TECHTRONICS II: HANDS-ON EXPLORATION OF TECHNOLOGY IN EVERYDAY LIFE

Paul A. Klenk, Lynn H. Wang, Gary A. Ybarra
Duke University Pratt School of Engineering, Durham, NC

Abstract

Techtronics: Hands-On Exploration in Everyday Life, is an after school program in engineering education designed for middle school students. A joint venture between the Pratt School of Engineering at Duke University and Rogers-Herr Middle School in Durham, North Carolina, and funded by a three year grant from the Burroughs Wellcome Fund, Techtronics seeks to stimulate intellectual curiosity in engineering through exposure to four engineering disciplines: civil, mechanical, electrical and computer, and biomedical engineering. For each unit, students typically work in groups of three to five to complete a project under the guidance of one of five undergraduate Pratt Engineering student teachers. A graduate student coordinates each team of undergraduate teaching fellows. In Techtronics I, students build balsa wood bridges, programmable robots, heart monitors, and solar powered devices. In Techtronics II, returning and new students are participating in an entirely new curriculum during the 2002-2003 academic year. Techtronics II is comprised of approximately half returning students and half new students. Though some students have been lost, the 50% return rate of students from last year's program suggests that the program is meeting its goals to provide a stimulating creative outlet for students with interest in science and engineering. In Techtronics II, returning and new students use computer-aided design (CAD) to test their civil engineering designs before building them in groups, compete in a group setting on the Lego Robotics Mars Rover project, and build AM radio kits. This paper provides an overview of the new structure of the Techtronics program and details the new hands-on, group-oriented modules used in Techtronics II.

Introduction

The Techtronics program, funded by a three year grant from the Burroughs Wellcome Fund, places undergraduate and graduate level engineering students into the classroom teaching engineering education to students at Rogers Herr Middle School in Durham, North Carolina. The program is a part of the K-PhD program at Duke University's Pratt School of Engineering[1]. Techtronics began as a pilot program during the 2001-2002 academic year with one class of approximately 20 middle school students that met once a week. In its second year, the program has doubled in size to two separate classes: Techtronics I has approximately 20 sixth graders and Techtronics II is comprised primarily of 7th and 8th graders, many of whom are returning students. Undergraduate and graduate level engineering students have been used in middle school classrooms in engineering outreach classrooms at other institutions including the University of Colorado at Boulder[2], the University of Texas at El Paso[3], and the New Jersey Institute of Technology[4].

The primary goal of the Techtronics program is to empower students to realize the excitement and potential for innovation in engineering through a simplified introduction to technology as students are often intimidated by science and mathematics. The intention is that, after participating in this program, these students will be more interested in math and science in high school and ultimately more inclined to pursue engineering at the college level and as a career. These goals are accomplished through hands-on exploration of the four engineering disciplines offered at the Pratt School of Engineering: mechanical, electrical and computer, biomedical and civil engineering. Curriculum development strives to incorporate technology to which students would not ordinarily be exposed to enhance the learning experience. For each unit, students develop teamwork and project management skills through completing hands-on projects in groups and pairs. Students are encouraged to "think outside of the box" and be creative in their approaches to solving design challenges. Increasing the participation of underrepresented groups in engineering is another important goal of the program that is addressed through the active recruitment of female participants and underrepresented groups in engineering. Specifically, Rogers Herr Middle School is primarily African American, and an even ratio of girls to boys is maintained.

Structure

Each section of Techtronics meets once a week for 2 hours after school. The classes are led by six Techtronics Fellows from Duke University's Pratt School of Engineering. Each team is composed of five undergraduates and one graduate student coordinator, who, in addition to teaching, also coordinates with school officials and parents. When students work in groups, each undergraduate facilitates a group to promote teamwork and ensure equal contribution by group members in completing the project. The low student to teacher ratio ensures that students are getting individual attention and encouragement.

Although the goals for Techtronics I and Techtronics II are the same, the composition of each class makes the curriculum development slightly different. Since many students returned from last year, Techtronics II is created in part as a continuation course with more challenging hands-on projects that build on what was learned in Techtronics I. Consequently, mostly 7th and 8th graders fill this class while Techtronics I is composed entirely of sixth graders.

There are four units that focus on the four different engineering disciplines offered at Duke. Units are approximately five lesson plans in length. Typically, the first 1-2 weeks are an introduction to concepts that are used to complete a hands-on project during the last 3-4 weeks. At the end of the unit, students are invited to the Duke campus for a half-day Saturday field trip. The Women in Applied Sciences and Engineering (WISE) outreach programs have used Saturday sessions as a similar initial step towards encouraging the pursuit of engineering at higher levels[5]. At Duke, students learn about current research relating to the completed unit, show their parents their completed projects, and get a glimpse of what life in college can be like. For example, for the Mars Rover Design Challenge, students were given a demonstration of a lab researching interactive robotic arms. For the Techtronics I solar racecar project, students were given a demonstration of the Duke Motorsports racecar. In the afternoon, Techtronics I students raced their solar cars and Techtronics II students tested their Mars rovers on an obstacle course while parents cheered for their children. Both sections had the opportunity to see what the other section was doing, thereby reinforcing a sense of community in Techtronics. Parental involvement is an important part of Techtronics. Each of the Saturday sessions gives the parents a chance to see what their children are working on.

Women in Engineering

Women are not proportionally represented in engineering careers or in engineering undergraduate and graduate programs in the United States. In 1990, only 9% of engineers were women[6], which barely increased to 10.6% by 1999[7]. In 1994, only 14.9% of bachelor's degrees in engineering disciplines were awarded to women[8]. The impressions students form regarding math and science are formed at an early age. Research has suggested that the middle school years are an important time to reach girls who might lose interest in mathematics and sciences[9,10]. In fact, students begin differentiating their perceptions of activities based on gender as early as the first grade[11].

Techtronics encourages women to maintain a strong interest in mathematics and the sciences by showing how engineering uses science and mathematics as tools for creative design. Techtronics attempts to maintain an even number of boys and girls in its classes. This is substantially higher than the proportion of women to men in engineering disciplines cited above. Studies have suggested that girls respond more positively to hands-on experiences than to a lecture type classroom situation[12]. In addition, women are more comfortable participating in collaborative rather than competitive activities[13]. For those reasons, Techtronics is well suited towards creating enthusiasm for engineering among female students since all of the projects feature hands-on, group-oriented activities.

Projects

In keeping with the goals of the program, Techtronics II builds on the hands-on projects used originally in Techtronics I. While concepts are introduced in the beginning of each unit, most of the learning takes place through the process of completing a project. Thus, each project incorporates all the learning objectives for each unit. The students work in groups or pairs to help them learn to work together to solve problems. In addition, they incorporate technology tools that induce curiosity and inquiry among the students. The units for Techtronics I were described previously[14]. The units for Techtronics II follow a similar format but build on the skills and knowledge gained in Techtronics I. Techtronics II is not composed entirely of returning students, thus care has been taken to design units that challenge both new and returning students. Finally, the units are designed to complement the North Carolina Standard Course of Study for 6th, 7th, and 8th grade[15]. The units described below, the Mars Rover project, the Balsa wood Tower project, and the AM Radio project are used in Techtronics II.

Mars Rover Project

The Mars Rover project uses Legos to introduce students to concepts in mechanical and electrical engineering and computer science. The project builds on the Techtronics I Robotics unit, in which students used Lego Dacta Mindstorms kits and the Robolab software to creatively design and program a robot in loosely facilitated groups of 2-3 students. During the Mars Rover project, students work in slightly larger groups of 4 facilitated by one of the Techtronics crew leaders. The project was adapted from some of the projects done in the FIRST Lego League[16]. Groups are presented with the challenge of designing and constructing a vehicle out of Legos to navigate the "terrain" of Mars. The rovers are required to navigate an obstacle course built to simulate the surface of Mars and climb the ramp that represents the largest volcano in the solar system, Olympus Mons. To accomplish this task, the groups must first discuss ideas, agree on a design and decide how to build the robot. Then, they must build and program the robot. Each group uses a large number of iterations to determine the best ways to control the turning of the rover. Details must not be overlooked; students learn about the friction of the tires and how that affects turning times over different surfaces. They also learn about and must use a gear ratio capable of providing enough torque to move the rover up the incline representing Olympus Mons. The crew leader is responsible not only for providing engineering insight, but also for facilitating discussion such that everybody's voice is heard.

The Mars Rover project induces curiosity in middle school students through introducing them to the capabilities of the Lego Mindstorms kits and then helping them use those capabilities to solve a problem. The Lego Dacta Mindstorms kits include RCX blocks, input and output sensors, and the Robolab programming software. The RCX block forms the brain of the robot, holds the programs, and controls the outputs. The input and output sensors include touch sensors, light sensors, motors, and lights. Robolab is a graphical programming language designed to make programming intuitive for the students and to introduce basic computer programming structures such as "for loops" and "if/then statements". The students enjoy experimenting with the different Lego formations and programs. Techtronics I focused on this innovative quality of the kits by challenging the students to be as creative as they like. Techtronics II builds on that by providing a challenge designed to intimidate the students at first. Through frustration and eventual success, the students are introduced to the power of engineering design.

Tower Project

The civil engineering unit for Techtronics II is a balsa wood Tower project in which the teams first design towers using CAD, then build and test them. The project builds on skills learned in the Techtronics I bridge building project. As in the Mars Rover project, the students are divided into groups of 4 students and a Techtronics crew leader. Like the Mars Rover project, the crew leader facilitates discussion between the crew members to arrive at design decisions, while ensuring equal idea contribution by each student. The members of the team must decide the basic structure of the tower by drawing a full-scale model on butcher paper. The butcher paper gives the students a chance to draw freely without being concerned about making mistakes. The same design methodology is used to design balsa wood bridges in Techtronics I, but Techtronics II adds the challenge of thinking in three dimensions. Unless the tower is designed with all of its sides perpendicular to each other, the students must consider the angles of the overall structure before they can draw a side of the tower in two dimensions to scale. After the basic design is done on paper, the students use Modelsmart 3D, a computer-aided design and analysis package, to draw and refine the design on the computer. Since it is difficult for four people to crowd around a single computer, students do computer modeling on their own or in pairs. The facilitators help the students with the computer program and encourage modifications to improve their structure. Finally, the students regroup, choose the best design from their computer creations, and build the structure.

The main differences between building towers in Techtronics II and building balsa wood bridges in Techtronics I are designing and building in 3D and building a physically larger and more exciting structure. First, new design challenges surface from building a 3D structure. A bridge can be easily designed in two dimensions because the students simply draw one side, build it twice, and connect both sides. This connection can be discussed after the sides have been built and need not be considered in the drawings. Designing in three dimensions both on paper and in Modelsmart 3D provides new challenges. Modelsmart 3D itself provides the technological excitement. Students tweak their designs in the program and then analyze them by placing forces at the top of the structure. The computer determines how much weight each tower can hold. The students can easily experiment with different variations of their original butcher paper design, just like real engineers, and determine the most effective. Second, the scale of the project makes it exciting for them and distinguishes it from the Techtronics I bridges some of them built the previous year. The towers are built with ¼" square cross section balsa wood instead of 1/8" square and are built to a height of 4ft, which is taller than some of the students.

AM Radio Project

The AM radio project is the electrical engineering project for Techtronics II. It builds on the knowledge gained in the Techtronics I heart monitor unit. The actual building of the AM radios is done in pairs since working in larger groups would decrease each student's hands-on time. Since the kits have instructions, there are not many design decisions to discuss. Instead, the students need to work together to understand the instructions and to build the kits. The kits are obtained from Gateway Electronics Corporation and require some soldering.

The AM radio unit uses hands-on technology to show them what they are capable of creating through engineering. Empowering the students in this manner requires the kit to be both simple enough to finish successfully but complex enough to be intimidating at first glance. The students must solder the parts to the board, which is different from Techtronics I where the students use breadboards to build their electrocardiogram circuits. Close supervision is necessary for soldering and the program structure makes this possible through the small student to facilitator ratio. Oscilloscopes and other measurement tools are used to analyze the signals from the radios and, illustrate waveforms for the students. Visualizing sound waves on the oscilloscope and then hearing them from the radios is the final exciting feature of the unit.

Assessments

A number of methods are used to assess Techtronics' ability to meet program goals, including looking at year to year retention rates and student surveys. First, the initial year of Techtronics I during the 2001-2002 academic year was a positive enough experience that about half of the students who completed last year returned for Techtronics II during the 2002-2003 academic year. Second, students complete unit evaluations at the end of each unit. These results are used to assess the immediate ability of the unit to meet program goals and to obtain feedback on the strengths and weaknesses of each unit. Long-term studies are required to determine the lasting impact of the program. Data is provided for the first unit of the 2002-2003 academic year which is Solar Energy for Techtronics I. The data for the solar energy unit of Techtronics I is shown below, broken down by gender. Figures 1 and 2 indicate that the unit did make students think about things they had not thought about before and that it helped them understand science better. Figure 3 indicates that students are enjoying Techtronics enough that the majority of them would participate in it again if given the opportunity. Proportionally, the responses from female participants are also very positive. Although a complete data set for the Mars Rover project could not be attained, initial feedback has been positive as well.

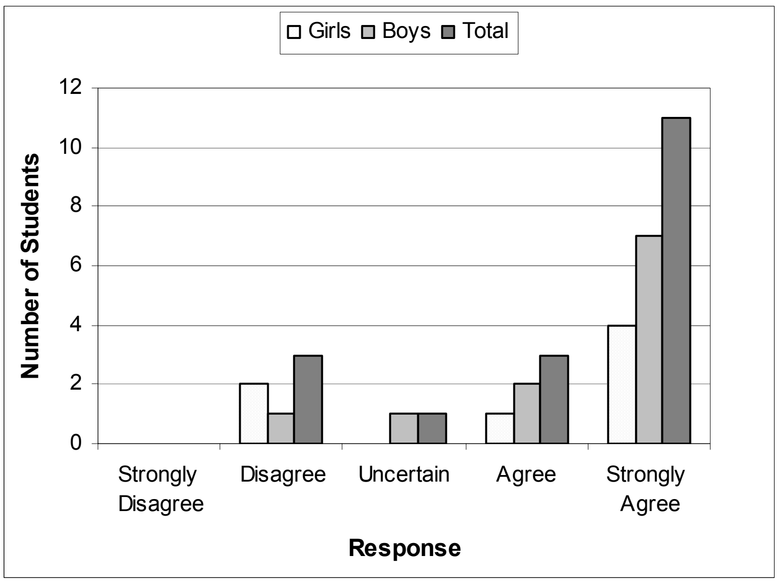

Figure 1. Student responses to the statement, "This program made me think about things I had never thought about before." Survey taken after the first unit of Techtronics I in 2002-2003.

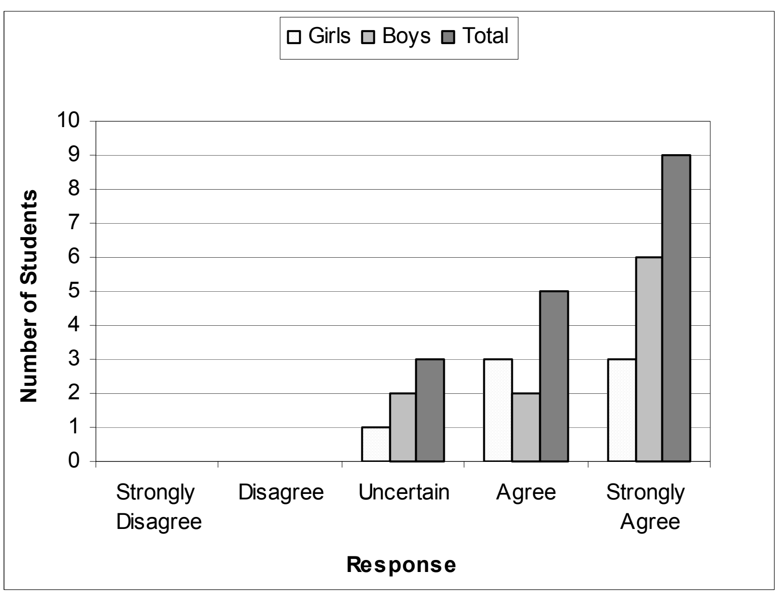

Figure 2. Student responses to the statement, "This program helped me understand science better." Survey taken after the first unit of Techtronics I in 2002-2003.

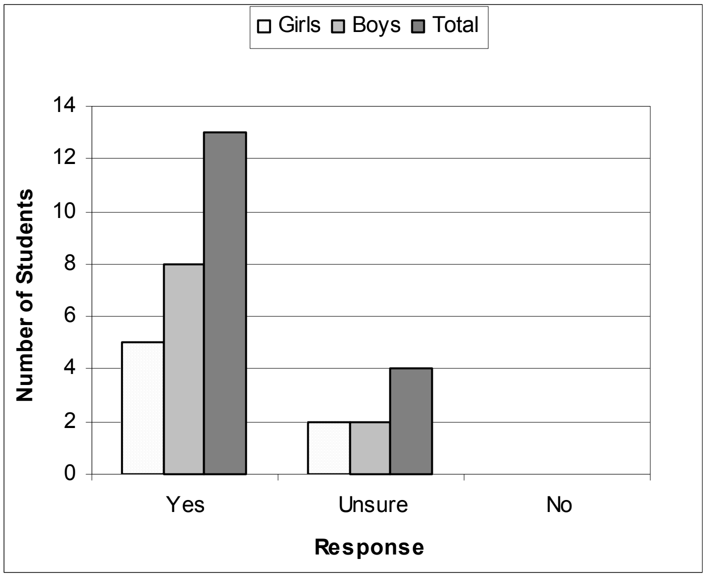

Figure 3. Student responses to the question, "Would you participate in this program again if you had the opportunity?" Survey taken after the first unit of Techtronics I in 2002-2003.

Another goal for the program is the creation of a diverse student body and to recruit from underrepresented minorities and females. The breakdown of both the Techtronics I and II classes are shown in Table I.

	Gender		Grade Level			Race/Ethnicity			
	Male	Female	6^{th}	7^{th}	8^{th}	African American	Hispanic	Asian	Caucasian
Techtronics I	10	9	19	0	0	14	2	0	3
Techtronics II	14	9	3	15	5	16	1	0	6

Table I. Information about students currently enrolled in Techtronics I and Techtronics II.

Conclusions

This paper has provided information on Techtronics: Hands-on Exploration of Technology in Everyday Life in its second year. Techtronics partners Duke University Pratt School of Engineering graduate and undergraduate students with Rogers Herr Middle School students in an after school program designed to inspire curiosity in engineering and the sciences. Specifically, it has addressed how the Techtronics program encourages women in engineering through hands-on, team-oriented design projects. The paper also provides examples of the units being used by Techtronics II: the Mars Rover unit, the Tower unit, and the AM Radio unit. The main challenge in developing the curriculum for these units is that they must cater to both returning students and new students. Survey data from students based on the initial year of Techtronics I, 2001-2002, and the initial units of Techtronics II and Techtronics I from the 2002-2003 academic year have been positive. Long-term studies will be required to determine if the program has increased student participation in science, math, and engineering later in life.

References

[1] Gustafson, M.R., Ybarra, G.A., Chancey, V.C. and Merdes, C.L. "Multimedia Teaching Modules in the Engineering K-PH.D. Program at Duke University." *Proceedings*. Frontiers in Education Conference. 2001.

[2] deGrazia, J.L., Sullivan, J.F., Carlson, L.E. and Carlson, D.W. "Engineering in the K-12 Classroom: A Partnership that Works." *Proceedings*. Frontiers in Education Conference. 2000.

[3] Villa, E.Q., Rios, L.D., Stafford, S. and Gandara, G. "K-16 Partnerships: Casting a Broad Net for filling the Critical Gaps in Engineering." *Proceedings*. Frontiers in Education Conference. 2001.

[4] Kimmel, H. and Cano, R. "K-12 and Beyond: The Extended Engineering Pipeline." *Proceedings*. Frontiers in Education Conference. 2001.

[5] Secola, P.M., Smiley, B.A., Anderson-Rowland, M.R., Castro, M. and Tomaszewski, B. "Assessing the Effectiveness of Saturday Academies in an Engineering Outreach Program." *Proceedings*. Frontiers in Education Conference. 2001.

[6] Tate, W. F. "Race-ethnicity, SES, gender, and language proficiency trends in mathematics achievement: an update." *Journal for Research in Mathematics Education*. Vol. 28. No. 6. 1997. 652-679.

[7] U.S. Census Bureau, Statistical Abstract of the United States. 2000. http://www.census.gov/prod/www/statistical-abstract-us.html.

[8] Camp, T. "The Incredible Shrinking Pipeline." *Communications of the ACM*. Vol. 40. No. 10. 1997. 103-110.

[9] Brush, L. "Cognitive and affective determinants of course preferences and plans." In S.F. Chihpman, L.R. Brush, and D.M. Wilson (eds.) *Women and Mathematics.* Hillsdale, NJ: Lawrence Erlbaum Associates. 1985. pp. 123-150.

[10] Blaidsdell, S. "Women in Science and Engineering Investments." Request for Proposal. 1998. 1-2. as cited by Secola, P.M., Smiley, B.A., Anderson-Rowland, M.R., Castro, M. and Tomaszewski, B. "Assessing the Effectiveness of Saturday Academies in an Engineering Outreach Program." *Proceedings*. Frontiers in Education Conference. 2001.

[11] Eccles, J.S., Wigfield, A., Harold, R.D., and Blumenfield, P. "Age and gender differences in children's self- and task- perceptions during elementary school." *Child Development*. Vol. 64. No. 3. 1993. 830-847.

[12] Burkam, D.T., Lee, V.E., Smerdon, B.A., "Gender and science learning early in high school: Subject matter and Laboratory experiences." *American Educational Research Journal.* Vol. 35. No. 2. 1997. pp. 297-331.

[13] Chesler, N.C., Chesler, M.A. "Mentory women students in engineering." *Proceedings of the 2001 American Society for Engineering Education Annual Conference and Exposition.* Session #2592.

[14] Klenk, P.A., K. Barcus, and G.A. Ybarra. "Techtronics: Hands-on exploration of technology in everyday life." *Proceedings*. Frontiers in Education Conference. 2001.

[15] North Carolina Standard Course of Study. North Carolina Department of Public Instruction publication #IS108. 1999.

[16] Geeter, D.D., J.E. Golder, and T.A. Nordin. "Creating Engineers for the Future." *Proceedings of the 2002 American Society for Engineering Education Annual Conference and Exposition.* Session #2002-1749.

PAUL A. KLENK is a doctoral student in Mechanical Engineering and Materials Science at Duke University's Pratt School of Engineering where he received a B.S.E. Degree in 2001. He is in his second year as a graduate student coordinator for the Techtronics program. In addition to his K-12 outreach work, he is researching novel therapeutic radiation delivery methods for cancer treatment.

LYNN H. WANG is pursuing her masters in engineering management (MEM) degree at Duke University where she also received her bachelor of science degree in biomedical engineering in 2002. She has been an active member of Techtronics for two years, first as a teaching fellow and this year as a graduate student coordinator. In the MEM program, Lynn has enjoyed exposure to the business and law aspects of engineering.

GARY A. YBARRA, Ph.D. is an Associate Professor and Director of Undergraduate Studies in the Department of Electrical and Computer Engineering at Duke University. He is the Principal Investigator of the Techtronics program and has been leading K-12 engineering outreach programs since 1988. He received a Ph.D. in Electrical and Computer Engineering from North Carolina State University in 1992 and has been on the ECE faculty at Duke University since 1993.