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Abstract

Students in today's world grow up surrounded by electronic and electromechanical gadgetry and become adept at using such gadgetry at an early age without necessarily understanding the underlying science and technology. Garage door openers, TV remote controllers, microwave ovens, remote-control toys, and cellular phones are but a few such items in wide use today. As complex as these gadgets seem on the surface, much of the scientific and technological mystery behind their functionality can be explained in simple terms well within the grasp of the high school, or even middle school students. The primary purpose of this project is the development of science and technology instructional units aimed at a variety of students with the goal of giving these students an understanding of and appreciation for the basic scientific principles underlying the technological innovations that surround them. Students are introduced to science and technology in a gentle, non-threatening manner by developing a collection of hands-on laboratory experiences based upon simple systems constructed out of LEGOs and controlled by small microprocessors. These laboratory experiences are designed to lead students, literally by their hands-on experimentation, through the use of technology in support of many everyday activities.

Disciplines

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Toying With Technology:
Mobile Robots and High School Interns

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Introduction

Students in today's world grow up surrounded by electronic and electromechanical gadgetry and become adept at using such gadgetry at an early age without necessarily understanding the underlying science and technology. Garage door openers, TV remote controllers, microwave ovens, remote-control toys, and cellular phones are but a few such items in wide use today. As complex as these gadgets seem on the surface, much of the scientific and technological mystery behind their functionality can be explained in simple terms well within the grasp of the high school, or even middle school students. The primary purpose of this project is the development of science and technology instructional units aimed at a variety of students with the goal of giving these students an understanding of and appreciation for the basic scientific principles underlying the technological innovations that surround them. Students are introduced to science and technology in a gentle, non-threatening manner by developing a collection of hands-on laboratory experiences based upon simple systems constructed out of LEGOs and controlled by small microprocessors. These laboratory experiences are designed to lead students, literally by their hands-on experimentation, through the use of technology in support of many everyday activities.

Laboratory experiences, inspired by work done at MIT[1,2], typically involve the design and construction (out of LEGOs) of simple models of familiar real-world systems, including an elevator and its controller, a garage door and its opener, a computer-controlled car, and a home security system. The supporting instructional material includes a laboratory manual and laboratory kits appropriate to the teaching of each unit.

Summer Internship Program for Women in Science and Engineering

The initial development and testing of laboratory experiences occurred during the summer of 1996 and involved high school students who were participating in a summer internship program directed at undergraduate and high school women in science and engineering fields. This program is administered each year by Iowa State University's Program for Women in Science and Engineering (PWSE). In the summer of 1996, eight high school women in this program designed and built mobile robots to perform certain prescribed engineering functions. They simulated these devices by constructing autonomous robots out of LEGOs (hence the title, "Toying with Technology"). A world-wide-web site was developed which highlights these efforts. It can be viewed at http://www.ee.iastate.edu/Mobile_Robot/mobiler.html. These

students were directly supervised by two undergraduate women, co-authors Kara Wright and Christine Collier.

The purpose of the internship program is to give young women experience in research laboratories under the mentorship of an Iowa State professor, thereby stimulating and solidifying their interest in Science, Engineering, and Mathematics (SEM) careers. The program allows talented high school women to explore research opportunities in science and engineering and to build their confidence in SEM related fields[3-5]. The students work independently on a research project with an ISU faculty member. The students complete a hands-on research project and present a formal paper and poster at the completion of the session. The high school students also agree to do a presentation for their home schools during their senior years.

The PWSE office administers pre- and post-event surveys of the interns and tracks their progress and attitudes[4,5]. A survey done by the PWSE office in 1993 reported that 68% of the respondents felt that the internship had furthered their interests in a career with science and engineering[5]. These findings demonstrate the success the program is having in promoting SEM career paths.

The Program for Women in Science and Engineering at Iowa State University is one of a number of programs that are trying to create opportunities for young women interested in science and engineering. PWSE accomplishes its goals through career conferences, scientific internships, and scholarships. PWSE also provides some financial support for women in science and engineering. This program, as well as many others, tries to make women aware of the career possibilities for them in technological careers.

We believe the use of PWSE summer interns in our Toying with Technology project worked very well. For one thing, the PWSE focus on getting women interested in science and engineering matches our own goal of stimulating such interest among young students. Thus, our project provided a nice, and highly motivational research experience for the high school women. In addition, it provided an excellent opportunity to test the use of "toys" in an instructional setting. Finally, the existing PWSE infrastructure provides suitable mechanisms for follow-up activities with the students.

The Summer of 1996

The summer began with a simple tutorial session in which the high school students, working in teams of two, were introduced to the use of a small microcomputer in controlling a simple, two-motor model car built out of LEGOs. Each student team was supplied with a kit that included a set of LEGOs, a small microcomputer system called the Miniboard (about the size of a credit card), batteries, plus motors, various connectors, wires, switches, and sensors. The kits cost about $150 each with the kit components obtained from readily accessible sources.

In this tutorial session, the students were first instructed in building a car from a kit of LEGOs. They were then shown how to operate the cars by powering the motors via signals generated by the microcomputer. The students were shown how to connect the motors to the computer and were given a sample program to control the motors. Their first assignment was to have the car

run forward for twelve inches and then stop. After this was accomplished, they were instructed to have the car move in a square pattern.

Most of these women, while having experience with LEGOs, had no prior experience with programming languages. The programming language they were given to use was ICC11, a subset of the programming language C. Included with ICC11 was a collection of built-in commands with which to control simple robots. One such command, motor(mtr,spd), is provided to instruct motor mtr to turn at speed spd. For the particular computer system used, four motors can be controlled with mtr given the value 1, 2, 3, or 4. The speed value, spd, can be in the range from -16 to +16 inclusive. Thus, for example, the command motor(1, 16) tells motor 1 to go in the forward direction at the speed of 16 (i.e., full speed ahead). The command motor(1,-16) causes motor 1 to go backwards at full speed while the command motor(1,0) turns motor 1 off.

A command, msleep(amt), causes the program to do nothing for an amount of time equal to amt milliseconds. The students had little trouble using the motor and msleep commands to create programs that will cause the model cars to move in various patterns. Moving a car a distance of twelve inches simply involves turning on both motors for a specified amount of time. The students could determine this time by experimentation.

Programming the car to move in a square pattern involves programming the car to execute a right angle turn and then combining this turn with the previously constructed program to form the square pattern. Various other patterns such as rectangles, equilateral triangles, and circles were suggested. Although the students generally had little difficulty mastering the logic of the various exercises, they soon discovered the "external" factors that influenced their results. Variability in surface friction, strength of batteries, drag on the motors, etc., were seen to interfere with the success of an otherwise logically correct program.

Controlling a car to move in prescribed patterns represents a control exercise involving output actions only. Although the students could recognize the existence of environmental factors on their car's behavior, they had no mechanism available to deal with such factors. The next step in the tutorial exercise introduced the students to input operations in the form of different sensors. The students were first introduced to simple "bumper" sensors in the form of push-button switches. A given push-button switch, when connected to the computer, produces a 1 signal when pushed down and a 0 signal when not pushed down. Commands were available for "reading" a sensor to determine its value, which they recognized as a "digital" quantity being either a zero or a one. The students, then, could program their car to react to its environment by determining if a given pushdown switch is pushed down or not. Their first exercise of this kind asked them to program their car to move forward until it struck an object and then reverse itself. In this way, the students were introduced to simple input operations to supplement what they had already learned about output operations.

After the students experimented with simple bumper sensors, they were given a special light sensor that could be commanded to emit a light and measure the amount of light reflected back to the sensor. Such a sensor, called a reflective sensor, produced values in the range from 0 to 255 inclusive and is regarded as an "analog" sensor (in contrast to the "digital" sensor that produces only two values, 0 and 1). The students were encouraged to experiment with the reflective

sensors applied to various surfaces to see what range of values would typically be produced when light was reflected from a nearby surface.

The students discovered that reflective sensors could be used to determine the difference between a black and a red surface. They were then asked to program their car to move forward on a red surface and to halt upon reaching a black stripe. A natural, although challenging extension to this exercise, asked the students to program a car to follow a black stripe. The students could use any number of sensors they desired.

Each student attacked the line following exercise differently. While some used a single reflective sensor and just followed the outline of the black stripe, others used four sensors, one located a couple of inches in front of the car, one right at the tip of the car, one to the left of the stripe, and one to the right of the stripe. Each student used their own ingenuity to solve the problem in their own way.

By this time, a natural interest among the students was being developed. From a common background, they were paired off and assigned their own projects. These projects varied in difficulty and in scope. One student concentrated on the use of gears in building a car to climb inclines of at least 30 degrees. She learned the gearing down ratio needed and used different sizes of gears to obtain the required gear ratio. In this way, she learned about gears, making gear boxes, and adapting gear boxes so as to propel a car.

One group of two students designed a garage door opener. They developed the necessary gearing mechanism to properly control the garage door speed and used bumper switches to determine when the door should be opened and when it should be closed. This group later adapted their garage door controller program to the controlling of a simple model train.

One of the more impressive demonstrations involved the implementation of a night light timer. The students designed, using a built-in clock on the microprocessor, a simple alarm clock. This clock would signal, via a special circuit, a light to turn on for a certain amount of time and then turn off. The students utilized a light sensor that sent a signal to the microprocessor indicating a low level of external light. The student's program, when sensing this low-light signal, then turned on the light and set the alarm clock to turn the light off after a specified delay.

One student worked with a special ultrasonic sensor that would transmit a sound wave and then detect a reflection of that sound wave when it bounced off an object. By determining the delay for the reflection, and by knowing the speed of sound waves, the student was able to determine the distance of the computer to the point of reflection. The student then mounted the sensor on her car to implement a simple object-avoidance mechanism for the car.

Since The Summer

More recently, we have worked with an enhanced microprocessor system, called the Handyboard. We program the Handyboard using the Interactive C programming language which, like ICC11, includes a set of routine for controlling mobile robots. We have implemented all of the summer experiments using the Handyboard.

The Handyboard includes a capability to both send and receive infrared (IR) light signals. Interactive C includes routines for interacting with IR send and receive circuitry on the Handyboard. These routines allow a program to detect a particular value transmitted from a standard TV remote control device. Using this capability, the microcomputer can respond to such IR signals and can control the car accordingly. For example, when a 2 is pressed on the remote control device, the car can respond by moving forward. Likewise, when a 4 is pressed, the car can, for example, go left. The program takes the signals transmitted by the remote control device, converts them into usable numbers, and uses those numbers to tell the car what to do. This process is similar to, but more sophisticated than, the interactions with other sensors.

We are using this collection of hands-on laboratory experiences based upon simple models constructed out of LEGOs and controlled by small microprocessors in many settings. Collectively, we form these laboratory experiences into laboratory-based instructional units focusing on science and technology for various levels of students. Many hands-on demonstrations for visiting K-12 students from area schools have already been done. A "road show" is being developed from the work of the 1996 summer interns for extending these demonstrations. Experiments have already been incorporated into the first engineering course students take at Iowa State University. This course includes engineering problem solving and a first course in programming. The mobile robots experiments add a "real world" experience in writing programs to solve problems and then applying those programs to an actual device. Perhaps the most far-reaching consequence of this work will be achieved when a new course is offered to future K-12 teachers at Iowa State. This course, also called Toying with Technology, will introduce these experiments and provide lesson materials to be kept by the students for their work with their own students in the future. The use of autonomous mobile robots in a non-threatening research environment has proven to be a highly motivational, confidence building introduction to SEM career paths for young women.

Acknowledgment

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Authors

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