USING ROBOTICS TO ENHANCE OUTREACH PROGRAMS FOR HIGH SCHOOL STUDENTS

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Abstract

The Fenn College of Engineering at Cleveland State University has developed a series of hands-on, minds-on engineering themed robotic activities aimed at exposing local high school students to various facets of engineering.

The paper describes the efforts made by the college to use the thrill and excitement of small mobile robots like Lego Mindstorms ™ and Parallax BoeBot ™ to introduce engineering concepts to 9th-12th graders. The college's outreach activities consist of formal presentations and hands-on activities given through the faculty lecture series and high school visits. The one-week summer camp component of the program consists of participants designing and building a project, working in teams, mastering tasks and sharing in themed robotic adventures with their fellow students. The participants learn how robots use touch, light and ultrasonic sensors and motor controllers to navigate their robot. There is a culminating activity at the end of the week that gives the participants an opportunity to describe and demonstrate various applications of their robot to parents, friends and family. More than 550 high school students have participated in the program to date.

Preliminary assessments of the program have demonstrated that early exposure to engineering focused activities encourage students to pursue an exciting and rewarding career in engineering.

I. INTRODUCTION

Addressing declining enrollments in engineering colleges is a challenge faced by universities across the country. In response, outreach programs have arisen which introduce engineering to high school students. A common goal in all these programs is to attract talented young people to careers in engineering. These programs vary in size and duration; for example, there have been one-hour experiences, half-day and day-long efforts, one-week to five-week intensive summer activities, and even on-going relationships with local high schools throughout the academic year.[1-7]

At Cleveland State University (CSU), the Fenn College of Engineering currently offers a variety of outreach programs for high-school students. These programs are aimed at raising the overall awareness of engineering and how CSU can help students achieve a lifelong career of meaningful work. Three programs specifically related to this paper are as follows:

- Faculty Lecture Program
- High School Visitation Days

- Engineering Challenges

Through the various components of each program, students are exposed to an overview of engineering as a career and to highlight the strengths and capabilities of the Fenn College of Engineering at Cleveland State University. The programs are detailed in Table 1:

Table 1: Educational Outreach Program

Education Outreach Program	Description	Engineering Disciplines	Topics
The Faculty Lecture Program	Engineering professors go to area high schools to give presentations on various engineering focused topics.	Chemical, Civil and Environmental, Electrical and Computer, Industrial and Manufacturing, Mechanical and Engineering Technology	Digital Audio and the CD, **Robotics,** Global Warming, The Bioartificial Pancreas for the Treatment of Diabetes, Fighting Friction in Machinery.
Engineering Activity Day	An intensive half day hands on program for high school math and science classes or specialized student organizations such as science clubs.	Chemical, Civil and Environmental, Electrical and Computer, Industrial and Manufacturing, Mechanical and Engineering Technology	Operation and Computer Control of a Heat Exchanger, Stirling Engine, Component Evaluation and Prototyping, Performance Optimization, Digital Audio and CD, Material Properties Comparison, Distillation Column, **Robotic Demonstration**
Engineering Challenges	Three separate weeklong camps that occur during the summer.	Mechanical, Engineering Technology, Electrical	Introduction to Fuel Cells, **Introduction to Robotics**, Solid Modeling and Rapid Prototyping

For the Faculty Lecture Program, engineering faculty from each discipline are available for travel to local high school classrooms to give a brief one-hour presentation on their area of expertise. Currently faculty are lecturing on the following topics:

- Digital Audio and the CD
- Robotics – Basic Tasks and Behaviors
- Global Warming
- Bioartificial Pancreas for the Treatment of Diabetes
- Fighting Friction in Machinery.

For the High School Visitation Days program, groups of high school students visit the college facilities for a half-day session including tours, presentations and activities. Students can attend two different one-hour presentations by engineering faculty, chosen from the following areas:

- Operation and Computer Control of a Heat Exchanger
- Stirling Engine
- Component Evaluation and Prototyping, Performance Optimization
- Digital Audio and CD
- Material Properties Comparison, Distillation Column
- Robotics Demonstration.

For the Engineering Challenges program, the engineering faculty have developed and offer three different week-long summer camps opportunities. Recent topic areas offered include the following:

- Introduction to Fuel Cells
- Introduction to Robotics
- Solid Modeling and Rapid Prototyping

In addition to these established outreach programs, the Fenn College of Engineering is developing a new and innovative initiative known as the Fenn Academy. The Academy is structured to be a consortium between Fenn College and a group of prospective high schools and local corporations. The mission of the Fenn Academy is to attract high school students to various engineering fields offered at Fenn College, and to support those students with technical, and when possible, financial means throughout their entire educational experience, starting in high school and progressing through their college years.

This paper will discuss how robotics is used in the CSU outreach programs to provide "hands-on, minds-on" exposure to the various engineering disciplines to high schools students in the Greater Cleveland, Ohio area. Robotics has been used successfully in other outreach programs.[5-11] Robotics is unique in that it is used in all three of our outreach program areas as indicated in Table 1.

Centering activities around robotics is an excellent way to reach these young people. In this format, these programs can range from short one-hour activities in the Faculty Lecture Program and High School Visitation Days, involving slide and video presentations and brief hands-on activities with Lego robots, to a week-long summer camp experience, where participants design and construct scale-model robots using Lego and Parallax BoeBot technologies.

The remainder of this paper is devoted to detailed descriptions of the activities designed for the various outreach programs offered. Section II will detail a one-hour robotics presentation, used as part of a Faculty Lecture Series program or High School Visitation Day program, which are devoted to attracting talented young people to careers in engineering. Section III will detail a week-long program designed to expose participants to the various engineering disciplines. Section IV will discuss the outcomes of these outreach efforts. Section V will describe an ongoing outreach effort, in which Fenn College provides support to Cleveland area high schools. In Section VI, conclusions and recommendations based on the robotics-based outreach efforts will be offered.

II A SHORT ONE-HOUR ROBOTICS PRESENTATION

Development of a short presentation on robotics was begun in 1999 by Professor Robert Mikel of the Department of Engineering Technology.[12] His presentation featured a video showing students in his senior design class demonstrating their autonomous robots, as shown in Figure 1. The robotics presentation was popular with local high schools, with 3 to 6 requests a year for the presentation.

Figure 1: Robot built in senior design class

In 2002 the Engineering Technology faculty began looking for ways to improve the outreach robotics presentation, with the goal to create more interest in the students. The video showing the senior design class robots was still the basis of presentation, but now actual robots were brought to class to demonstrate robot behaviors. One or two of the autonomous mobile robots from senior design class would be set on the floor in front of the audience, as shown in Figure 2, and allowed to roam about, avoiding obstacles. The audience would often become vocal, calling or talking to the robot as it moved about in a life-like manner. Interest by the high school student was now definitely higher than when just viewing the video and listening to a lecture on robotics.

Figure 2: Robots demonstrated on High School Visitation Day

During university-based presentations (e.g., High School Visitation Day), an educational robot manipulator, as shown in Figure 3, was brought to class to demonstrate the execution of a pick and place program, under computer control and under manual control. In the lecture, information was added about careers in engineering and technology, complete with employment and expected salary data. At the conclusion of the presentation, every visitor would receive an envelope with pamphlets and brochures about careers in engineering and training programs at CSU.

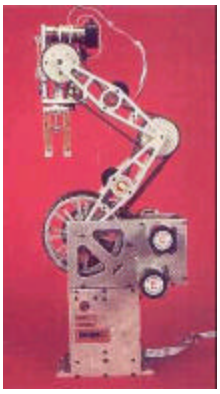

Figure 3: Educational robot manipulator

Despite the apparent increased interest in the robotics presentation by the high school students, it was felt that the students are just passively listening to presentations, and that we need to find some way to engage them physically in process. Most educators believe there is no better way to learn than through personal, hands-on experience (as opposed to merely listening and passively absorbing lectured material). Hands on - Minds on became the motto.

It was decided to bring in small mobile robots, such as the Lego Mindstorms shown in Figure 4, and allow the students to handle and operate the robots in a way that also conveys some basic information about robots and engineering and technology in general.

Figure 4: Lego Mindstorms robot used for hands-on activities

The current format for our short one-hour presentation on robotics is a follows:

- Introduction: Greetings and a brief description of the who we are at CSU
- Slide presentation: Basic Tasks and Behaviors

  An interesting survey of where we find robotics at work, in space and the military, in hobbies, around the house, in hospitals performing surgery, in service roles, and performing hazardous duties. It includes a look at walking robots, flying robots, underwater robots, crawling robots, and stationary robots. And it concludes with a quick look at educational robots, including the Lego Mindstorms robot, the Boe-Bot mobile robot, and the Rhino manipulator robot.
- Video: Introduction to Successful Robotic Solutions

A fast-paced, informative look at industrial robot applications, produced by the Robotic Industries Association, Ann Arbor, MI.

- Slide presentation: Lego Mindstorms features

  A very short look (10 slides) at how to handle, operate, and program the Lego Mindstorms robots (that they are about to work with).

- Hands-on table-top activities with the Lego Mindstorms robot

  5 preprogrammed activities

  1. forward, back, turn maneuvers
  2. touch sensor activates motion
  3. light sensor calibration and tone generator
  4. light sensor activates motion
  5. light seeking maneuvering

Although the robot is quite simple in geometry, the students go through several steps, including installing touch and light sensors and running a number of built-in robot programs which demonstrate basic tasks and behaviors of autonomous mobile robots.

Many of the young people attending the sessions have had no experience with the Lego robot. A number of these high school students with no robotics experience at all appear to easily adjust to handling and working with the robots even though they have had no Lego building history.

Sometimes there are members of the high school that are already skilled Lego robot operators. For them we provide a few computers in the room with Lego software running and we invite them to explore reprogramming their robot, while their classmates are experimenting with the five preprogrammed maneuvers.

Recently, we have introduced the groups to the remote controlled Robosapiens at the very end of the program. And for a few minutes, at the close, everyone enjoys watching some of their classmates control the machines and cause them to march up the aisles.

The result has been positive. There is genuine excitement in the room. Some schools now bring second and third classes to Engineering Activity Day and request the robotics presentation. There have even been requests for follow up visits by schools visited during the Faculty Lecture Series.

For the Faculty Lecture Program, we take the Engineering Activity Day program on the road to various high schools that request a presentation. The Lego Mindstorms are compact units that are easily carried into the high school classroom, using a convenient 2-wheel utility cart. The schools must provide the video player and monitor, if we are to view the 9-minute industrial robot applications video. We take along a slide projector, but usually the schools provide this item also. Students engage in the hands-on activities on table tops (if available) or in clear areas on the floor. We cannot engage in any reprogramming activities, however, since the schools don't have the software on their computers.

III. A WEEK-LONG ROBOTICS SUMMER CAMP

Each summer, Fenn College sponsors a week-long outreach program entitled *Engineering Challenges.* It is intended to give participants an in-depth experience in an engineering

discipline of their choice. Programs are offered in the disciplines of Mechanical Engineering, Engineering Technology, and Electrical and Computer Engineering.

The Engineering Technology offering is centered around robotics. Students build their robots with a goal in mind – some kind of individual challenge project or classroom competition. Many of these robotic challenges, races, and competitive events are scheduled throughout the week.

The summer program introduces students to the electronics, mechanics and computer science of robotics, through a series of daily autonomous robot challenges. Students build, program and operate autonomous mobile robots capable of sophisticated sensing and intelligent decision-making.

The students spend four and one-half days from 9:00 a.m. to 3:00 p.m. working on their robotics activities. They get hands-on experience by learning how to build and program their own miniature robots. This is an opportunity to increase student awareness of engineering technology. It allows students to build robots and learn about how robots see and work. A schedule of robotic events for a recent summer robotics camp is given in Appendix A.

Hands-on activities involve designing and building robots, learning programming and presentation software, working in teams, mastering tasks, and sharing in themed robotic adventures with other students. The students learn how to program robots to navigate using touch, light, and ultrasonic sensors and motor controllers. Three different robots are used: the Lego Mindstorms, the Boe-Bot, and the Robosapien robot.

Using Legos, students work with gears, motors, axles, pulleys, microcomputers, and touch sensors to build robotic vehicles that navigate mazes, avoid obstacles, and escape from corners. Students then enter their best designs into a Ben-Hur style chariot race in a competitive activity to see whose machine was built and programmed the best for navigation around the track. Adding light sensors to their machines allows students to build and program a robot that can respond to a light beam or to follow a thick black line around a paper grid. This culminates in an Indy-style race in which student entry robots have to move quickly within their race lane (black tape on floor) and be the first to successfully navigate the serpentine-shaped track.

Using Boe-Boe robots introduce students to more complex technology in very simple ways. They learn to use electronic wiring diagrams, resistor color code, and electronic parts such as microcontrollers, diodes, speakers, photo-resistors, and ultrasonic sensors. They also learn to use a new programming language (PBASIC) to control their Boe-Boe machines. Their final themed adventure with the Boe-Bot involves a hunter-prey scenario; the hunters (Robosapiens, controlled by fellow campers) stalks the prey (several Boe-Bot robots).

By introducing progressively more challenging daily contests and providing important information in brief lectures, the summer camp Engineering Challenge builds incrementally on the students' knowledge and the robot systems until, at the completion of the camp, the students can perform a variety of activities with their robot. As a final assignment, campers plan and develop a presentation (a Show-N-Tell) on Day 5 for their parents and guests, in which they demonstrate with their robots what they have learned throughout the week. For example, each

robot team (of 2 students) explains how a particular sensor functions and then demonstrates with their machine a maneuver that utilizes that sensor. Table 2 below shows a list of the robots from the Summer 2004 camp and what sensors and robot activities were performed.

Table 2: Robots and their final presentation activities (from Summer 2004 camp)

Sensor Featured	Bot Name	Activity	Navigation
Whiskers (Touch)	Repeat Offender	Obstacle Avoidance	Back,turn,go
Whiskers (Touch)	Ugly Bot	Corner Escape	Turn sequence
Photoresistor (Light)	Good Docs Bot	Navigate with Light	Turn to/from light
Photoresistor (Light)	Steve Bot	Follow the Line	Turn to/from line
Infrared Detector	Slow Bot	Wall Hugger	Avoidance
Infrared Detector	Whatever Bot	Cave Escape	Avoidance
Infrared Detector	Wired Bot	Hunter-Prey	Seek
Infrared Detector	Scrap Bot	Shadow Vehicle	Seek

IV. IMPACT

The programs have been successful in reaching a relatively large number of high-school students in the Greater Cleveland, Ohio area. For example, over 500 students from 15 school districts have participated in our High School Visitation Days programs and attended the robotics-themed activities. Our experience has shown us that our programs have impacted students and helped direct career decisions. A mother shared with us her son's decision to become an engineer because of his participation in two of our programs. Brandon, a recent high school graduate, has decided to major in engineering, a career he knew nothing about until he participated in the Engineering Activity Day and the Summer High School Engineering Challenge.

To date, we have had 46 students from over 30 school districts participate in our Introduction to Robotics' Summer High School Engineering Challenges. Five of these students subsequently enrolled in an engineering degree program at CSU. One student in now a sophomore and the other four are freshman. Two of these students have started their own Lego's Club in the Education/Engineering Innovation Center of the Fenn College of Engineering and meet regularly each week to build various robotic inventions.

V. PROGRAM SUPPORT

Since our program began, we have successfully formed collaborations, partnerships, and secured funding from various foundations, and industry to offer quality engineering programs and activities to Cleveland area students. Support has come from organizations including Eveready ™, GrafTech International Limited and the Convergence Education Foundation.

VI. SUMMARY

Cleveland State University's Fenn College of Engineering sponsors a number of outreach efforts designed to attract talented students to the engineering profession. The purpose of these

programs is both to expose students to an overview of engineering as a career and to showcase the strengths and capabilities of Fenn College. In addition to these established outreach programs, the Fenn College of Engineering is developing a new and innovative initiative known as the Fenn Academy. The Academy is structured to be a consortium between Fenn College and a group of prospective high schools and local corporations.

The use of robots in these outreach programs has proven to be an effective way to grab the attention of these young people, particularly when hands-on activities are designed into the presentations. Centering activities around robotics is an excellent way to reach these young people. In this format, these programs can range from short one-hour activities in the Faculty Lecture Program and High School Visitation Days, involving slide and video presentations and brief hands-on activities with Lego robots, to a week-long summer camp experience, where participants design and construct scale-model robots using Lego and Parallax BoeBot technologies.

The results have been positive. To date, over 500 students from 15 school districts have participated in the robotics-themed Engineering Activity Day, and in the past two years alone 46 students from over 30 school districts have participated in our week-long summer robotics camp. About 10% of these summer robot campers are now currently enrolled at CSU in Fenn College.

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Appendix A

Summer Camp Engineering Challenge – Introduction to Robotics

Schedule of Robotic Events

DAY 1

Time	What You Will Do	What You Will Learn
9:00 a.m.	Introduction	Expectations, safety, code of conduct
	Slide Presentations	
	Introduction to robotics	Basic principles of robots
	Introduction to Lego Mindstorms	Basic features and operation of Lego
	Building tips	Sturdy construction, available parts
10:00 a.m.	LEGO CHALLENGES	
	Build robot	Creating own design
	Learn to program	Make it move forward, back, turn
Lunch Break		
12:30 p.m.	Drive straight a required distance	Navigation by timing (no sensors)
	Drive straight and turn	Navigation with more complex timing
	Build bumper (add touch sensors)	Construction using pivots and supports
2:30 p.m.	CONTEST #1	Chassis strength for contact competition
	Ben-Hur Chariot Race	The pride of victory & agony of defeat
3:00 p.m.	End of Day 1	

DAY 2

Time	What You Will Do	What You Will Learn
9:00 a.m.	Unstructured free time	Reconstruct, reprogram, investigate
10:00 a.m.	Add light sensor:	
	test & calibrate sensor	Sensor range, accuracy, and calibration
11:00a.m.	LEGO CHALLENGES	
	Follow a line (using light sensors)	Navigation using feedback information
Lunch Break		
12:30 p.m.	Program with Not-Quite-C language	Structured language similar to C
1:30 p.m.	LEGO CHALLENGE	
	Navigate maze & stop on gray	Sensing for range of light intensities
2:30 p.m.	CONTEST #2	
	Drag Race (stay in track with light)	Fast navigation without losing control
3:00 p.m.	End of Day 2	

DAY 3

Time	What You Will Do	What You Will Learn
9:00 a.m.	Introduction to Boe-Bot robot	Robot made by Parallax Corp.
10:00 a.m.	Slide Presentations	Boe-Bot electronics & wiring
	Hardware layout	Basic electronics, microcontroller info
	Programming, debug output	PBasic language for programs
	Servos, using PULSOUT	How servos work with pulse inputs
	Number systems, binary #'s	World of the computer is in binary
11:00 a.m.	Program and test the Boe-Bot	
	Programming (in Pbasic)	Structured language programming
	Testing servos (motors)	Speed using pulse width control
	BOE-BOT CHALLENGES	
	Navigate a square (3-foot sides)	
	Navigate a circle (3-foot radius)	
Lunch Break		
12:30 p.m.	Install ultrasonic detector	
1:00 p.m.	Install on Boe-Bot	Wiring on breadboard
	Program to avoid obstacles	Program logic for avoidance navigation
	Robosapien (remote control robot)	
	Learn controls	Use of hand-held control
	Program capture moves	Practice navigation and arm motion
2:30 p.m.	CONTEST #3	
	Hunter-Prey	Capture vs avoidance
3:00 p.m.	End of Day 3	

DAY 4

Time	What You Will Do	What You Will Learn
9:00 a.m.	Install photoresistors on Boe-Bot	Wiring on breadboard
	Monitor output vs light intensity	Calibration of light sensor
10:00 a.m.	CHALLENGE	
	Make Boe-Bot seek flashlight beam	Program to respond to light intensity
11:30 a.m.	CONTEST #4	
	Seek-the-Light Race	Light activated and guided motion
Lunch Break		
12:30 p.m.	Plan and prepare for Show-N-Tell	Teamwork, group effort assignment of
1:00 p.m.	presentation to parents and guests on Day 5.	duties, preparation for presentations
3:00 p.m.	End of Day 4	

DAY 5

Time	What You Will Do	What You Will Learn
9:00 a.m.	Finish preparations and practice for Show-N-Tell presentation to parents and guests on Day 5.	Teamwork, group effort assignment of duties, preparation for presentations
Lunch Break	Luncheon with parents and guests	
12:30 p.m 1:00 p.m. 2:00 p.m.	Certificates of Completion award Presentation to parents and guests End of Day 5	