity of designs before fabrication.

To improve the program, we plan on emphasizing the connections between the lectures, labs, and final project. We are also planning on shortening the lab report requirements for the labs and integrating the labs into the final projects. This way, once the lab is complete that module of the final project is also complete. More stocked components, such as motor shaft couplers and gear sets, are also planned in an effort to make the designs more ro-

bust and not require the students to manufacture or specify and acquire them. These changes will allow for more time for testing and debugging and not as much of a time-crunch right before the competition days. We also plan to emphasize more solid modeling techniques and require a CAD prototype of the mechanisms in the designs as part of the design reviews. This way they can simulate the kinematics of the design and evaluate it more effectively before fabrication is started. Motor load calculations will also be required to ensure that the design is feasible.

CONCLUSIONS

Robotics is great way to teach students about engineering and technology. It makes the experience fun and goal-oriented. We have shown that it is possible to start teaching robotics at the high school level and injecting engineering and design content into the curriculum at a very early stage to help recruit and retain students. The top-down education style allows for the success of programs like these. The presence of a well-defined, open-ended final project/design competition helps facilitate teaching and implementation of the design process. Analytical concepts are taught on an as-needed basis to support the required design and prototyping, while more general concepts and applications are presented in the formal education component of the course. We currently know of 3 of the college-age students from the first year of the program now enrolled as freshman engineering students here at our university and are in the process of obtaining data on the whereabouts of the other college-age students from the first year of the program. In the future, it will be interesting to track the college placement of the rising-sophomores and juniors who were enrolled in the program to see if their interest level in engineering has been sustained and/or fostered from participation in this program.

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