



# *RoboHunt*: A Study of Instructional Strategies and the Gender Differences that arise in a Robotics Workshop

Submitted By  
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## **ABSTRACT**

Over the years, the gender gap has been decreasing. However, a considerable difference between the number of female students pursuing a career within the fields of science, mathematics, engineering, and technology still fall behind the number of males who enter the field. At a time when technology is a ubiquitous component of daily life, it is important that students are introduced to engineering and technology related concepts at an early age. Even more importantly, it is pertinent that students' interest in learning those principles is maintained. This thesis describes the design and evaluation of an eight-week after school workshop intended for fourth, fifth, and sixth graders. The curriculum is based on Papert's constructionist learning philosophy and Gardner's theory of Multiple Intelligences. Focus is placed on effective instructional strategies for retaining student interest as well as on the gender differences in learning style that arise in this type of educational environment.

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Being on the Robotics Academy has been an eye opening experience. Throughout my four years in college, I have never experienced anything quite like it. It will certainly remain as one of my most memorable experiences at Tufts University.

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## **INTRODUCTION**

### *Gender and Education*

Looking back in history, the majority of renowned mathematicians, scientists, inventors, and engineers have been male. If one were to ask the average person to name a female who has made a memorable contribution within the domains of science, mathematics, engineering or technology, most people would have trouble coming up with more than one name. In contrast, a list of males in those fields could be generated effortlessly. A possible explanation of this phenomenon is that in the past women had fewer opportunities than men to attend college and to pursue further studies. However, this line of reasoning does not explain why there is still a lack of women in science, mathematics, engineering and technology (SMET) related fields even now at a time when women attend college at rates similar to men (Thom, 2001).

Over the years, several studies have indicated that the gender gap has been decreasing. More females have been attending math and science courses, and advanced classes are experiencing an increase in female participation (Thom, 2001). Nevertheless, a discrepancy between the sexes is still present. There has been an increase in SAT mathematics scores for males and females within the past two decades, yet overall, boys are still scoring 35 points higher than girls (College Board, 2001a as cited in Clewell & Campbell, 2002). Furthermore, males are still outperforming females on national science achievement tests at the elementary, middle school, and secondary levels (Mullis et al., 1994 in Meece & Jones, 1996). As a result, girls generally state being less confident about what they are learning in SMET courses or about their accomplishments in spite of the fact that as a group they are taking more male-dominated mathematics and science courses (Benbow, 1992 in Meece & Jones, 1996). Even in the case of the most mathematically gifted adolescents in the country, national studies indicate that the girls

are more likely to report lower estimates of confidence and lower achievement expectations than their male counterparts (Benbow, 1992 in Meece & Jones, 1996).

This lack of confidence in ability provides an explanation for the small number of females pursuing higher education and a career in SMET related fields. For instance, in 1999, females comprised only 20% of the total undergraduate enrollment in engineering programs. The gender gap is even more apparent in fields that are traditionally thought of as male dominated within SMET undergraduate and graduate programs. For example, few women pursue degrees in aerospace engineering, electrical engineering, mechanical engineering, and physics (National Science Foundation, in press as cited in Clewell & Campbell, 2002).

Some researchers suggest that this gap occurs because boys and girls are treated differently from elementary school through high school; usually those differences are in favor of the boys. For instance, in a study by Arambula Greenfield (1997), boys received more attention from the teachers than girls even when the girls asked more questions at higher grade levels, initiated more work-related contacts with teachers, and outnumbered and outperformed boys in high-level science and math courses (Clewell & Campbell, 2002). The findings of this study are discouraging because by seventh grade, girls' achievement in math and science start to decline despite previous achievement in those areas while the males' achievement level typically remains constant. "The extra attention in class that boys garner from teachers, the underlying expectations of future social roles, and peer pressures all play a part in psychological reactions that cause girls to lose confidence in their ability to do as well as boys" (Bolt & Crawford, 2000). Furthermore, there is a lack of female models in the advanced science and mathematics courses. By observing the presence of a male teacher and a majority of male students in an optional science class, girls receive the message that advanced science and mathematics courses are

abnormal for girls to take and unimportant courses for their careers (Lawrence & Welch, 1983 in Mason, Kahle, & Gardner, 1991). It is no wonder that a divide between the sexes in careers and career aspirations exist.

### *Gender and Technology*

Technology has become an integral part of every day life as people are becoming more dependent on computers to carryout every day tasks. Since 1984 there has been an increase of more than five hundred percent in household computer ownership. Three years ago, fifty-four million households in the US, accounting for 51% of the population, had one or more computers in their house (US Census Bureau, 2001). Since technology is ubiquitous in almost every facet of daily life, it is important that students are exposed to and become proficient in using technology at an early age so that they can benefit from these experiences in their adult life. Consequently, technology in educational settings has become increasingly prevalent, even in early educational environments like preschools. For instance, in 1984, the ratio of computers to students was 1:125 whereas in 1997, the ratio of computers to students was to 1:10 (Clements, 1999).

Despite these low ratios of computers to students within classrooms, school age females are less willing to become involved with technology than their male peers. Perhaps this stems from the fact that boys and girls approach the use of computers very differently. While boys tend to treat the computer like a toy rather than a tool, girls tend to view computer technology with specific uses in mind.

In a study at Carnegie Mellon, males in computer science referred to their early experiences with technology as a fun and passionate attachment to the computer. They were

more likely to mess around with the equipment taking apart the computer to examine it and then put it back together again. Most of the males were interested in figuring out how the computer worked (Margolis & Fisher, 2002). In contrast, females in the computer science field cited their attachment to computers as a gradual process that usually peaked in high school. Rarely did girls report forming an exclusive or early passion for the computer or engaging in hands-on exploration of the computer (Margolis & Fisher, 2002).

Some researchers suggest that this gender difference in approach to exploration of the computer may be attributable to the fact that girls are socialized to be cautious and careful while males are raised to be adventurous and bold and to take risks. This interpretation of the phenomenon was supported by the “roaming radius study” which compared the distance on a playground that a child was allowed to explore without interference by a parent or caretaker; in general, boys were allowed to explore a larger area before the parent or caretaker intervened than girls were (Margolis & Fisher, 2002). As a result, males may be more inclined to explore and take apart the computer because they do not have a fear of “getting lost” or breaking the computer.

It is unclear why the number of women who choose majors and careers in science and engineering are so low, particularly in physical sciences, computer science, and engineering. However, research implicates that gender differences in scientific and technical careers may stem from girls’ attitudes and career orientations rather than their levels of achievement (Clewell & Campbell, 2002). In fact, “predictors of women’s participation in university-level courses in mathematics and science found the strongest link to be between the quality of the math or science experience and the amount of math or science preparation” (Clewell & Campbell, 2002). As a result, it is important to provide an instructive environment that provides effective strategies

for teaching girls and that fosters positive attitudes towards scientific and technical topics. Some strategies that have proven to be effective in teaching math and science to a diverse group of students are small-group instruction, cooperative learning, inquiry approaches, and activity-based instruction (Clewell & Campbell, 2002).

### *Massachusetts Curriculum Frameworks*

Despite the fact that technology has become an integral part of every day life, there is a shortage of individuals, males and females, in the nation entering careers in technology and engineering (Creighton, 2002). In an effort to encourage more young people to pursue a career in science and engineering, Massachusetts took the initiative and added a new discipline to the state curriculum for the first time in one hundred years. In the year 2000, Massachusetts became the first and only state to require engineering instruction within the public school system for students in preschool through tenth grades. This idea of “elementary engineering” strives to give students problem solving and design skills, to help them gain a better understanding of an increasingly technology-based world, as well as to inspire them to follow a career in engineering and science (Mathias-Riegel, 2001). Twenty-five percent of the science component in the Massachusetts standardized test is focused on questions regarding engineering and technology so that students’ progress in this new subject area can be determined.

### *Proposed Study*

With the addition of engineering and technology related subject matter to the Massachusetts curriculum frameworks, it is important that effective teaching methods are evaluated so that students, both male and female, can benefit from curricula and classroom

environments that optimize their learning potential. Since females are less inclined to pursue a career in engineering and technology than males, it would be worthwhile to investigate effective teaching strategies focused on retaining female interest. Through observation of fourth and sixth grade students in *RoboHunt*, an eight week after school robotics enrichment workshop, it is hoped that the data collected will provide a better understanding of how children learn with robotic technology and more specifically, how the learning style of females differ from the learning style of males in an engineering and technology based classroom setting. Based on Seymour Papert's constructionist philosophy, Howard Gardner's theory of Multiple Intelligences, and a curriculum modeled after the Massachusetts curriculum frameworks, the *RoboHunt* workshop will provide students with the opportunity to explore engineering and technology related concepts through various robotics projects that have personal meaning to them.

## **CONTEXT**

### **History and Ideology behind the Robotics Academy**

Funded by the National Science Foundation, the first Robotics Academy at Tufts University was created in the fall of 2003 with the intention of providing engineering and child development students alike with the opportunity to explore their respective fields in an applied project-based manner. Under the supervision of faculty members from various engineering and child development departments<sup>1</sup>, a multidisciplinary team of undergraduate students was formed

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<sup>1</sup> The Tufts University faculty members supervising the Robotics Academy members are professors: Douglas Matson and Chris Rogers of the Department of Mechanical Engineering; Marina Bers of the Department of Child Development; Caroline Cao of the Department of Human Factors; Stephen Morrison and Jim Schmolze of the Department of Electrical Engineering; and Judith A. Stafford of the Department of Computer Science

to design and implement a robot that would address a practical, real world problem. Last year, the Robotics Academy, comprised of nine undergraduate members, focused on improving the colonoscopy procedure by creating the Tube Crawler, a robot designed to navigate through narrow pathways. At the end of the year, academy members wrote senior honors theses to document their yearlong efforts. Some sample thesis titles from last year are: “The Tube Crawler and Sustainability of the Robotics Academy” by Mechanical Engineer Anthony Schrauth; “Human Factors in Minimal Access Environments: The Tube Crawler” by Engineering Psychology major David Cades; “Robotics and Teaching: Promoting the Effective Use of Technology in Education” by Child Development major Diana DeLuca; and “Robotics in Education: ROBOLAB and Robotic Technology as Tools for Learning Science and Engineering” by Child Development major Laura Hacker.

The first half of the year was dedicated to the conceptualization and prototyping of the robot. Each discipline focused mainly on his or her respective area of study. The mechanical engineers were responsible for the design and construction of the robot while the electrical and computer engineers worked on the programming and the wiring. The engineering psychology students concentrated on creating a user-friendly interface for the robot while the child development majors adapted the engineering and technological principles used in building the robot to an educational curriculum.

During the second half of the year, all the disciplines explored their teammates’ respective fields by helping with the building and wiring of the robot



**Figure 1** *An engineer helping a girl*

and interface as well as with the teaching in the classroom. Before the engineers started helping

out in the workshop, they were emailed some guidelines<sup>2</sup> to provide them with some hints on how to work with the students so that the teaching method throughout the workshop would be consistent. At the end of one year in the Robotics Academy, participants gained a greater appreciation for the hands-on aspect of their respective fields and learned how to effectively collaborate with and communicate complex technological concepts to people of different ages and from various educational backgrounds.

### **Current Robotics Academy Members**

This year there were two different groups in the Robotics Academy, Team Spot and Team Kinetic. Team Spot, comprised of mechanical engineer, Adeline Sutphen; electrical engineers, Emily Mower and Laurel Hesch; and child development major, Louise Flannery, focused on creating a team of three robots that communicated with one another to find a spot of light in a dark room. Their goal is applicable to current research on ways to locate and remove potentially harmful gases in the case of a bioterrorism attack.

The second group, Team Kinetic, made up of mechanical engineers, Michael Kelly and Jarred Sakakeeny; electrical engineers, Jason Adrian and Marc Weintraub; engineering psychology major, Kristi Hamada; and child development major, Sandra Tang, focused on creating an interactive kinetic sculpture. The kinetic sculpture had a ball rolling on a track that would stop before certain events to wait for an input before continuing along the track. Successful inputs included repeating a pattern of lights similar to the game of Simon, tracing a star with a laser, squeezing a grip to a specified strength, creating a certain level of noise, and matching a pitch level by changing the distance between the hand and the sensor. The challenge

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<sup>2</sup> See Appendix A

of the project was to create something that could serve as a fun yet educational learning device of basic science and technology for elementary school children.

## **Theoretical Background**

### *Constructionism*

At a very young age children must learn basic human functions such as, walking, talking, running, and climbing. Children typically learn these skills by doing them. Instead of parents giving step-by-step instructions on the technique of walking, they allow their children to master the skill through practice because they know that the best method for them to learn to walk or talk is through experience. Despite the success of learning through this method, once children enter school the style of learning changes from “learn by doing” to passive absorption of theories on how to do the tasks (Schank & Cleary, 1995).

For instance, math and science are traditionally taught through an *instructionist* framework where teachers provide or transfer concepts to students by giving them a number of problems to practice new skills. The belief behind instructionism is that for better learning to occur, the teaching must be improved (Papert, 1993). In contrast, art classes are taught through a *constructionist* model where students explore different techniques through creating things such as artwork, music or dance routines according to their own interpretation of the concepts. The belief behind constructionism is that students learn best when they discover the knowledge, as it is pertinent to their own needs. In order for learning to be effective, it should occur in an environment that is of interest to the student so that s/he can make connections with the subject matter and be motivated to learn more. Under the constructionist philosophy of teaching and learning, providing the student with the necessary tools to attain more knowledge is the most

important component to an individual's educational experience. Though it may seem that understanding art is more favorable than math and science to this design-based learning strategy, constructionism has proven to be an effective approach to introducing science and technology to students (Bers & Urrea, 2000; Resnick, Bruckman, & Martin, 1996; Harel & Seymour, 1993).

The constructionist paradigm embodies the concept that "Knowledge is not passed from teachers to students, but is developed by everyone through their activities and interactions with one another" (Resnick, et. al, 1996). Students learn through hands-on involvement with the designing and manipulation of familiar materials. When students are involved with the designing procedure, they become active participants and gain a higher sense of personal involvement in the learning process. In addition to gaining a greater sense of control over their learning development, students' thought processes are mirrored externally in their projects allowing others to understand their internal mental models (Resnick, et. al, 1996). When the mental constructs are supported by a public construction that can be shown, discussed, and examined by others, it adds value to the thinking and creating process (Papert, 1993).

In a constructionist framework, it is crucial that teachers create a learning environment that has a loose sense of control yet is also supportive of exploration. Through the creation of spaces for activities and experiences, students are able to explore their environment in their own way and at their own pace. In order for the constructionist-learning environment to be effective, it must contain the potential for students to make personal and epistemological connections to the task or assignment. Firstly, the projects should link the student's experiences, passions, and interests so that they can build upon their previous knowledge by connecting new ideas to their pre-existing ones. Secondly, the activities should stimulate new ways of thinking while bridging important domains of knowledge (Bers, Ponte, Juelich, Viera, & Schenker, 2002). Given these

two components, “students are more likely to explore and develop deep ‘connections’ with the mathematical and scientific concepts that underlie the activities” (Resnick & Ocko, 1991).

### *Powerful Ideas*

It is important that the learning environment is a relaxed setting with numerous opportunities that cater to students’ multiple areas of interests. Through this design-based learning atmosphere, individuals are able to make meaningful connections to projects and learn overarching concepts through the manipulation of familiar materials. Due to hands-on experience with working on a personally meaningful project, individuals are able to explore new ways of putting knowledge to use. Seymour Papert identified this as the creation of powerful ideas. Powerful ideas are intellectual tools that allow the individual to re-create the meaning of certain concepts as well as the process of thinking itself (Bers, et. al, 2002). By making connections to projects and creating powerful ideas that can be applied across disciplines, children are able to reconstruct their understanding of reality by continually testing their internal models of the world (Bennett, 1996).

Papert’s theory of powerful ideas is based upon Eleanor Duckworth’s concept of wonderful ideas where personal insights and revelations provide a foundation for thinking about new things for the individual. Though both are similar in many regards, the powerful ideas theory is culturally based while the concept of wonderful ideas focuses on the individual’s developmental process (Bers, et. al, 2002). Powerful ideas are influential to the student’s learning process because they allow the individual to uncover and amend previous conceptions of reality by himself without having a teacher or mentor explain the idea to him. Often, children come to understand a definition or concept through experiencing and re-experiencing a concept in different contexts, thus reorganizing their intuitions into more complete models, rather than

through rote memorization of the concept's definition (Resnick & Ocko, 1991). As a result of the self-initiated discovery, the new ideas are more clearly understood by the individual and take on a larger relevance resulting in more motivation to learn and work on the project.

### *Howard Gardner's Theory of Multiple Intelligences*

Traditionally cognitive theories have claimed that intelligence is a single, quantifiable intelligence. However, Howard Gardner, a professor of education at Harvard University, has conducted research that indicates people possess various domains of intelligences refuting the traditional idea that a person's cognitive ability can be measured solely based upon IQ scores on a standardized test. Gardner's Multiple Intelligences theory points out that there are eight major areas of intellect, linguistic, logical-mathematical, musical, intra-personal, inter-personal, bodily kinesthetic, spatial, and naturalistic, that people possess, each with several sub-intelligences within an area. Most people have all eight domains, but combine and use them at varying quantities (Campbell, Campbell & Dickinson, 1999).

One of the most recognizable spheres of cognitive ability is linguistic intelligence. This encompasses the ability to communicate ideas through the use of language, whether in the written or verbal form. This kind of intelligence is nurtured through a language-rich



**Figure 2** *Students sharing ideas*

environment, such as in a classroom, which allows students to speak, discuss, and explain concepts to others. In addition, with the development of this cognitive domain, children have the advantage of learning more about their own thinking processes and abilities by listening to what they have verbalized and reading what they have written (Campbell,

Campbell, & Dickinson, 1999). Through peer teaching, which involves explaining concepts and discussing ideas that they have learned with others, children are able to understand the concepts at a deeper level and develop confidence within the area.

Logical–mathematical intelligence is another recognizable domain of cognitive abilities. This area of intelligence, described by Gardner as an umbrella domain embracing the three interrelated fields of mathematics, logic, and science, requires problem solving, recognizing patterns, doing mathematical calculations, and engaging in inductive and deductive reasoning (Campbell, Campbell, & Dickinson, 1999).

Students with high bodily-kinesthetic intelligence, learn best when they are able to experience and manipulate what they learn. Typically, these individuals prefer to involve their whole bodies in their activities or “learn by doing” through work with concrete, real-life experiences. In addition, individuals gain a better understanding and retain concepts when they are able to connect with the activities within a multi-sensory environment. For these types of learners, experiential materials that can replicate objects in their environment, such as LEGOS, blocks, and Popsicle sticks, are very important to the learning process because they can help the student to see and control the situation, allowing for learning at a deeper level (Campbell, Campbell, & Dickinson, 1999).

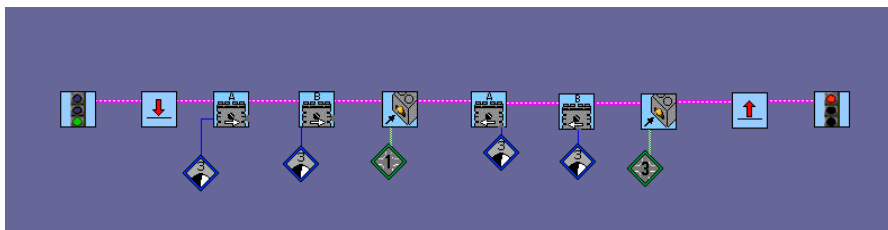
Individuals with high visual-spatial intelligence learn best by first observing and then replicating the process. Usually they rely on visual images in recalling information. Visual-spatial thinkers learn best when there are different colors, and graphic representations. Often times, these individuals also enjoy communicating their thoughts and ideas through drawing, doodling, or producing objects in a visual form (Campbell, Campbell, & Dickinson, 1999).

The other four domains of intelligence pointed out by Howard Gardner are musical intelligence, interpersonal intelligence, intrapersonal intelligence, and naturalist intelligence. The range of musical intelligence within individuals is large and varied. However, individuals with sensitivity to pitch, rhythm, melody, and tone, are considered to have aptitude within the musical realm. Individuals who excel at collaborating with others, mediating conflicts, and communicating with others often have a high level of interpersonal intelligence while individuals who are competent at understanding themselves have a higher intrapersonal intelligence. The most recent domain of intelligence added on by Howard Gardner is the naturalist intelligence. Individuals with a strong inclination toward this cognitive domain, are typically successful at distinguishing among members of a group, have a sense of cause and effect, and are able to perceive predictable patterns of interaction and behavior. Through their observations, students generate hypotheses and possible solutions; they have an enthusiasm for understanding how things work (Campbell, Campbell, & Dickinson, 1999).

Howard Gardner's Multiple Intelligences theory is perceived to be an instructional framework that can augment the learning process of any discipline because it can adapt lessons into multimodal learning opportunities for students. It is not necessary for all eight domains of intelligence to be represented in the lessons; it is recommended that each topic be taught in at least four of the domains (Campbell, Campbell, & Dickinson, 1999). Through this type of framework, students are introduced to subjects by various means that are concurrent with the individual's unique learning style. Similar to a constructionist framework, curriculum based on Gardner's Multiple Intelligences theory produces students who are more enthusiastic about the subject matter and who are more engaged in the projects.

## LEGO Mindstorms Kit: The Primary Tool

In order for this project-based learning to be effective, it is important that teachers provide a learning environment that stimulates children to explore, scaffolds their learning, and supplies them with interesting materials to create projects (Bers & Urrea, 2000). Materials such as the LEGO Mindstorms robotic construction kits serve as an example of technology coupled with traditional children's toys. The concept behind the LEGO kit, which was developed by the MIT Media Lab, combines familiar materials, LEGO pieces, with equipment such as, power motors and light and touch sensors, to mimic building materials used by engineers. Children use this kit to design robots that respond to programs, which they write in ROBOLAB, the software that comes in the LEGO Mindstorms Kit. Developed in partnership between Tufts' Center for Engineering Educational Outreach, LEGO Education, and National Instruments, ROBOLAB allows students to write programs to command their robots to carry out different behaviors through an icon-based interface (Hacker, 2003). By clicking and dragging icons into a sequential order, children are able to write complex directions for their robots to complete through an easy to understand graphical venue.



After the program is written in ROBOLAB, it is loaded onto the Mindstorms RCX, a

programmable brick, through an infrared transmitter where it processes information collected from the environment by means of various sensors to power the motor and turn on the lights.

Through manipulation of these kits, children are able to learn and work with concepts that were previously considered too advanced for them (Bers, et. al, 2002). Since LEGO building

materials have a strong presence in children’s culture, children are able to make powerful personal and epistemological connections to projects involving the robotic kits (Resnick, et. al, 1996).

## **METHODOLOGY**

### **Description of Workshop Participants**

Similar to last year’s after-school robotics workshop, students were recruited through a description in a course packet<sup>3</sup> distributed by the Center for Engineering Education Outreach (CEEEO), to families in the Medford and Somerville areas on the CEEEO mailing list. The class description focused on recruiting students in fourth through sixth grades that have not previously worked with robotics. The eight-week class emphasized the creative process used in building and programming LEGO bricks. Originally, the workshop was scheduled to start on January 28<sup>th</sup>. However, due to difficulties in recruiting students, especially female students, the start date of the workshop was pushed to February 4<sup>th</sup>.

In an effort to recruit more female participants, a letter<sup>4</sup> and flyer<sup>5</sup> aimed directly at females were faxed to principals of several Medford and Somerville elementary schools to be distributed to females in the 4<sup>th</sup>, 5<sup>th</sup>, and 6<sup>th</sup> grades. The flyer featured a photo of a young female student engaged in a building activity as well as a description that emphasized being mentored by Tufts Engineers, making new friends and using the imagination. An email



**Figure 4** *Group Work*

promoting the program was also sent out to faculty and staff in the engineering departments at

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<sup>3</sup> See Appendix B

<sup>4</sup> See Appendix C

<sup>5</sup> See Appendix D

Tufts to encourage them to enroll their children or children of family friends. By the first day of class, there were a total of five students, three males and two females.

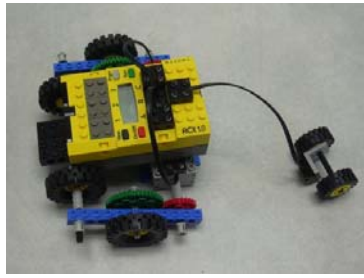
The students signed up for the workshop were a very mixed group. Four out of the five students were in fourth grade while only one girl was in sixth grade. Three of the students attended a Medford public school, two students attended a Somerville public school, and one student was home-schooled. Two of the five students had a learning disability and one of the students did not own LEGO bricks at home or frequently play with them at school. Nevertheless, all the students signed up for the class out of their own volition and were very enthusiastic to be there.

### **Description of General Curriculum Plan and Reasoning behind each Phase**

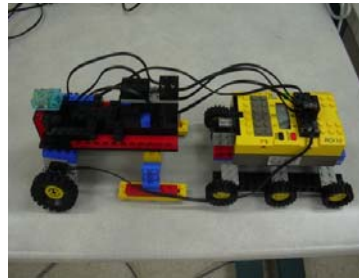
The goal of the *RoboHunt* Workshop was to provide students with the opportunity to learn the basic principles of science and technology through the design, construction, and programming of LEGO structures with ROBOLAB, the programming software that comes with LEGO Mindstorms<sup>6</sup>. In a fun and creative environment, students explored the capabilities of their structures and learned basic concepts about structural analysis and friction, while practicing verbal and written communication of technological ideas. Based on a constructionist framework, the classroom environment encouraged students to work on technological projects that were congruent with their own interests. Through open-ended challenges, students were able to learn about science and technology while constructing personally meaningful projects.

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<sup>6</sup> See Appendix E for original concept chart.



**Figure 5** *Girl's robot with a "monkey tail"*



**Figure 6** *Boy's robotic train*

The workshop included the three key ingredients, students in control, multiple paths to learning, and a sense of community, which Resnick and Ocko (1991) claimed were needed in creating a rich design environment for children. In all of the hands-on activities, students were put in control of the designing and creating of their projects. After providing the basics, students were given latitude in choosing the type of robot that they would like to build for the final project. With the choice of building moving vehicles or moving structures, students were offered multiple paths to learning. Finally, a sense of community was supported in the workshop through group discussions and sharing of ideas, designs, and actual constructions (Resnick & Ocko, 1991).

In addition, the structure and curriculum of the after school workshop was mostly centered on four domains of intelligence that were delineated in Howard Gardner's theory of multiple intelligences - linguistic, bodily-kinesthetic, logical-mathematical, and visual-spatial. This instruction arrangement provided students with the opportunity to learn science and engineering concepts in an environment most suitable to their individual learning styles. For instance, the feedback activity during Week 5 and Presentation Day during Week 6 provided structured activities for students with a high linguistic intelligence to further explore concepts by allowing them to use verbal means to communicate their ideas. Every week students also had the opportunity to engage in peer teaching, which allowed them to explain concepts to others and at the same time help themselves understand the concepts at a deeper level.

While the workshop provided numerous outlets for people with high logical-mathematical capabilities in problem solving as well as inductive and deductive reasoning, Week 4's light sensor activity especially emphasized this domain of intelligence. Students were each given light sensors, asked to take readings of various objects, and to find a pattern or the relationship between the numbers and readings of different objects. Their problem solving and inductive/deductive reasoning capabilities were further enhanced through the constructionist-based method of asking open-ended questions in response to students' queries instead of giving direct answers.

The third area of intelligence touched upon by the curriculum was the bodily-kinesthetic domain. Students with a high affinity toward the "learning by doing" method related to working with LEGOs because they are an experiential material that replicates the environment. In addition the theatrical improvisation exercise in Week 1 allowed students with bodily-kinesthetic intelligence to understand the programming.

Another area touched upon in the workshop was the visual-spatial domain of intelligence. Since students who are highly competent in this area learn best when they are given the opportunity to observe and then replicate a process, class demonstrations of programming, models of sample cars, and access to projects by the Robotics Academy were provided for students to examine and use as models for their own projects. In addition, the ROBOLAB icon-based software aided students' understanding of the material through graphic representations.

Some activities, like the journals, combined more than one domain of intelligence. They provided an outlet for students with high linguistic abilities to communicate their ideas through the written form and in the visual form with the pictorial prototypes of their robots that the students' sketched in their journals. The communication of ideas through drawing and sketching is natural for students' with an affinity for the visual-spatial intelligence domain.

**Table 1** *Four Domains of Intelligence emphasized during the Workshop*

<b>Gardner's Intelligence Domain</b>	<b>Component of Workshop</b>
Linguistic	<ul style="list-style-type: none"> <li>– Prototyping in Journals</li> <li>– Discussion with classmates (giving and receiving feedback)</li> <li>– Having student read out loud their program</li> <li>– Peer teaching</li> <li>– <i>Presentation Day</i></li> <li>– Group work</li> </ul>
Bodily-Kinesthetic	<ul style="list-style-type: none"> <li>– Exploring and Using LEGO kits</li> <li>– Theatrical improvisation of Programming</li> <li>– Connect computer to external manipulative</li> </ul>
<b>Gardner's Intelligence Domain</b>	<b>Component of Workshop</b>
Logical-Mathematical	<ul style="list-style-type: none"> <li>– Problem solving in all challenges of workshop</li> <li>– Learning about gear trains and ratios</li> <li>– Distinguishing patterns in the light sensor activity</li> <li>– Asked open-ended questions in response to students' queries</li> </ul>
Visual-Spatial	<ul style="list-style-type: none"> <li>– Graphic representation in Journals</li> <li>– Visual Tools, a ROBOLAB icon-based software</li> <li>– Class demonstrations</li> <li>– Sample LEGO Car Models</li> <li>– Robotics Academy project demonstrations</li> </ul>

The workshop was held in the Center for Engineering Educational Outreach in Curtis Hall on the Tufts' Medford Campus every Wednesday afternoon during the months of February,

March, and April, with the exception of the weeks of public school winter break and Tufts spring break. Class instruction formally began at 3:15pm and ended at 5:15pm, but students usually arrived around 2:30pm and stayed until 6:00pm because they were eager to work on their projects. As a result, there was a total of 28 hours of instruction time. Every week, two engineers from the Robotics Academy came in to help out with the workshop. Since there were only five students in the workshop, they received a lot of one-on-one attention from the engineers and myself.

### **Original *RoboHunt* Curriculum**

The basic structure of the *RoboHunt* workshop was created using last year's robotics workshop curriculum as a guideline. Some of the exercises from last year remained in this year's curriculum while certain activities were replaced with new challenges centered on concepts used in the projects from this year's Robotics Academy. The most notable difference between the two curricula is the duration of the workshop. Instead of holding class for eleven weeks, this year's workshop had only eight sessions in order to leave time for the analysis of data collected from the workshop.

The eight-week workshop is divided into four different phases. Phase one consists of one introductory session in which the goals and agenda of the workshop are explained to the students. They are introduced to the concept of a robot, given time to explore the LEGO kits, and asked to build a sturdy car. A discussion centered on important concepts to keep in mind when designing a durable car follows to allow students to the opportunity to share their ideas with one another. Then students are given and encouraged to write in their journals to document their prototypes through words and sketches. After a snack break, the students are introduced to

the basic icons used with programming in ROBOLAB through a theatrical improvisation. Using enlarged images of different icons pasted to a different colored construction paper for each icon category, students pretend to be the motor, timer, stop sign, IR, and RCX. One student acts as the programmer and “writes” a program by arranging everyone. Another student acts as the car and follow the directions. This activity, borrowed from the Con-Science Workshop at MIT, is introduced on the first day of class with the intention of helping students to become acquainted with the programming language. Afterwards, students are given time to program the cars that they built using ROBOLAB. Last year, students were introduced to the Pilot programming level in the first week and gradually introduced to Inventor 4, a higher functioning programming level over the course of the workshop. Since this year’s robotics workshop has fewer sessions, the students will be taught to program with Inventor 4 at the beginning. According to Clements (1999), it is important that instructors encourage in-depth knowledge of one program rather than having brief exposure to a variety of software programs.

Phase two and phase three revolve around working with mobile and stationary robots, respectively. Unlike last year’s workshop curriculum, which mainly focused on mobile robots, this year’s workshop has equal emphasis on mobile and stationary robots to reflect concepts from the projects of Team Spot and Team Kinetic. The activities of the first session of each phase focuses on output challenges while the second session requires students to program their robots to take inputs from sensors and perform a specific output. At the beginning of the first session of the mobile robot phase, students learn about gear trains and gear ratios. Then they divide themselves into groups and complete a ramp



**Figure 7** *Navigation Map*

exercise and a map navigation challenge from last year's curriculum. During the second session of mobile robots, students build a car that has touch sensors on both ends and program it to reverse direction when a touch sensor is pressed in. Afterwards, they engage in a communication challenge named "Go Fish." In this challenge, they learn to program their cars to emit and receive values between 1 and 4 using the container function in ROBOLAB. They are to create a program for their car so that it emits a positive tune when it receives a matching value from another RCX and a negative tune when it receives a non-matching value from another RCX. After completing phase two, students should have learned the basics of structural analysis, inclined planes, programming, power versus speed, and using touch sensors.

During the first session of the stationary robot phase, students explore levers and gears. In the first exercise, they discover the difference between lifting various weights with just a motor and lifting them with a gear and lever. Afterwards, in groups of two, they build a stationary robot that performs a special function when a touch sensor or light sensor is activated. In the second exercise, students build a lighthouse that is programmed to turn on at least one light and revolve for varying lengths of time. After completing phase three, students should have a better understanding of the difference between autonomous robots and remotely operated robots.

Phase four, consisting of three sessions, is the longest segment of the workshop because it encompasses all of the concepts from the previous sessions. During phase four students engage in creating, building, and programming their own stationary or mobile robot that will inhabit Treasure Island, a made up robotic island. Students have the opportunity to be involved in all aspects of the design process for the island. In addition, this phase will emphasize working on a

project with input from all workshop students. This process includes learning about compromising, negotiation, and clear communication.

In a hands-on, constructionist-based classroom, students learn a concept at their own pace and in a way that is most meaningful for them. As a result, multiple opportunities for spontaneous and informal assessment of each student's progress will arise during the course of the workshop. Questioning students while they are engaged in designing and building projects will be the primary method of gauging whether students are learning about the science and engineering involved. Journals, which contain their creative ideas, illustrations of designs, diagrams and key words like friction, gears, power, and speed, will be another form of assessment that documents the learning process of the key concepts for each student. Thirdly, assessment can be achieved through the use of video interviews and general video documentation of regular workshop activities. Lastly, in a more traditional method of evaluation, students' understanding of science and engineering concepts can be measured through how well they communicate their ideas to their parents, siblings, and friends during *Presentation Day*.

### **Adaptation of Curriculum**

Though much of this year's curriculum was a condensed version of last year's syllabus, after the first two sessions in the workshop, it was apparent that the curriculum needed to be changed to fit the learning style and pace of this year's students<sup>7</sup>. Contrary to the original plan, group work was not assigned because of the small number of students in the workshop. The only group work that occurred happened on the last day of class when the students worked on connecting and making all the robots work together.

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<sup>7</sup> See Appendix F to view the weekly changes made to the curriculum to adaptations to the students' progress.

The curriculum was changed every week to adapt to the progress from the previous week. Some of the challenges had to be omitted or altered because students took more time to complete certain tasks than was anticipated. During the mobile robot phase, the structured activities involving traveling up ramps covered in different surfaces and navigation of a map were taken out because the students spent the majority of the class time understanding gear ratios and building a car using gears. Similarly, the communication challenges that focused on using container values had to be omitted because students spent most of the time working on the bumper car challenge.

Since some of the students were unable to finish the challenge during the allotted time in the previous week, the first day of the stationary robot segment was dedicated to finishing the bumper challenge and learning to program and use light sensors. Due to this lag in the syllabus, the stationary robot segment was condensed into one session in order to ensure that the students had enough time to work on their final projects, on which they would give a presentation to their peers, family members, Robotics Academy members, and interested Tufts professors.

Originally, the presentation was set for the last day of class. However, one of the mothers requested that the presentation date be moved up one week because her child would not be able to make it to the last class. As a result, the presentation date was moved to the second to last session. Consequently, instead of presenting on their finished projects each child presented on their work-in-progress. The last day of class was reserved for the finishing touches to Treasure Island.

## **GENERAL CLASSROOM OBSERVATIONS**

### **Phase One: Introduction**

When students arrived in class on the first day, they were given the “Draw An Engineer” exercise<sup>8</sup>. For those students who finished early, they had the chance to decorate the cover of their journal. Once all the students were present and introductions were made, the students were informed about the structure of the class. They were told that they would get the chance to build mobile robots, stationary robots, and a robotic island during the course of the workshop. Each student was given a journal and asked to write about their favorite activity, least favorite activity, reactions to the projects and challenges as well as to sketch their ideas and prototypes every week. After the logistics were explained, the class engaged in a discussion about robots. Students were asked to share their explanation of a robot to the class. This exercise served as a way for students to become familiar with one another and to practice communicating their ideas to a group of people.

After the discussion on robots, each student was given a LEGO kit to explore. They were shown the most frequently used pieces (flat pieces, gears, motors, axels, wheel, and bricks) and asked where they saw those pieces in their surrounding environment. This exercise was intended to help those students without much prior experience working with LEGOS to understand how LEGO pieces are similar to common structures found within their everyday environment. By making this association, it was hoped that the students would have an easier time building structures.

After the students became acquainted with the different pieces, they were asked to build a car. The one object of their car was to pass the “Shake Test.” This test, borrowed from last year’s after school robotics workshop, assessed the sturdiness of their car. If a car did not fall

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<sup>8</sup> See Appendix G for “*What is an Engineer?*” Survey

apart when shaken very hard, then it passed the “Shake Test.” All students had difficulties with attaching the motors to the RCX and having them stay on. Often students would add a piece to their car and upon pressing down on the structure, their entire car would fall apart. One student had his car break apart on him a total of 4 times within the first session! Finally, some of the students discovered that with a flat piece they could “sandwich” the motors to the RCX. Student also discovered that if they provide more surface area for the pieces to connect to, the structure becomes sturdier. While all students had trouble building their cars, the girls seemed to have more trouble understanding how the wheels attached to the motors and the purpose of doing so.

After building a sturdy car, students performed in the theatrical improvisation of computer programming. In this activity, students physically arranged different icons carried by their fellow classmates to “write” a program for an engineer or another classmate to follow. The purpose of this activity was to familiarize students with the icons used in ROBOLAB as well as the language of programming. The students were very enthusiastic and engaged with “writing” programs. After this exercise, students were introduced to the actual software on a computer. They were shown the basics of Inventor 4, the highest programming level that allowed for the greatest creativity and flexibility. After the demonstration, they each went to their own computers and wrote programs for the cars. In contrast with the building portion of the class, students had much less difficulty with the programming.

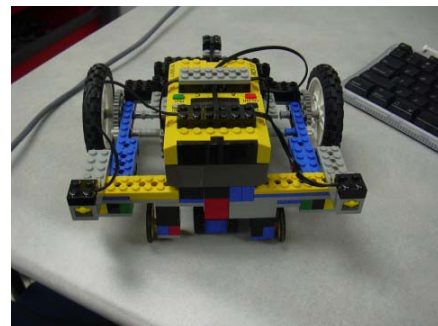
### **Phase Two: Mobile Robots**

On the second day of class, students were introduced to the idea of gears, gear ratios, and gear trains. Meant as a quick exercise, students were asked to build a car using different gear ratios that moved very slowly. The exercise ended up taking up the majority of the class time

even though four robotics academy members were present to help with the instruction that day. Students had a lot of trouble understanding the gear ratio concept and figuring out how to use gears with motors and wheels. As a result, only two boys, the two with the most experience building with LEGOS, completed the task and moved on to the ramp activity.

On the third day of class, Laurel from Team Spot explained and demonstrated her team's project to the students. They were very excited to see the robots communicating and moving to the point of brightest light. However, since the room was not completely dark, sometimes the robot would not move to the point of brightest light. This sparked discussion among the students and one girl claimed that the robot might have been fooled by the glare on the floor produced by a nearby window. Consequently, she started forming hypotheses about what would happen if the robots were outside in the daylight or near a light protruding from underneath the gap of a door.

After the demonstration, students worked on building a car that would stop when the touch sensor was pushed in. Most students did not have a lot of trouble with the programming. However, they did have some difficulties figuring out how to secure the touch sensor so that it would not fall off when it came into contact with another structure. After completing this



**Figure 8** *Bumper Car*

task, they were asked to build a bumper car with a touch sensor in the front and back of the structure. The objective of the activity was to build and program a car that would continue to move forward until it ran into a wall. Once the touch sensor at one end of the car is pushed in, the car starts moving in the opposite direction until the touch sensor on the other end of the car is pushed in once again reversing the car's direction. As

a result, the car will end up running between walls changing direction once a touch sensor makes contact with a wall.

One boy finished the challenge so quickly that with the help of an engineer, he started writing a program so that his car would respond to remote control. However, the other students had a lot of trouble with making their touch sensors stay in place after hitting a wall. Also, many students had to redesign their car when they realized that a part of their car, such as their wheel, was too large or was protruding too much thus inhibiting their touch sensor from touching the wall. By the end of class, only the one boy had completed the challenge.

### Phase Three: Stationary Robots

Instead of working on stationary robots as planned, the students resumed their efforts on making a bumper car on the fourth day of class. The second person to complete the challenge was a girl who also moved on to making a car that responded to remote control.

Everyone else spent the majority of class time finishing the bumper car challenge. Once they completed the

challenge, students were introduced to light sensors and the “View” function on the RCX. They were asked to take different light readings of different objects and to write them down in their journal. Students took light readings of the table, their clothing, the lights, the computer, etc. Afterward, they were told to try and find a pattern among the readings. Most students discovered the relationship between the number from the light readings and the lightness or darkness of the object on their own.



**Figure 9** Girl's Pictorial Prototype

On the fifth day of class, students were introduced to the idea of stationary robots. In an effort to get students writing and sketching in their journals, students were asked to draw a pictorial prototype of a stationary robot that they would like to build, to give their robot a name, and to write a description of what the robot would do once the touch sensor was pushed in. Afterwards, the students presented their ideas and received feedback from their classmates. The main objective of this activity was to help the students learn how to communicate technical ideas to their peers in a manner that was understandable to their peers.

The students took the exercise very seriously and gave very helpful feedback to one another. Both boys and girls were active in giving feedback. One interesting trend that emerged was that the boys were more prone to giving suggestions that involved changing the physicality or the operation of the robot while the girls gave suggestions on variations of how the robot should act. After the feedback session, students started building their stationary robots. By the end of the class, none of the students had completed their stationary robot.

#### **Phase Four: Treasure Island**

During the sixth day of the workshop students continued working on their stationary robot. Given the slow working pace of the class and the constraints on time, that there were only three more sessions left in the workshop, and one mother had requested that Presentation Day be moved to the next class date, it was not feasible to start the planning of



**Figure 10** *Boy rebuilding robot*

Treasure Island. As a result, the sixth day was dedicated to finishing the stationary robots so that the students would have something to present for the next week on *Presentation Day*<sup>9</sup>.

The first part of the seventh day was dedicated to finishing up the stationary robots. The last forty-five minutes of the class was allocated for the presentations. The students had their parents, siblings, and even some friends show up for the presentation.



**Figure 11** *Boy explaining project to Robotics Academy member*



**Figure 12** *Girl explaining remote controlled car to Professor Rogers and her family*

The students explained and demonstrated a mobile robot and a stationary robot that they had built during the workshop. They talked about the type of changes that they had made to their robots, why they had designed the robot a certain way, what they found difficult about the building process, and what they enjoyed the most about building the robot. In addition, they shared some building tips that they learned. After the presentations, parents had a chance to look around at all the students' projects and to ask additional questions. Pizza and drinks were served.

On the last day of class, only three students showed up. As they were waiting for others to arrive, they filled out a questionnaire<sup>10</sup> and participated in a personal interview. Half of the class time was spent figuring out a way to make all the robots interact with one another. For example, they decided to make a train of robots that would some how set off one another in a

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<sup>9</sup> See Appendix H for Invitation to *Presentation Day*

<sup>10</sup> See Appendix I for Questionnaire

domino-like effect. However, the three students had a lot of trouble with this activity because they had to figure out how to activate and/or alter their classmates' robots to interact with their own robot. Due to the low number of student enrolled in the workshop, most of the workshop activities did not necessitate collaboration between the students. This last exercise provided an opportunity for them to do so.

## **ANALYSIS**

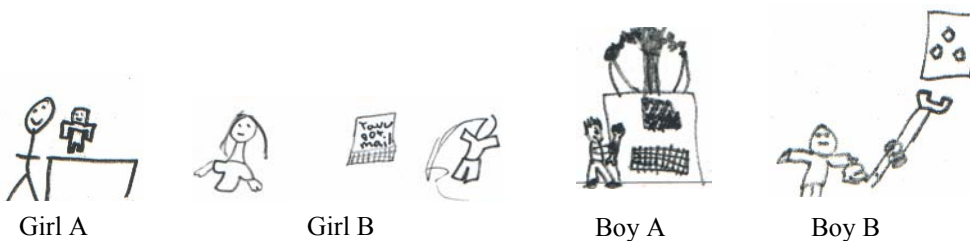
### **Draw an Engineer Exercise**

On the first day of the workshop as students were arriving into class, they were given a short questionnaire called, "What is Engineering?" Modeled after the "What is a Scientist" questionnaire that has been used in several studies to gauge students' perceptions about the science and technology fields, this condensed version of the study consisted of six questions that asked students to write their own definition of an engineer, to draw an engineer at work, and to describe their drawing in words. In addition, the questionnaire asked whether the student knew any engineers. The "Draw an Engineer" exercise was administered to learn about the students' perceptions of engineering prior to the robotics class. In addition, it served as a good segue to start a conversation on robotics while helping students to relax in a new environment by engaging them in the familiar "school-like" exercise of answering questions and drawing pictures at the beginning of the first class.

The first question asked students to write down their explanation of engineering. The most popular response given was centered on the idea of building things; three out of five students mentioned the concept of building in their response. Interestingly, only the girls mentioned the use of wires in engineering. Deviating from the rest of the class, one boy stated,

“To me it’s (engineering) a guy that works on a train.” However, as he was filling out the questionnaire, he told me that he never thought that using LEGOS to build robots and program them to move was considered engineering. In contrast to his comment, one girl wrote that engineering “has a lot of do with wires and electric things and making things move.”

The second question asked students to describe an engineer. Except for the one boy who wrote that an engineer “drives a train,” the two other boys wrote that an engineer “builds things” or “makes machines.” However, when verbally asked to describe an engineer one boy gave a completely different answer. “When I think of an engineer, I think of a scientist - an old guy with a lab coat and protective eyewear.” When prompted for further explanation, he stated, “An engineer creates stuff or finds things out that no one knows.” His answer reflects a common mix up that children often have with distinguishing between scientists and engineers. While scientists discover new things, engineers make things work better. One girl included “fixing stuff” as part of an engineer’s profession while the other girl stated that an engineer “puts things together and does computer work.” This is also a common trend among children. They often confuse engineers with mechanics.



**Figure 13, 14, 15 and 16** *Sketches of engineers from students’ journals.*

The third and fourth questions asked students to draw a picture of an engineer at work. Four out of the five students drew a picture of a male engineer at work while only one student, a

girl, drew a picture of a female engineer. However, in her picture she also drew a robot that looked to be of male gender. Interestingly, all the boys drew a picture of an engineer with a tool in his hand working directly with a machine, robot, or railroad track up-close. In contrast, the girls drew pictures of engineers standing with a computer or robot, but not interacting with those objects. One girl drew a picture of a female engineer standing very far away from the computer and robot. In the field of child art, this can be interpreted as the student feeling “distanced” or “removed” from engineering constructs.

Lastly, questions five and six asked students whether they knew any engineers and their relation to the student. All students stated that they knew an engineer. However, based on their description of an engineer, it is questionable whether they are thinking of people in the profession of engineering or of people who fit their description of an engineer. For example, one girl listed her brother’s friend who she implied fixes cars. Based on what I know of her high school brother, she may be thinking of one of her brother’s high school friends who is a mechanic or who likes to work with cars. As a result, the validity of questions five and six are questionable.

## **Journals**

On the first day of class, each student was given their own journal to document pictorial prototypes of their robots, to express in written form their thoughts on the challenges and exercises completed during class time, and to have a tangible product that they could take home with them at the completion of the workshop. The journals were introduced to the students through the association of the famous inventor and engineer, Leonardo DaVinci, who kept a logbook of his own. Students were informed that before DaVinci started building or creating any

inventions, he would always document his progress in a notebook or journal so that he could sketch out his ideas at the beginning of his projects to see if his ideas were feasible as well as for keeping a record of his thinking process. During each workshop session, students were asked to make sketches of the robots they wanted to build, to write down what was their favorite and least favorite activity of the day as well as what activities they found difficult to do.

In theory, the journals would have provided an outlet for students who demonstrated high linguistic and visual-spatial intelligences. By writing or drawing their ideas in their journal, they could create a public interpretation of their mental constructs allowing others to examine and discuss their ideas. As a result, their thinking and creating processes are validated (Papert, 1993). In addition, when students look back upon what they have written and drawn, they are able to learn more about their own thinking processes. However, in practice, the journals were not very popular with the students. Students were very reluctant to write or sketch in their ideas. Often they had to be prompted multiple times to write in their journal. In fact, near the end of the workshop, after having been asked to write down his thoughts about the activities from that day in his journal, one student adamantly claimed, “Journals are stupid!” A chorus of agreement by all the other students followed his comment.

The students’ lack of enthusiasm for writing and drawing about the activities of the day or their creations is evident when looking at the sparse nature of their journals. At the end of the eight weeks of class, student journals ranged from three to six pages, most of which were written within the span of two sessions. One boy never wrote in his journal; besides the first day of class, the only time that he wrote or sketched in his journal was after the all the students were told that they would be presenting their sketches to one another and receiving feedback and suggestions from the class. In fact, none of the students in the workshop chose to write in their

journals out of their own volition. Though students voluntarily spent time building new structures or working on new programs, they always had to be motivated to write in their journals.

Several factors may attribute to the students' reluctance to write and sketch in their journals. Since many of the students had trouble finishing their projects within the allotted time of the workshop, it is possible that they did not have enough time to work on their journals. Another reason may be that they were not interested in answering the posed questions. It is also possible that students in the fourth and sixth grades are still developing their writing skills and are not comfortable with their spelling. Consequently, it may take them more effort than they are willing to expend to answer the questions. Lastly, it may also be possible that writing responses to questions in their journal and sketching pictures is too similar to school work given in classrooms at school. Since students signed up for the robotics workshop as a fun, extra-curricular activity, they may not want to do work associated with school. In fact, some of the students mentioned that they wanted to do video journals instead of paper journals because it was "more fun" and "not as boring." Unfortunately, this was not feasible for the majority of the workshop due to the delayed approval of the study from the Institutional Research Board (IRB).

Despite students' limited writings and sketches in their journals, they provide a new perspective on each student's internal thinking process in addition to displaying general similarities and differences between the two genders within the context of the workshop. One of the most obvious findings from the journals is the fact that the girls spent more time writing in their journals than the boys. The two girls had a combined total of around 24 written phrases in their journals whereas the three boys only had a combined total of 8 written phrases. This

disparity between the quantity of written phrases occurred despite the fact that the boys were reminded to write in their journals more often than the girls were reminded to do so.

Though the degree of detail within the sketches and the number of colors used in the sketches did not differ significantly between the genders, there was a difference in the type of creativity used with the journals. For instance, the boys only drew engineering related objects on the cover or inside their journals while the girls included flowers, smiley faces, and stars on the cover and within their journals. In this sense, the girls branched out and connected the engineering or robotics concept with things outside of the technological realm. However, in examination of the progression of pictorial prototypes, the boys were more creative and willing to diverge from their first prototype. While the girls were inclined to pick one kind of prototype for their robot and continually use that model with little changes throughout all of the workshop activities, the boys were more likely to sketch prototypes of robots that differed in style from their previous models.

## **Questionnaire**

During the last day of class, the three students that showed up were given a questionnaire. The three-page questionnaire was based on a more comprehensive study on the attitudes toward math, science, and engineering, created by a research group<sup>11</sup> from Wellesley University. Since the workshop students are in fourth and sixth grades, the language of the questionnaire was modified to a more age appropriate level and the questionnaire itself was condensed to only include questions regarding science and engineering.

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<sup>11</sup> Questions for “What is an Engineer?” is adapted from a survey developed by Sumru Erkut and Fern Marx of Wellesley College. The original survey can be found in the Four Schools for WIE interim report to the National Science Foundation.

As expected from students in a robotics workshop, both males and females agreed that learning science is important, that they will use it in many ways as an adult, and that they have had science teachers who have validated their efforts in science. However, there was a noticeable difference in response with their level of confidence in their science abilities. Whereas the boys were more inclined to state that they could get good grades in science, the girls were not as certain about their abilities. This difference may be a result of girls really feeling less confident about their science abilities or it could just be that girls are more modest about their abilities.

There were not many differences in attitude toward engineering between the two genders. Both boys and girls agreed that engineering was interesting for them because they like to solve technical problems, they both believed that they could earn a lot of money with an engineering degree, that they would like a job that uses math and science, and that their parents would be supportive of a career in engineering. In addition, boys and girls both strongly disagreed with the statement, “all engineers that I’ve met have been very boring.” Given the little interaction that they have had with engineers, students probably answered this question in relation to their experience working with the engineers from the Robotics Academy.

## **CASE STUDIES**

*Mary*<sup>12</sup>

Mary enrolled in the *RoboHunt* After School workshop one day before class started. As a fourth grader, found out about the workshop through a flyer, which was faxed to principals of various schools in Medford and Somerville, targeted specifically at recruiting girls in the 4<sup>th</sup>, 5<sup>th</sup>, and 6<sup>th</sup> grades. Her brother, a high school senior, dropped her off on the first day of class. She

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<sup>12</sup> Student names have been changed to protect their identities. Mary and John are pseudonyms.

gave me the impression of being a very friendly girl that seemed a little nervous on the first day of school.

As she began working on her first task of designing the cover of her journal, she became more relaxed. She chose to decorate her cover with several vibrant colors. Watching her draw stars and rainbows along with robots on her cover brought to mind her mother's description of her daughter as "a very creative individual that enjoys the process of making things." In fact, the mother of the other female student in the workshop had indicated that her daughter's creativity instigated her to make the decision to enroll in the robotics class as well.

During the activities of the first day, it became apparent that Mary was a very outgoing girl who was unafraid to speak her mind. In our initial conversation, she had revealed to me that she had never owned or worked in-depth with LEGO bricks before. Nevertheless, she raised her hand and contributed ideas during class discussions as often as her male peers, who had prior experience working with LEGO bricks. In addition, during the theatrical improvisation activity, she was very eager to be the first person to arrange her peers and "write" a computer program. Her enthusiasm and inclination to volunteer as the guinea pig with new activities persisted throughout the duration of the workshop.

While her lack of prior experience with LEGO bricks did not differentiate her enthusiasm and appeal toward classroom activities from the excitement of those students who did have more experience with them, her lack of familiarity with the pieces did create a dichotomy between her building skills and those of her male counterparts. For instance, Mary had a lot of trouble with the initial activity of building a car; she was unable to figure out how to attach the wheels to the motors. Through her external constructs, I was able to observe her internal struggle with the concept. The different methods in which she used to attach the wheels to the motors

demonstrated that she did not have a clear understanding of how the wheels were powered. She did not understand the necessity for a motor in the car. As late as the fourth session, she asked:

Mary: Do I need a motor (for her new robot)?

Me: Well, what do you want your robot to do?

Mary: Move, run away when your robot pushes in my touch sensor.

Me: So what do you think? Do you need a motor to do that?

Mary: Yeeeessss (*a little embarrassed*)

However, even after having this conversation, Mary was still experiencing problems with the idea of putting the motor on her robot for her final project. In her mind, she was unable to make the connection that a motor was needed to make a robot move. Instead, she had been adding the motor to the car out of ritual or formality. She did not make the connection between the motor and its function until she started the process of programming in ROBOLAB. As she added on the motor icons to her program, she realized that she did not even have a motor on her robot, “Oh man, I don’t even have a motor on my robot! It’s not going to work if I have don’t have them. (*Giggle*) I need to go and add those.” Mary came upon a powerful idea when she finally understood the job of the motor because she had made the discovery on her own in a context relevant to her own personal project.

One thing that I have observed about Mary is that when she has trouble with a concept, she gets frustrated very easily. For lack of a better word to describe it, she would start to whine with the expectation that an engineer helper or I will give her the answer. At the beginning of the workshop, she gave up easily when no one provided her with a direct answer to the problem even after she whined about it. She would often reply, “I don’t know,” to questions meant to provide direction in her thinking. Instead of trying to figure out the solution herself, she was

inclined to look for direction in how to solve the problem. However, by the end of the workshop, Mary learned to try different solutions herself. She was less inclined to ask for the answers to the problem. In fact, in a video interview she stated, “If you have a problem with something, you can’t whine about it. You just have to keep trying different things until you get it.”

Mary was used to this type of inquiry in school because she learned that it was the most effective method for getting an answer. Since schools have rigid schedules and strict guidelines on the amount of curriculum that needs to be taught by the end of the school year, teachers typically convey information and concepts through an instructionist methodology because it is less time consuming than the constructionist approach. Typically, teachers provide students with direct instructions or solutions rather than creating an environment that allows the student to explore the problem on their own.

I have also noticed that Mary likes to talk out loud when trying to solve a problem. For instance, when thinking about the programming, she said, “maybe I should put a stop sign” or “oh, I need motor B, because that’s the port it’s connected to.” Often she’ll say these things aloud whether or not an engineer or I am around her. However, when one of us is nearby, she’ll look up to confirm her conjectures. Often, I find myself agreeing, or saying, “Well, why don’t you try that and see what happens.”

This need for validation from others also accounts for her enthusiasm for *Presentation Day*. When asked why she listed presenting her robots to others was her favorite activity, she explained, “If I did things and took it apart without anyone looking at it, it’s kind of like...*(pause)*. It’s better if I present it because people know you can do it.... People will know that boys and girls can do it.” In fact, Mary’s comment is in accord with the notion that girls

tend to find the locus of their self-esteem outside of themselves more so than boys do. Girls tend to look to others for confirmation while boys find it within themselves (Bolt & Crawford, 2000).

Mary's comment on girls and boys having the ability to do the same things was a reoccurring theme that appeared in our conversations, one-on-one interview, as well as her responses to the questionnaires and survey. In the interview, she stated, "All people can be an engineer. It's not like mostly boys or mostly girls. If you want to do it, you can." When asked where she learned that from, she said she discovered it in third grade when her class was building an electronic castle. At first she thought it was too hard and that she would not be able to do it, but she soon realized that both boys and girls could do it. Despite her response, I think that part of the reason for her strong belief in aptitude equality among males and females stem from her personal life. Raised by a single-mother, she has experienced a female role model from who she has learned that women can be just as strong and resourceful as men.

### *John*

On the first day, John, a fourth grader, came to class with his good friend. Every week the two friends, who also happened to be classmates at school, arrived and left the workshop together. John, a very polite boy with a good sense of humor, was often seen exchanging suggestions and discussing ideas for projects with his good friend. During one of our few uninterrupted one-on-one conversations, I found out that John has many LEGOS at home and spends a lot of time building and constructing things with the help of his father.

Since John had prior experience with LEGOS, he did not undergo a lot of trouble with attaching the motors to the wheels, like Mary did. However, he did have problems with building sturdy structures. In several instances, he would misjudge his strength and press down too hard

on his robot causing it to fall apart just as he was adding the last piece. Over the course of 4 sessions, his projects fell apart a total of 7 times. Luckily John was able to laugh at himself over his bad luck and did not lose motivation when his robots fell apart.

Since building a sturdy structure seemed to be a reoccurring problem for John, I decided to ask him a couple of questions regarding the construction of sturdy structures with the intention of focusing his thoughts on different ways in which he could improve his robots so that they would not fall apart so easily.

Me: How can you make a structure sturdier?

J: If they, the motors, are in the middle of something it will make it sturdier so they don't fall off the edge.

Me: How do you know that that will make the structure sturdier?

J: (*Points to sloping on underside of RCX.*) See here it goes down and so the motors can't attach to it as well. But if you put one piece here and connect the two motors to the middle of the RCX, then they stay on better.

In this scenario, John has devised a method to make things sturdier. He found that by “sandwiching” pieces together and overlapping pieces in a crisscross fashion, the structure becomes much sturdier. Since he made this discovery on his own through hands-on interaction with his projects, he came upon a powerful idea.

One observation that I have noticed about John is that he likes to build his project right away. He seems to come up with ideas fairly quickly in his head and likes to put his ideas into action. Many times, he will start building one thing, only to change his mind midway and build something else. Similar to the other students in the workshop, he rarely wrote about or sketched his project ideas in his journal. In fact, the only time he used his journal for pictorial prototyping

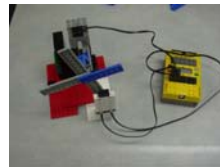
were the times that I specifically ask him to do so. Though he did not use his journal often, when he did use it, the workings of his mind are visible through his drawings. By following the progression of his pictorial prototypes, it is apparent that John has multiple and varied ideas. Unlike the other students within the workshop who drew and created projects of a similar style, John's journal and final project showed a more diverse set of ideas.



Robotic Car



Robotic Gate



A Windmill: John's Final Project

**Figure 17, 18 and 19** *John's different project ideas*

While John seldom documented his ideas on paper, he enjoyed giving suggestions to other students. For instance, in the fourth session, I asked students to share with one another their designs for a new robot. When one boy was describing a train that would move backwards, John asked him how he was planning on connecting the pieces of the train.

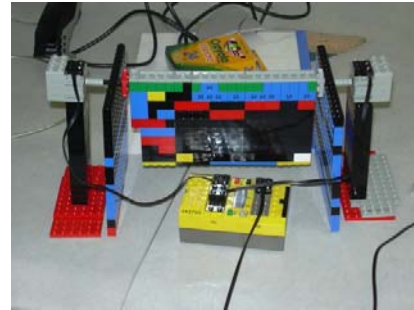
J: How are you connecting the pieces? Cause if you're connecting with a wire, then when it goes backwards, the pieces will go like this (*moves his hands to simulate how the cars would be jumbled*).

Boy: Oh, I didn't think about using wires. But that is a good idea! I think I will do that!

J: No, that's what I meant. If you used wires, then it would be bad because the wires would get messed up when your train goes backwards. Oh, but you could just use two motors, one at the back of the train and one at the beginning. If you wanted to

go backwards, you just turn on the motor at the back of the train and if you go forwards, you turn on the motor at the front of the train.

This conversation showcases John’s ability to think “outside of the box” and to take chances with creative projects and solutions. According to Clements research (1999), boys tend to take greater risks when programming while girls concentrate more on accuracy. For example, in the open-ended design project, he was the only student to think of a project that followed the guidelines for robot interaction with an additional twist. For instance, they were told to design a robot that



**Figure 20** *Robotic Garage Door*

performed a certain action when another robot came in contact with theirs. John decided to build a gate that would flip open. However, instead of using a touch sensor, he decided to use a light sensor. When his robot sensed the approaching robot’s light sensor, the gate would flip open. All the other students opted to use the touch sensors.

### *Gender Trends*

In both cases, John and Mary were not shy about giving help or suggestions to their peers. However, the nature of suggestions that they recommended was distinctly different. This difference was very prominent during Week 5 when students gave a mini-presentation on their pictorial prototypes and discussed their ideas for the final project with the class. After students presented on their project, the class was asked to give suggestions on how the presenter could improve upon their project. Whenever Mary gave a suggestion, it was usually geared toward

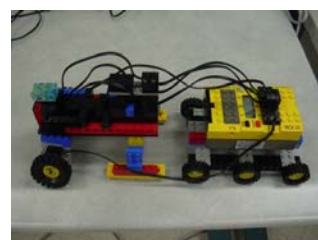
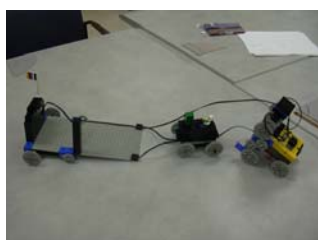
aesthetic or creative peripheral changes. In contrast, John always gave suggestions that focused on how to change the physical structure or operation of the robot to improve its functionality.

For instance, when giving one student suggestions on how to improve his robot, which he planned to have move backwards until it hit a wall and stop once the touch sensor was pushed in, Mary suggested that after the robot hit the wall, it should move forward and then in circles for a couple of seconds while playing music. In contrast, John suggested different ways in which the touch sensor could be secured to the robot so that it would not fall off when it came in contact with the wall. This was a trend was visible among many of the students. The boys were more prone to giving suggestions that involved changing the physicality or the operation of the robot while the girls gave suggestions on variations of how the robot should act or look.



**Figures 21, 22, and 23** *Various projects with aesthetic additions by girls*

Both of the female students' proclivities to adding creative aspects to their projects were apparent in the types of robots that they built. The additions that they added had no bearing on the function of the robot. In contrast, the many of the robots built by the males had the same train theme, but were constructed in several different ways.



**Figure 24, 25 and 26** *Various train projects by the boys*

Another commonality that occurred between the two girls was the tendency to talk out loud when working on their projects. I could hear them running through each step as they were building the robot. I did not see this occur as often with the boys. This may be an effect of girls' tendency to seek confirmation of their actions from others. Unlike males, females are more inclined to find the locus of their self-esteem outside of themselves. By speaking aloud, they are finding a way to communicate to others' their thought processes. This phenomenon can be interpreted in another way. The procedure of speaking out loud permits the girls to reconstruct the existing information in their minds. Since the girls in this workshop engaged in this activity more often than the boys, it is possible that these girls had a higher level of linguistic ability than their male peers.

## **DISCUSSION**

### *Effectiveness of the workshop*

Through various conversations with parents and students, I found that the *RoboHunt* workshop was very successful in peaking students' interest in learning about and working with engineering and technology principles. One parent of a male student commented several times, "He loves this class. It's all he talks about at home. He can't wait until the next class." Another parent of a female student voiced the same sentiments. She also commented that her daughter's class just started a robotics curriculum in school. Since she had some experience with programming and building from this workshop, she was able to do better on the projects than her partner, one of the best (straight A) students in the class. When her daughter realized this, she was very happy and "her self-esteem just skyrocketed." Through the answers on the

questionnaire and the “*What is an Engineer*” survey, students expressed their enthusiasm for the workshop and their intentions to take another robotics class next year.

The constructionist philosophy of the workshop was an integral aspect of what made the workshop so successful with the students. The science, engineering, and technology principles were conveyed to the students through exploration of concepts via a hands-on, project-based curriculum. Students were motivated and excited to learn because they were able to try new things and make personal connections to their projects. Furthermore, with the curriculum based around Howard Gardner’s multiple intelligence theory, they were able to construct their understanding of concepts and the world in the way that best fit their individual learning style.

In contrast to the studies that claim females typically do not feel comfortable in the fields of math and science, that they do not enjoy these subjects, that they do not see themselves as successful practitioners in these fields, and that they do not see these subjects as useful (Clewell & Campbell, 2002), results from general observations of classroom interaction as well as the female responses to the questionnaire and personal interview show just the opposite. From the responses to the questionnaire administered on the last day of class, the responses of the female student indicated that her attitude towards engineering and science were very similar to the boys’ attitudes. She agreed that science was important for future study, that she would like to be an engineer in the future, and that she had an interest in learning more about engineering and technology.

It is possible that she garnered this attitude through her experiences in the after school workshop, which had an environment that was modeled after instructional strategies noted for being effective in teaching and fostering positive attitudes in girls. The strategies employed

within the workshop included small-group discussions, cooperative learning, an inquiry approach, and activity-based instruction.

In contrast to optional or advanced science classes that often have a male instructor and strong male participation, which indicate to the female student that it is unusual for a female to be taking these type of courses (Mason, Kahle, & Gardner, 1991), a female instructor and multiple engineers, mostly female<sup>13</sup>, led the workshop. The presence of female role models in the robotics workshop conveyed the message that it is normal and important to their careers for females to be in advanced or optional science and engineering classes. Moreover, since there were three boys and two girls, there was not a large majority of either gender. Given the small class size students received a lot of one-on-one attention and feedback from the engineers and myself resulting in a rise of confidence. There was no noticeable discrepancy in attention paid to one gender over the other.

Lastly, the workshop promoted an enthusiasm for engineering and technology among girls because it encouraged them to “mess around” with the material and make mistakes. As documented earlier, girls are often socialized to be more hesitant and to avoid risks than boys are (Margolis & Fisher, 2002). Since the workshop was based on the constructionist philosophy, students were given leeway to experiment and make mistakes on their own. Students were never told that their ideas were wrong. Instead, they were encouraged to find out if their ideas would work by trying it out. In research conducted by Mason, Kahle, & Gardner (1991), they found that students “felt more positive about science when the teacher did not make them feel ‘dumb’ by . . . asking questions which demanded a “right” answer.”

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<sup>13</sup>Due to scheduling conflicts, many of the engineers were unable to help out in the workshop for the entire session. As a result, one female engineer helped out almost every single week.

### *Limitations*

There are several limitations to this study. One limitation stems from the composition of the study participants. Due to problems with recruitment of students for the class, particularly female students, there was a very small sample size. As with any study based on a very small, nonrandomized study sample, the results cannot be generalized to the population without reservations. The five participants, two girls and three boys, in this study were a self-selected group that had characteristics unrepresentative of the general population. For instance, this particular group chose to spend their afternoons building robots while foregoing other activities. Unique group features such as being home schooled, having learning disabilities, having very limited experience to LEGOS versus having previous exposure to last year's Robotics Academy workshop were cause for many unforeseen challenges when working with the group. In addition, the original study set out to observe students and the different roles that they assume when collaborating in mixed gender groups. However, due to the small class size and students' unpredictable arrival times<sup>14</sup>, it was very difficult to foster collaboration of students within mixed gender groups.

Another drawback of the study was the limited amount of data collected for analysis. Even though the application for approval was handed in to the Institutional Review Board weeks before the workshop started, approval for the project<sup>15</sup> was not granted until the seventh week of class. As a result of this delay, it was not possible to videotape workshop sessions or individual interviews with the students during the initial six weeks of the workshop. Instead, most of the data collected for this study were drawn from student journals and hand written notes taken

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<sup>14</sup> One boy had to leave half an hour early every session because of scheduled swimming lessons; he would always arrive to class half an hour before class started to make up for the time. One girl always arrived fifteen minutes to half an hour after class started because she had to partake in a homework club at her school.

<sup>15</sup> See Appendix J for Consent Form and Appendix K for Debriefing Form

during class conversations. Unfortunately, students rarely wrote or sketched in their journals resulting in sparse data. Furthermore, the availability of engineers to help out during the workshop had an impact on the amount of data collected. Due to several scheduling conflicts, the number of engineers present to help out in the workshop often fluctuated. On days when there was only one engineer, it was very difficult to focus on collecting data and observing all the students at work without the assistance of a video camera to document student interactions and comments, since many required individualized attention.

A third limitation of the study was timing. Though the class officially started at 3:15pm and ended at 5:15pm, students were allowed to arrive as early as 2:30pm and to leave as late as 6:00pm. Borrowed from last year's robotics workshop, the purpose of this flexible time feature was to make the program more appealing to families who may not have been able to provide care for their child between the end of school and the beginning of the workshop at 3:15pm, or for those parents who were unable to get out of work until a later time. However, as a result of this large and flexible time frame, students arrived at disjointed times making it difficult to teach new concepts or to show demos to the group all at one time. As a result, much of the time within each workshop session was spent repeating lessons to individuals.

In addition, another aspect of timing that proved to be difficult was the length of the workshop. Eight weeks is a very short time for students to learn new concepts and to explore ideas in depth and in innovative ways. Since many students were perfectionists, they often stuck with a project until the final product mirrored their internal representation. For example, students may have completed 90% of a project, only to take it all apart to add one little piece to it. Due to this time-consuming work style, many students were unable to complete all of the

scheduled activities for the day. As a result, many of the scheduled activities had to be cancelled or simplified.

## **CONCLUSION**

Given these limitations, the results from this study are inconclusive. While the findings suggest important implications about effective learning environments for females, and provide a window into the gender differences that may arise in an engineering and technological-based classroom, these results cannot be used to make generalizations to the population.

Nevertheless, there is still merit in the qualitative data that was collected during this workshop. Since the changes to the Massachusetts Curriculum Frameworks have been made relatively recently, there is a limited amount of research available on how learning styles in an engineering and technology-based environment differ between males and females. Now that there is a lack of individuals, especially females, entering the field of engineering, it is imperative that techniques with the potential of sparking interest in pursuing a career in engineering and technology are explored.

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## TIPS FOR STUDENT ENGINEERS in TEACHING the ROBOTICS AFTER SCHOOL WORKSHOP

*“Knowledge is not passed from teachers to students, but is developed by everyone through their activities and interactions with one another.”*

### *Structure of Class:*

*Brief Introduction of Concepts*

*Demonstration of project samples*

*Most of the class time will be spent Designing, Creating, and Building*

### *When a child has the wrong idea:*

*Do not immediately correct them.*

*Let the child try out his/her design as long as it is serious.*

*It is important that the student has the freedom to fail. In order for them to understand a concept, sometimes they need to be able to see for themselves that the idea does not work.*

### *When a child is stuck:*

*Help by asking questions and giving encouragement.*

*Do not give out answers or explicit directions immediately.*

*Though some students might find it difficult to think for themselves without getting explicit directions.*

*Let them explain their thought process and test out their own ideas*

### *How to give Constructive Criticism:*

- 1. Start with a positive by pointing out good aspects of the model or team's work ethic. (It's a good way to initiate dialogue)*
- 2. Ask about most obvious limitation of the work. Keep remarks impersonal.*
- 3. Ask if they have suggestions for improvement. If not, ask if they would like to hear yours. Check back with them later.*

*This method is a bit time consuming, but it helps the child to build self-confidence and a better understanding of the concepts.*

Title: RoboHunt

When: Jan 28; Feb 4, 11, 25; Mar 3,10, 17, 31.

Time: 3:15-5:15 (Students may arrive between 2:30 and 3:15 but MUST be picked up by 6:00pm)

Who: The workshop is open to students in 4th-6th grades. The class can accommodate 8 students, four boys and four girls. Enrollment is on a first come first serve basis.

Description: This after school workshop, taught by the Robotics Academy, will give students a hands-on experience with building and programming robots using LEGOS and ROBOLAB software. With the guidance of engineers from several disciplines, students will learn how to find creative solutions to problems using mechanics and robotics. As a final project, students will design an obstacle course which their robots will navigate through in a race to find a hidden treasure. This is a fun and rewarding opportunity for students to explore their creative side. Beginners only.

January 28, 2004

Subject: After School Robotics Workshop at Tufts University

Dear Principal,

I am a senior at Tufts University majoring in Child Development and Community Health. Starting Wednesday, February 4, I will be teaching an after-school workshop on Robotics for beginners at the Center for Engineering Educational Outreach at Tufts University. This after school workshop will give students a hands-on experience with building and programming robots using LEGOS and ROBOLAB software. With the guidance of engineers from several disciplines, students will learn how to find creative solutions to problems using mechanics and robotics. As a final project, students will design an obstacle course that their robots will navigate in a race to find a hidden treasure. Currently, there are open spots in the workshop for girls in 4<sup>th</sup>, 5<sup>th</sup>, or 6<sup>th</sup> grades.

I would appreciate it if you could distribute the enclosed flyer to the appropriate classrooms and encourage female students to participate in this eight-session workshop. This is a great way for students to get a foundation in engineering/technology principles in a fun learning environment. Thank you for all of your help.

If you have any questions, please do not hesitate to contact me at [Sandra.Tang@tufts.edu](mailto:Sandra.Tang@tufts.edu) or 617-627-1842.

Sincerely,

Sandra Tang  
Tufts University  
Robotics Academy  
[Sandra.Tang@tufts.edu](mailto:Sandra.Tang@tufts.edu)

**Calling all GIRLS!**



DO YOU LIKE TO **CREATE** and **WORK**  
with **TECHNOLOGY?**

**ARE YOU LOOKING FOR SOMETHING FUN TO DO  
AFTER SCHOOL?**

**If you are a girl and are in the 4<sup>th</sup>, 5<sup>th</sup>,  
or 6<sup>th</sup> grades, then you should sign-up for  
the RoboHunt after school workshop at Tufts  
University! Beginners Welcome! Classes  
start this Wednesday!**



When: Feb 4, 11, 25; Mar 3,10, 17, 31; April 7.

Time: 3:15 pm - 5:15 pm (Students may arrive between 2:30 pm  
and 3:15 pm but **MUST** be picked up by 6:00pm)

Cost: \$175, financial aid may be available upon request.

This workshop will teach you to create and program your very own robots. Throughout the class, you will meet several Tufts Engineers and learn about their projects and specialties! By end of this hands-on workshop, you will have learned some basic engineering concepts and have met new friends! Come join us and see where your imagination can take you!

If you have any questions or would like to enroll, please contact Elissa Milto of the CEEO at (617) 627-5888 or Sandra Tang at 617-627-1842 or [Sandra.Tang@tufts.edu](mailto:Sandra.Tang@tufts.edu)

<b>Science/ Engineering Concept</b>	<b>Definition</b>	<b>Projects or activities that displayed concept</b>	<b>Massachusetts curriculum frameworks application: Science and Technology/ Engineering Sections</b>
Inclined Plane	A flat surface that is at an angle so that one end is higher than the other because less force and energy is needed to move things up or down at an angle than straight up or down	~Three ramps activity ~Treasure Hunt Island	Motion of Objects section of Physical Sciences, Grades 6-8.
Energy Transformation	When a certain form of energy transforms into a different form and in doing so creates motion or change	All activities and projects using motors to transform electrical energy into mechanical energy	Forms of Energy section of Physical Sciences, Grades 3-5.
Friction	The force that creates resistance when two surfaces in contact move relative to one another	All activities involving movement on a surface	~Motion of Objects section of Physical Science, Grades 6-8 ~Identify and explain friction in Technology/Engineering section, Grades 6-8
Programming	A way of using code to give instructions to a system so that it carries out operations in the manner and order in which you tell it	All activities that have been programmed	Using symbols to communicate a message in Technology/ Engineering section, Grades 6-8

Robotic Autonomy vs. Remotely Operated	The difference between an object that can operate itself by either reading programmed instructions or by organizing input that it collects and an object that requires input from a source other than itself in order to operate	All activities that have been programmed	Using symbols to communicate a message in Technology/Engineering section, Grades 6-8
Analysis of Structure	The process of assessing the structure of an object and developing structural changes that would make the object more efficient or effective	All activities involving building	Engineering Design Process of Technology/ Engineering section, Grades PreK-10
Gear	A circle with teeth around the edges that rotates. When combined with other gears, it can change transfer motion by increasing or decreasing speed, torque and force or changing direction.	~Inclined ramps activity ~Map Driving activity ~Treasure Hunt Island	Technology/Engineering section, Grades 3-5
Power vs. Speed	Through alteration of gear ratios, power and speed levels can be changed. A small gear to a big gear leads to more power. A big gear to a small gear leads to more speed.	~Three ramps activity ~Treasure Hunt Island	Technology/Engineering section, Grades 3-5

Appendix E: Original Concept Chart

Lever	A straight platform resting on a fixed point, the fulcrum, so when one end of the platform moves, the opposite end moves an object more easily.	Lifting of weights using levers	Simple Machines Technology/Engineering section, Grades 3-5
Sensors	Equipment that registers an input from the environment and transmits a signal to a central processor.	~Light that turns on in tunnel ~Car reversing direction when it hits wall	
Accuracy of movement	Ability to create and manipulate a robot that moves as you intend it to.	~Map driving ~Obstacle course	
Manipulating hypotheses and solutions	Ability to generate, test, and revise predictions and proposed solutions.	All activities	Steps of the engineering design method Technology/Engineering section, Grades 6-8
Present data graphically	Use of graphs, sketches, diagrams, graphic organizers, etc. to show someone your ideas or results.	Journals kept every session	Graphic representation of a problem. Technology/Engineering section, Grades 3-5, 6-8
Communicate process and results verbally	Ability to explain to someone else your design process.	Student to student and student to teacher dialogue about their processes	Steps of the engineering design method Technology/Engineering section, Grades 6-8

Material properties	Qualities of a material, e.g. smoothness, density, weight, strength, or flexibility, that affect why and when you would use it.	~Stationary robot design ~Island design	Identify materials used to accomplish a design task based on a specific property Technology/Engineering design method Grades 3-5, 6-8
Design features	Size, weight, shape, etc. of a finished product.	All activities	Identify relevant design features Technology/Engineering section Grades 3-5, 6-8 Identify properties of a material vs. those of an object Technology/Engineering section Grades 3-5

## ASSESSMENT of CONCEPTS LEARNED:

Abundant opportunities for spontaneous, informal assessment will arise during the course of the after-school program.

1. Through asking questions while students are engaged in designing projects and at the conclusion of each activity I will have a fairly good idea of how much they are learning about the science involved.
2. By looking through their Journals, which will have their creative ideas, illustrations of designs, diagrams and key words like friction, gears, speed, power, etc.
3. Video Interviews
4. Oral Presentations

Sample Questions:

- What did you create?  
Have them describe in words and illustrations and point out design features that work.  
How can you improve upon the model?
- How does it work?  
What type of energy does your invention need to operate? (Mechanical, sound, light, other)  
What forces are making your invention work?  
How does the mechanism of your invention work?
- How did you test your creation?  
Provide data from your test.  
Make a graph.  
Give brief description of graph/data.
- Production  
What materials did you use to make your toy?  
Would you use different materials? Why?
- What was the largest problem you or your team had to overcome?  
How did you come up with ideas for solutions?

In Journal:

- Sketch project design and label main parts.
- List materials needed.
- List energy source requires.
- What happened in the test and how will you improve the design?
- List ideas for improving project.
- What have you learned that will help you the next time?
- What did you like best? What did you like least?

	<b>PLANNED ACTIVITIES</b>	<b>COMPLETED ACTIVITIES</b>	<b>SCIENCE/ENGINEERING CONCEPT</b>	<b>PHASE AND PURPOSE</b>
<b>WEEK 1</b>	<ul style="list-style-type: none"> <li>- Explore LEGO kits</li> <li>- Build a Sturdy Car</li> <li>- Write in journals to document prototypes</li> <li>- Theatrical improvisation of programming</li> <li>- Program cars using computers</li> </ul>	<ul style="list-style-type: none"> <li>- Explore LEGO kits</li> <li>- Build a Sturdy Car</li> <li>- Write in journals to document prototypes</li> <li>- Theatrical improvisation of programming</li> <li>- Program cars using computers</li> </ul>	<ul style="list-style-type: none"> <li>- Structural Analysis</li> <li>- Graphic presentation of data</li> <li>- Energy Transformation</li> <li>- Teamwork</li> </ul>	<i>Introductory Phase:</i> To learn concept of a robot, explore LEGO kits, become acquainted with programming language
<b>WEEK 2</b>	<ul style="list-style-type: none"> <li>- Learn about gear trains and ratios</li> <li>- Ramp and Map Navigation Challenge</li> </ul>	<ul style="list-style-type: none"> <li>- Learn about gear trains and ratios</li> </ul>	<ul style="list-style-type: none"> <li>- Structural Analysis</li> <li>- Inclined Planes</li> <li>- Programming</li> <li>- Power versus Speed</li> <li>- Touch Sensors</li> </ul>	<i>Phase Two:</i> To learn about mobile robots and focus on output challenges
<b>WEEK 3</b>	<ul style="list-style-type: none"> <li>- Team Spot Project Demonstration</li> <li>- Build a bumper car with touch sensors at both ends</li> <li>- “Go Fish” Communication Challenge</li> </ul>	<ul style="list-style-type: none"> <li>- Team Spot Project Demonstration</li> <li>- Build a bumper car with touch sensors at both ends</li> <li>- Build a remote controlled car</li> </ul>	<ul style="list-style-type: none"> <li>- Gear Trains</li> <li>- Gear Ratios</li> <li>- Friction</li> </ul>	<i>Phase Two:</i> To learn about mobile robots and focus on input challenges

	<b>PLANNED ACTIVITIES</b>	<b>COMPLETED ACTIVITIES</b>	<b>SCIENCE/ENGINEERING CONCEPT</b>	<b>PHASE AND PURPOSE</b>
<b>WEEK 4</b>	<ul style="list-style-type: none"> <li>- Explore gears and levers</li> <li>- Lever Challenge</li> </ul>	<ul style="list-style-type: none"> <li>- Finish bumper challenge</li> <li>- Finish building a remote controlled car</li> <li>- Learn to program and use light sensors</li> </ul>	<ul style="list-style-type: none"> <li>- Gears and Levers</li> <li>- Light Sensors</li> <li>- Programming</li> <li>- Structural Analysis</li> <li>- Autonomous robots versus remotely operated robots</li> <li>- Giving and Receiving feedback from classmates</li> <li>- Prototyping in Journals</li> </ul>	<i>Phase Three: To learn about stationary robots and focus on output challenges</i>
<b>WEEK 5</b>	<ul style="list-style-type: none"> <li>- Team Kinetic Project Presentation</li> <li>- Build a lighthouse programmed to turn on a light and revolve for varying lengths of time</li> </ul>	<ul style="list-style-type: none"> <li>- Build a stationary robot using light or touch sensors</li> <li>- Prototype robots in journals and class discussion with feedback</li> </ul>		<i>Phase Three: To learn about stationary robots and focus on input challenges</i>
<b>WEEK 6</b>	<ul style="list-style-type: none"> <li>- Build autonomous or remotely operated robot</li> <li>- Design robotic island layout</li> <li>- Prototype robots in journals</li> <li>- Discussion with classmates including feedback</li> <li>- Team Kinetic Project Presentation</li> </ul>	<ul style="list-style-type: none"> <li>- Build autonomous or remotely operated robot</li> <li>- Create domino link between robots used in presentation</li> <li>- Learn to collaborate with others in group work</li> <li>- Team Kinetic Project Presentation</li> </ul>	<ul style="list-style-type: none"> <li>- Communication of ideas to others</li> <li>- Teamwork</li> <li>- Design</li> <li>- Programming</li> <li>- Structural Analysis</li> <li>- Redesigning Robot</li> </ul>	<i>Phase Four: To combine concepts learned throughout course to build own robot for Treasure Island</i>
<b>WEEK 7</b>				Presentation Night
<b>WEEK 8</b>				<i>Phase Four: Wrap up of class</i>

## What is Engineering?

Name: \_\_\_\_\_

Grade: \_\_\_\_\_

I am:    male        female    (please circle one)

Briefly answer the questions below in one or two sentences. Don't worry about being right or wrong—just write what you think.

(1) In your own words, what is engineering?

(2) What does an engineer do?

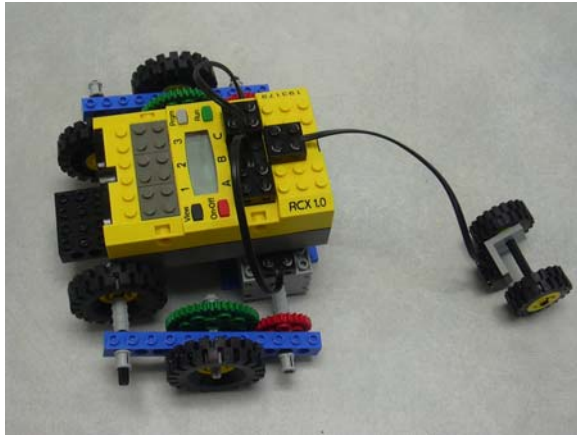
(3) Draw a picture of an engineer at work.



(4) Please describe what you drew above in words.

(5) Do you know any engineers? (circle one) Yes        No

(6) If so, who are they? (for example, "my cousin", "my neighbor")



**RoboHunt  
Workshop  
PRESENTATION**

(COVER)



**You are invited to join us for a  
Pizza Party  
On  
Wednesday, March 31, 2004.**

**Come and listen to the students  
of the RoboHunt Workshop talk  
about their projects!**

**Presentations will start at 4:30  
pm.**

(INSIDE)

## Questionnaire

Circle your answer.

1. I am a \_\_\_\_\_. Boy Girl

2. What grade are you in? 4<sup>th</sup> 5<sup>th</sup> 6<sup>th</sup>

3. Do you want to go to college? Yes No

4. Do you know any engineers? Yes No

Who are they?

Mother      Father      Grandparent      Brother or Sister  
Other relative      Neighbor      Family Friend      Other Adult

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Read the sentence. Then circle the phrase that you agree with the most.

### Attitude Toward Science

1. Science is hard for me.

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

2. I will not use a lot of science when I get out of school.

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

3. Taking science is a waste of time.

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

4. I will use science in many ways as an adult.

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

5. I can get good grades in science.

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**6. I know I can do well in science.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**7. Doing well in science is not important for my future.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**8. I am no good in science.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**9. I study science because I know how useful it is.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**10. Science teachers have made me feel I have the ability to go on in science.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**11. I will choose a career in science.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

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**Attitude toward Engineering**

**1. A degree in engineering will allow me to obtain a well paying job.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**2. I do not want a job that uses math and science.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**3. People will call me a “geek” or “dork” if I get a job in engineering.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**4. My friends will make fun of me if I choose engineering as a career.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**5. I will earn a lot of money with a degree in engineering.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**6. My parents do not want me to be an engineer.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**7. I like playing computer games. I do not care about how they work.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**8. I would like to learn how to make safer make-up.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree      Strongly  
Disagree

**9. All engineers that I've met have been very boring.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**10. Engineering interests me because I like to think about solving technical problems.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

**11. I am not interested in what makes machines work.**

Strongly Agree      Somewhat Agree      Not Sure      Somewhat Disagree  
Strongly Disagree

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Write your answer below. Be honest. Your answer will help me understand what you hope to learn from this class.

**Why did you choose to take this class?**

**What makes learning in science, or engineering interesting for you?**

Dear Parent,

Thank you very much for enrolling your child in *RoboHunt*, a robotics after-school enrichment program. Not only will this class be a great way for your child to get a head start on learning some engineering and technological concepts that are featured in the Massachusetts State Science & Technology/Engineering frameworks, but it will also provide your child with the opportunity to learn from various Tufts engineers of the Robotics Academy.

In addition to writing this letter to express how excited I am about teaching this class, I would also like to take this opportunity to inform you about research that I will be conducting during each classroom session. As a child development major from Tufts University, I am writing a senior honors thesis on the roles that children adopt in group engineering learning experiences. I am interested in finding out more about children's learning processes of engineering concepts in order to understand how to provide a learning environment that is gender equitable. With the information collected from observations of the students during the workshop, I hope to gain a better understanding of how to create a science and technology based classroom environment that is equally favorable for the learning styles of males and females. In order to conduct this research, I need to ask for your permission to include your child in the study for my senior honors thesis that will occur during the workshop.

By signing this form, you grant permission for staff of the Tufts University Robotics Academy to:

- a. Interview your child in class concerning his or her experiences related to engineering. These interviews will occur in the classroom during the class activity, and will be documented by written notes.
- b. Photograph and videotape your child while he/she is working with engineering concepts and activities.
- c. Examine your child's written or illustrated work related to engineering.

Please be assured that every reasonable effort will be made to ensure that children's ideas and experiences with the class will be kept confidential, and pseudonyms (made-up

names) will be used for all student names in field notes and research reports. All photographs and videotapes will be taken in front of the class, in the normal classroom setting. If you do not wish your child to be photographed or videotaped, or do not want the photographs and video to be used outside the research project, please indicate so on the consent form (the attached form).

The participation of your child in interviews, photography, and videotaping are voluntary and you have the right to withdraw consent or to stop at any time. Withdrawing from the research only means your child will not be interviewed, photographed, or videotaped. If at any point during the research you decide that you do not want your child to participate in the research any longer, your child may withdraw from the study with no negative consequences to him or her by contacting me, Sandra Tang, or my senior thesis advisor, Professor Marina Bers. If you choose not to agree to have your child photographed, videotaped or interviewed there will be no effect on your child's participation in the class. Your child will still participate in all of the robotics and engineering activities.

This project has been reviewed by the Tufts University Human Subjects Committee. Please feel free to ask any questions that you may have about the goals of this study and the procedures involved. If you have any concerns about this project at any time, you may communicate your concerns –anonymously, if desired—to:

Sandra Tang	Prof. Marina Bers	Human Subjects Committee
Tufts University	Eliot-Pearson	Ballou Hall
C242 Latin Way	Tufts University	Tufts University
Medford, MA 02155	Medford, MA 02155	Medford, MA 02155
(617) 627-1842	(617) 627- 4490	(617) 627-3417
<a href="mailto:Sandra.Tang@tufts.edu">Sandra.Tang@tufts.edu</a>	<a href="mailto:Marina.Bers@tufts.edu">Marina.Bers@tufts.edu</a>	

Once the consent form has been completed, please hand it in at the beginning of the next class. Thank you for your time.

Sincerely,

Sandra Tang

Appendix J: IRB Consent Form

## CONSENT FORM

If you do not wish for your child to participate in interviews, photography, or videotaping regarding his or her experiences with engineering, you have that option. **Please be sure to check one box in each of the three areas below.**

### 1. CONSENT FOR INTERVIEWS

- I **consent** for my child (if he or she wishes) to be interviewed by members of the Tufts University Robotics Academy during the after school enrichment class, RoboHunt, for the purposes of research on gender roles in an engineering learning environment.*
  
- I do **not** agree to have my child interviewed as part of the senior honors thesis study.*

\_\_\_\_\_  
Student's Name (Please print)

\_\_\_\_\_  
Student's Signature

\_\_\_\_\_  
Parent's or Guardian's Signature

\_\_\_\_\_  
Date

### 2. CONSENT FOR PHOTOGRAPHY

- I **agree** to have my child photographed and to have pictures used outside the research project in scholarly publications or meetings. His or her name will not be used.*
  
- I do **not** agree to have my child photographed as part of the senior honors thesis study.*

\_\_\_\_\_  
Parent's or Guardian's Signature

\_\_\_\_\_  
Student's Signature

### 3. CONSENT FOR VIDEOGRAPHY

- I **agree** to have my child videotaped and to have video used outside the research project in scholarly publications or meetings. His or her name will not be used.*
  
- I do **not** agree to have my child videotaped as part of the senior honors thesis study.*

\_\_\_\_\_  
Parent's or Guardian's Signature

\_\_\_\_\_  
Student's Signature

## DEBRIEFING STATEMENT

Dear Study Participant,

Thank you very much for participating in this study. Your help is fundamental to the success of my senior honors thesis. Using the data that you have provided, I will analyze the relationship between gender roles and group engineering learning experiences to gain a better understanding of how to provide a gender equitable learning environment for engineering and technological concepts in a classroom.

As a reminder, the identities of all participants in the study will be kept confidential. Pseudonyms will be used for all student names in field notes and research reports. Video tapes of the classroom activities, individual questionnaire responses and individual interviews will not be viewed by anyone else except for myself, the principal investigator, as well as my three thesis committee advisors, Professor Marina Bers, from the department of Child Development, Professor Christopher Rogers, from the department of Mechanical Engineering, and Professor Caroline Cao, from the department of Human Factors in Mechanical Engineering.

If you should have any questions or concerns regarding this study now or in the future, please feel free to contact me, Sandra Tang, using the information underneath my name. Once again, thank you for your time.

Sincerely,

Sandra Tang  
C242 Latin Way  
Tufts University  
Medford, MA 02155  
617-627-1842  
[Sandra.Tang@tufts.edu](mailto:Sandra.Tang@tufts.edu)

Appendix K: Debriefing Form