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DESIGN OF A ROBOTICS WORKSHOP FOR CAMP REACH

An Interactive Qualifying Project Report

submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

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1.0 Introduction

1.1 Project Goal/Definition

The goal of this project is to create an effective, affordable workshop for Camp REACH, a girls' summer camp held annually at Worcester Polytechnic Institute (WPI), that will be both educational and enjoyable for the campers. We will also set criteria for evaluating potential workshops for the camp that can be used to evaluate workshops in the future. At the project's completion, we will turn over a detailed list of the materials necessary for the workshop, and both electronic and hard copies of all worksheets to the camp staff.

2.0 Literature Review

2.1 Introduction

This literature review contains information pertinent to the development of a successful educational camp workshop, specifically one using the facilities available on the campus of Worcester Polytechnic Institute.

2.2 Camp REACH

Camp REACH (Reinventing Engineering And Creating new Horizons) is a two week summer program held at WPI for thirty girls entering seventh grade, mainly from the Worcester area. Camp REACH was designed as an Interactive Qualifying Project in 1996, in the project "Design of an Engineering Camp for Girls", by Stephanie Gagne, Robert Grelotti, Chi-Yan Tsang, and Elisabeth Wagner, with the goal of demonstrating that girls have the characteristics to become good engineers and scientists.[1] The camp itself has been in existence since the summer of 1997, when it was started by the efforts of Professors Denise Nicoletti and Chrys Demetry, along with a grant from the National Science Foundation. The purpose of Camp REACH is to stimulate interest in science and engineering among girls who might not otherwise realize the opportunities that an engineering degree can offer them. Another goal of the camp is to increase the girls' self-esteem and prevent them from thinking that engineering is just a field for men who enjoy mathematics and computers.

The camp has three major components: a large project where the girls do a comprehensive design of a solution to a real-life problem and then implement it, field trips to off-campus sites so the girls can see women engineers in action, and where the girls get to actually try small engineering projects.[2]

2.2.1 Previous workshops

One workshop that has been developed for Camp REACH already is a radio construction workshop. In this workshop the girls actually build their own small radios and are able to test and use them. The students that designed this workshop developed a very specific evaluation system for their decision-making process in choosing a workshop, considering such topics as whether the girls would be exposed to computers, whether the project would use facilities unique to WPI, and other characteristics. However, as we discovered from reading their results section, the major problem with their workshop was the radios often would not work, which caused a great deal of frustration to the girls and lowered their enjoyment of the workshop.[3] This showed our group that as high as success rate as possible for the workshop would be an important factor to consider as we developed our workshop.

Another workshop that has been developed for Camp REACH is a workshop that analyzes the effectiveness of different materials for insulating a home.[3] The girls build miniature houses and place a thermometer inside the house, then test different materials as insulation to see how well each holds in heat. The main thing we liked about this workshop was that it dealt with more than one specific aspect of science and engineering. The girls had to explore parts of both civil and electrical engineering to successfully complete the workshop. This was a quality that we worked to include in our workshop, because, in the professional engineering world, projects are almost always not just within solely one engineering discipline.

Another workshop that has been developed for Camp REACH by an IQP group is a workshop that deals with solving a fictitious crime by using forensic techniques.[4] Of the three IQP workshop development projects, this one is the most popular with the girls at the camp.[5] The girls use chemical processes like gas chromatography to analyze "evidence" from the crime scene to determine the criminal. After reading through this project, we were very impressed because the group not only designed a workshop that taught the girls about science and engineering, but something that allowed them to have some fun doing it. This was another quality we definitely wanted in our workshop.

There are a number of other workshops that have been designed by teachers and professors for Camp REACH. These workshops involve activities like taking the girls on a field trip to Cape Cod to build sandcastles and learn about civil engineering.[6] One thing we noticed about both of these workshops was that they are somewhat weather-dependent, since a rainy day could render either one of them unable to be completed. But, after reading all of these previous workshops, we felt we had a good idea of exactly what we wanted to consider when we were developing our own workshop idea.

2.3 Other Programs

Camp REACH is not the only program working to further the cause of women in science and engineering by educating the girls at a young age. One similar program is the Women in Technology program at the University of Vermont.[7] The WIT program, which was founded in 1994, consists of a rigorous five-day program where the campers meet girls from other schools that have the same interests as they do. They also use workshops to teach the girls about the aspects of separate disciplines of engineering, but the WIT workshops are shorter than the Camp REACH workshops, due to the shorter time period of the actual camp. Also, the WIT program has a separate program called the Advanced Topics in Technology program, where the girls have the opportunity to come back between their ninth and tenth grade years to continue their exploration into science and engineering. This is a positive aspect of the WIT program because it enables them to see the influence of their program on the campers and to help the ones who want to continue to pursue a career in science or engineering to deal with some of the social pressures they might face in a high school environment.

Another program that acts to increase female interest in science and engineering by educating them at the seventh and eighth grade level is the "Future Science: Future Engineering" (FSFE) program at the University of Michigan. The FSFE program is a week long program that educates girls through experimentation, computer simulations, and demonstration of online resources that can help the girls learn about topics that interest them that they might not have a chance to learn about in a public school environment.[8] The girls also get to meet real life female scientists and engineers that can serve as role models for the girls as they think about their future career paths.

A third program working in a similar vein to Camp REACH is the Role Model Project for Girls, started by Womenswork, an organization based in Palo Alto, California.[9] The focus of the Role Model Project for Girls is to provide the girls access to women working in science and engineering careers. The program gives them the ability to ask questions and go see these women performing their jobs in the workplace. This program is important because, according to WomensWork, there has been an "overabundance of papers, studies, and speeches which illustrate a striking imbalance in how girls and boys are treated in school, they are portrayed stereotypically in the media, they view themselves differently with regard to career choices, and these cultural stereotypes and actions translate into a wide gap in the level and pay of women and men in their professional lives."[9]

2.4 Psychological/Developmental Characteristics of the Campers

2.4.1 Development

At twelve years of age, girls have not yet entered adolescence and are still in middle childhood.[10] Children have already developed habits necessary for success in school during the difficult early grades, in which children must face the challenge of developing the discipline to sit still for six hours and spend the necessary time on homework. Middle childhood is a time for building on these already set patterns. Children focus on testing themselves, and on meeting the challenges imposed by the environment.

Freudian theorists refer to this developmental phase as latency, a period of relative calm before the upheavals of adolescence.[10] At this age, the gender gap between boys and girls in science and math classes has not yet developed, as it will when the children reach adolescence and high school. This gap, which seems to be rather well accepted, has been substantiated by several studies, including one conducted by Advocates for Women in Science, Engineering and Mathematics, or AWSEM. Science teachers were observed in rather blatant examples of teachers encouraging boys over girls in science classes. Leads to girls developing a tendency to assume less active roles in science classes and a tendency to look towards non-science related careers. In order to counter this trend, society needs to encourage its teachers to make a special effort to ensure that girls receive equal opportunities in science classes, and an effort should be made to interest girls in science before high school.

2.4.2 Interaction in Groups

It has been proven that girls develop differently and interact differently than boys.[11] At the age of Camp REACH campers (around age twelve) children's dependence on groups of peers for companionship and acceptance peaks, and group behavior has the largest impact on individual behavior.[12] This can have both positive and negative results. While girls who are more peer-oriented are more likely to take up lying, smoking, and using foul language, groups of friends can be an excellent support mechanism, especially among girls. This type of support mechanism may actually prevent undesired behavior such as underage drinking and smoking.

Groups of young female friends are networks, overlapping groups of one-on-one friendships.[12] Because they nurture these one-on-one relationships, girls form very tight relationships with their friends, and as a result girls have more effect on their friends than boys do. A result from the differences between the ways boys and girls interact with their friends is that girls see their friends as a support base, where boys' friends are allies in mischief. There are also outward signs of these developmental differences in that boys will only touch each other if they are involved in rough play, while girls will hold hands and hug each other.

2.5 Teaching Philosophies

2.5.1Teaching Methods

In order to assess the degree to which our goal of creating an enjoyable and educational workshop is attained, we must examine each facet of that goal separately. How enjoyable the workshop developed will be for the girls is somewhat hard to quantify. After failing to find literature on how to make a workshop enjoyable for a specific age group, we turned to camp staff of past years for information.

The girls attending the camp in past years had responded very well to hands-on learning experiences, in which they not only learned new engineering principles, but also had the chance to try these out during an experiment.

They also seemed to prefer workshops that included some type of demonstration or spectacular example of the principles that they were investigating.[13] Camp staff also felt that a key component of an enjoyable workshop was that the results of any experimental portion be easily obtainable when the workshop is done carefully and completely. In past years, workshops had been conducted in which the results were dependent on uncontrollable variables such as weather. These workshops did not yield good results even when the girls conducted the experiment correctly. This was very frustrating to the girls, and would ruin even an otherwise well thought out and well planned workshop.

The second aspect evaluated was the educational value of the workshop. While much of the writing on teaching philosophies deal with the personality and personal style of the teacher, it is the value of learning in a workshop environment that was the focus of our literature review of teaching philosophies. Since the goal of any teaching is to convey knowledge to the student, any technique that accomplishes this can be considered a success. The traditional approach to teaching, involving the presentation of information to a passive audience, is the usual picture of teaching at all age and grade levels. While this may be the most effective way to present the fundamental concepts necessary to develop basic skills such as reading and mathematics in early grades, and later to present the facts necessary to the study of such subjects as history and general science, it is not the only way in which students can learn. Learning in a group environment, the basis for this project, presents the opportunity to explore an academic problem in a cooperative learning environment.

Studies have found that classrooms in which superior achievement was observed were most likely to be the result of having a teacher that does not blindly follow a single-behavioral instructional path to the exclusion of other options.[14] It seems vital, then, that work in groups be used as a method to allow students an alternative (or supplement) to the traditional lecture. The Massachusetts Board of Education's curriculum requirements are rooted in the traditional base of lecture centered learning.[15] There has been, however, some incorporation of group learning in order to explore the scientific method and develop an understanding of the experimental process

2.5.2 Philosophy of Evaluation Methods

Methods with which to evaluate the effectiveness and educational value of teaching were also examined. The educational content of a workshop can be analyzed rather objectively, so it is the manner in which it is communicated to its intended audience that becomes that subject of scrutiny. The problem of determining how effectively the teaching conveys the subject matter, as well as how well it holds the attention of the students, has always challenged teachers and administrators.

Various methods of evaluating the effectiveness of the teaching were encountered. Classroom visitation, self-appraisal, student opinion, recording devices, and team teaching were all presented in research material.[16] Classroom visitation, not often used in any school system, is often met with resistance from the teaching staff, as the intrusive presence of an administrator may influence the actions of both teacher and students, and any observations made might not accurately reflect the actual classroom environment. Self-appraisal can be a valuable tool, as teachers undoubtedly have their own opinion on how the material is being received. As the teacher inevitably spends the most time with the students, they have the best opportunity to observe the students and can gain true insight through self-appraisal.

Student opinion, however, is probably the most heavily relied upon indicator of success in the presentation of the material. "Despite the doubt of the competency of students to judge good teaching, they are the instructor's primary audience."[16] There are two ways in which to obtain the opinion of the students involved. One method is by conducting an open forum at the end of the workshop, in which the students would be encouraged to share their opinions on the workshop, including criticisms and suggestions for improvements. The second method involves the use of a questionnaire such as those commonly seen on college campuses. Both methods incorporate some common problems to be overcome in order to ensure that the students' responses are not influenced by the manner in which their opinions are polled. A third party in charge of giving out and collecting forms and assurances that the student's anonymity is protected will all help gain a measure of objectivity.[16]

2.6 Curriculum

2.6.1 Science

The following is the expectations for grades five through eight, excerpted from the 1996 Massachusetts Science and Technology Curriculum Framework. This framework consists of a complete listing of all scientific topics required to be taught between fifth and eighth grade in the Commonwealth of Massachusetts. While researching child development is vital to ensure that the workshop satisfies the emotional, social, and developmental needs of the children, such curriculum guidelines are crucial to ensuring that the academic content of the workshop for Camp REACH is appropriate for the grade level of the campers.

Topic	Learning Standards and Examples of Student Learning[17]
Inquiry	• Note and describe relevant details, patterns, and relationships. • Differentiate between questions that can be answered through direct investigation and those that cannot.

Inquiry	• Apply personal knowledge and experience to make predictions. • Apply multiple lines of inquiry to address and analyze a question, e.g., experimentation, trial and error, survey, interview, and secondary sources. • Design an investigation or problem specifying variables to be changed, controlled, and measured. • Use more complex tools to make observations, and gather and represent quantitative data, e.g., microscopes, graduated cylinders, computer probes, stress and impact testers, wind tunnels, and timers. • Describe trends in data even when patterns are not exact. • Reformulate ideas and technological solutions based on evidence. • Analyze alternative explanations and procedures. • Represent data and finding using tables, models, demonstrations, and graphics. • Communicate ideas and questions generated, and suggest improvements or alternatives to the experimental techniques used. • Communicate the idea that usually there is more than one solution to a technical problem. • Design a solution involving a technological problem and describe its advantages and disadvantages.
Domains of Science: Physical Science	*Properties of Matter* • Identify properties that allow materials to be distinguished from one another and often make them well suited to specific purposes. *For example, compare and measure different materials in terms of their characteristic properties such as density, texture, and color.* • Identify and classify elements and compounds with similar properties, such as metals, metalloids, and non-metals; acids and bases; combustibles and non-combustibles. • Present evidence that a chemical change involves the transformation of one or more substances into new substances with different characteristic properties. Give examples that such changes are usually accompanied by the release of or absorption of various types of energy, especially radiant energy such as heat or light. • Explore and describe that the mass of a closed system is conserved. *For example, if a wet nail is put in a jar and the lid closed, the nail will rust (oxidize) and increase in mass but the total mass in the contents of the jar will not.* • Measure and predict changes in the pressure, temperature, or volume of a gas sample when changes occur in either of the other two properties. *Particulate Model of Matter* • Describe a particulate model of matter that accounts for the observed properties of substances. • Recognize and explain how experimental evidence supports the idea that matter can be viewed as composed of very small particles (such as atoms, molecules, and ions), which are in constant motion. Illustrate understanding that particles in solids are close together and not moved about easily,; particles in liquids are about as close together and move about more easily; and particles in gasses are quite far apart and move about freely. • Provide evidence that shows how the conservation of mass is consistent with the particulate model that describes changes in substances as the result of the rearrangement of the component particles. *Motions and Changes in Motion* • Show and describe how forces acting on objects as pushes or pulls can either reinforce or oppose each other. • Demonstrate that all forces have magnitude and direction. Create situations to model how forces acting in the same direction reinforce each other and forces acting in different directions may detract or cancel each other.

Domains of Science: Physical Science (cont.)	• Describe and represent an object's motion graphically in terms of direction, speed, velocity, and position. *Transformation of Energy* • Represent an understanding that energy cannot be created or destroyed but exists in different interchangeable forms, such as light, heat, chemical, electrical, and mechanical. • Present evidence that heat energy moves in predictable ways, flowing from warmer objects to cooler ones until both objects are at the same temperature. *Predict and use tools to measure this movement.* • Illustrate an understanding that energy comes to the Earth as electromagnetic radiation in a range of wavelengths, such as light, infrared, ultraviolet, microwaves, and radio waves. *Explain ways in which the amount of each type of radiation reaching the surface of the Earth depends on the absorption properties of the atmosphere.* • Investigate and describe an understanding of visible electromagnetic radiation, which we generally call light, with reference to qualities such as color and brightness. Illustrate understanding that light has direction associated with it, and can be absorbed, scattered, reflected, or transmitted by intervening matter. *Demonstrate and explain refraction as the process by which light's direction can be changed by passing from one medium to another.* • Explain ways that energy can be changed from one form to another. *For example, heat and light are involved in physical or chemical changes and at times may be accompanies by sound.* • Demonstrate principles of electrical circuits. Use wires, batteries, bulbs, and instrumentation to measure and analyze electrical energy resistance, current, and power. Use electric currents to produce electromagnetic coils of wire, and, conversely, use a moving magnet to generate a current in a circuit.
Domains of Science: Life Sciences	*Characteristics of Organisms* • Identify the cell as the basic unit of life and the smallest unit that can reproduce itself. Give examples of single and multi-cellular organisms. • Explore and describe an understanding that plants, animals, fungi, and various types of microorganisms are major categories of living organisms. Each category includes many different species. Note that these categories are subject to change. Life does not always fit into neat categories (e.g., are viruses alive?) • Observe and explain that in single cells there are common features that all cells have as well as differences that determine their function. *Compare the features of plant and animal cells noting similarities and differences.* • Investigate and illustrate evidence that cell replication results not only in the multiplication of individual cells, but also in the growth and repair of multi-cellular organisms. • Present data to illustrate that all organisms, whether single or multi-cellular, exhibit the same life processes, including growth, reproduction, and the exchange of materials and energy with their environments. • Describe ways that cells can differ in multi-cellular organisms, assuming different appearances and carrying out specialized functions. • Investigate and explain that complex multi-cellular organisms are interacting systems of cells, tissues, and organs that fulfill life processes through mechanical, electrical, and chemical means, including procuring or manufacturing food, and breathing and respiration. *Diversification and Adaptation of Organisms* • Explain situations in which short-term changes in available food, moisture, or temperature of an ecosystem may result in a change in the number of organisms in a population or in the average size of individual organisms or in the behavior of individuals in a population. *Explore through models and evidence ways in which long term changes may result in the elimination of a population or the*

Domains of Science: Life Sciences (cont.)	*introduction of new populations.* • Explore and illustrate that in both the short and long term (millions of years), changes in the environment have resulted in qualitative and quantitative changes in the species of plants and animals that inhabit the Earth. *Heredity, Reproduction, and Development* • Explain the importance of reproduction to the survival of the species. *Students compare and contrast sexual and asexual (e.g., yeast) reproduction.* • Investigate and describe processes by which organisms that have two parents receive a full set of genetic instructions by way of the parents' reproduction cells specifying individual traits from each parent. Offspring exhibit traits from each parent. • Illustrate an understanding that sorting and recombining of the genetic material of parents during reproduction produce the potential for variation among offspring. • Examine evidence and describe that there are minor differences among individuals from the same population or among individuals of the same species. *Explore ways in which some differences are acquired by the individual and affect only that individual, while other differences can be passed on to the individual's offspring.* *Ecosystems and Organisms* • Present evidence that species depend on one another. *Describe ways in which interactions of organisms with each other and non-living parts of their environments result in the flow of energy and matter throughout the system.* • Explore and illustrate how energy is supplied to an ecosystem primarily in the form of sunlight. *Examine evidence that plants convert light energy into stored energy which the plant, in turn, uses to carry out its life processes. Describe how this serves as the beginning of the food chain for all animals.* • Observe and illustrate the variety of ways in which plants, animals, fungi, and microorganisms interact. *Represent how matter is cycled and recycled through these interactions, and energy flows through ecosystems.* • Classify organisms according to the function they serve in a food chain (any single organism can serve each of these functions): production of food, consumption of food, or decomposition of organic matter.
Domains of Science: Earth and Space Sciences	*Interactions and Cycles in the Earth System* • Demonstrate an understanding of the internal and external structure of the planet earth. *Students might create models or diagrams that represent this structure.* • Explore and illustrate an understanding that heat flow and movement of material within the earth moves the continents, causes earthquakes and volcanic eruptions, and creates mountains and ocean basins. • Evaluate conditions under which sedimentary, igneous, and metamorphic rocks form. • Identify ways in which soil is formed by the weathering of rock and the decomposition of dead plants and animal debris. *Give examples of how soil is essential for the survival of most life on land, and is the connection between many of the living and non-living constituents of the Earth System.* • Give evidence that water in the Earth System exists naturally in all three states and water continuously circulates through the earth's crust, oceans, and air, e.g., water cycle. *Provide examples illustrating that water plays important roles in regulating Earth's climate and shaping Earth's crust.* • Demonstrate an understanding that, like all planets and stars, the Earth is approximately spherical in shape. *Use models to demonstrate how the rotation of the earth on its axis every 24 hours produces the night-and-day cycle.* • Present evidence that Earth's oceans are a reservoir of nutrients, minerals, dissolved gases, and life forms which are the major source of water vapor for the atmosphere, and store of heat transported by ocean currents greatly affect,

Domains of Science: Earth and Space Sciences (cont.)	Earth's climate. • Observe and describe evidence that local climate changes over periods of years or decades, while global climate changes much more slowly. *Give examples illustrating that climate changes over Earth's history have profoundly affected the evolution of life forms, and their present distribution.* • Examine and demonstrate evidence that weather can be studied in terms of properties of the atmosphere such as pressure, temperature, and humidity, wind speed and direction, precipitation , and amount and type of clouds. *Classify clouds by their composition, height, and type of precipitation.* • Explain that clouds reflect much of the sunlight intercepted by Earth, while at the same time returning to Earth's surface a large fraction of the far infrared energy emitted from the surface. *Describe ways in which these two effects are important elements in determining Earth's global climate.* • Examine and demonstrate evidence that the atmosphere and the oceans have a limited capacity to recycle minerals naturally. • Explore and describe that rain or snow falls and moves by gravity from higher to lower areas both on the surface and on the ground and that the natural flow region is called the watershed. *Use maps to look at topography of nearby towns and make a model of the hills and valleys that make up the local watershed.* • Investigate and illustrate ways in which human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the Earth's land , oceans, and atmosphere. *Earth's History* • Examine evidence and illustrate that the movement of the continents have had significant effects on the distribution of living things. • Examine and describe ways in which rocks, fossils, ice cores, and tree rings record events of Earth's history, documenting plate movements, volcanic eruptions, cycles of erosion and deposition, and the evolution of life. *Examine ways in which the types, number, and distributions of fossils provides information about how life and environmental conditions have changed over time.* *Earth and Space* • Observe and demonstrate that the patterns of stars in the sky stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons. • Explore and explain that telescopes magnify the appearances of some distant objects in the sky, including the Moon and the planets. *Compare the number of stars that can be seen through telescopes to the number that can be seen by the unaided eye.* • Observe and illustrate that planets change their positions against the background of stars. • Recognize and describe that the Solar System contains the central Sun, the known planets, their moons, and many asteroids, meteors, and comets that orbit the Sun. *Describe ways in which the planets differ in size, temperature, composition, surface features, and number of rings and moons. Use this information to determine those conditions that make the Earth the only planet suitable for life.* • Demonstrate evidence that the Sun is a medium-sized star located near the edge of a disk-shaped galaxy of stars, part of which can be seen as a glowing band of light that spans the sky on a very clear night. • Illustrate the universe contains many billions of galaxies, and each galaxy contains many billions of stars. • Observe and explain that Earth has a natural satellite, the Moon, that circles the planet approximately every 29 days. *Use models to describe how the motion of*

Domains of Science: Earth and Space Sciences (cont.)	*the Moon about Earth and the location of the Sun relative to Earth and its Moon are responsible for the regularly occurring patterns of Moon phases, eclipses, and tides.* • Give evidence that gravity is a force that produces an attraction between matter. Gravity pulls on or anywhere near the Earth toward the Earth's center and acts across space to the Moon in its orbit around Earth and the planets in their orbits around the Sun. • Illustrate that the sun produces energy and is the major source of heat and light for the Earth. *Examine evidence that energy received from the Sun as heat and light drives many processes on Earth's surface and in its atmosphere.*
Technology: The Design Process	• Identify and work on their own problem or one developed by a peer. *Investigate which tops might spin the longest based on design features.* • Explore and illustrate possible solutions and from these propose one solution. • Make a plan for building a device considering the limitations of the material, and including multiple views. • Evaluate designs, devices, or solutions and develop measures of quality. *Decide whether design limitations have been followed.* • Communicate the process of technological design.
Technology: Understanding and Using Technology in Society	*The nature and impact of Technology* • Explain how technological progress has been the result of cumulative work over many centuries by men and women from various cultures and races. • Describe ways that technological devices have improved the quality of life for individuals. *Choose an example of such an invention that formed the bases for a major change in the way we live our lives.* • Describe ways that technological advances have positive effects but may be accompanied by negative effects. *Technology yesterday, today, and tomorrow* • Explain how the evolution of technology led the change from an agricultural to an industrial to an information-based society. • Provide evidence that technology is growing at a faster rate today than ever before in history. • Describe ways in which innovations and inventions address human biological, physical, and psychological needs. *Choose an invention that has contributed to your happiness and find out about how it came to be.* *The tools and machines of Technology* • Document ways that a range of tools and machines, such as measuring, hand, and optical tools, are used to implement solutions to design problems. • Use tools, materials, and machines safely and effectively. *Resources of Technology* • Explain how the choice of materials depends upon their properties and characteristics and how they interact with other materials. • Use the results of material tests (i.e., hardness, tensile strength, conductivity), to suggest appropriate uses for materials. *Explain what certain metals are useful for, and give examples.* • Model the ways that multiple resources are used to develop new technologies. These include: people, information, tools and machines, materials, energy, capital, and time. *Technological areas of communication, construction, manufacturing, transportation, and power technologies* • Give examples that information can be communicated both graphically and electronically by a range of technological processes. • Explain how a manufacturing enterprise produces a product by converting raw materials into goods. *Choose a recreational product, such as sports shoes or a*

Technology: Understanding and Using Technology in Society (cont.)	*football, and research its manufacturing history.* • Identify the processes used in construction: site preparation, building, and finishing a structure. • Compare how transportation systems are devised to transport people and products on land, water, air, and in space. • Describe how power systems are used to convert and transmit mechanical, electrical, fluid, and heat energy. Describe limited (i.e., fossil fuels), unlimited (i.e., solar, gravitational), and renewable (i.e., biomass) energy sources.
Science, Technology, and Human Affairs	• Describe situations in which science, technology, and society have influenced each other in the past. • Identify the influences science and technology have on today's society. • Give examples that the decisions we make as individuals, groups, and communities can affect society and the natural environment, and that these changes are not always easy to reverse. • Recognize and demonstrate that while technology can help us to manage societal and environmental problems, it can also have a negative impact on society and on the natural world.

2.6.2 Mathematics

The following is the expectations for grades five through eight, excerpted from the 1996 Massachusetts Mathematics Curriculum Framework. This framework consists of a complete listing of all mathematical topics required to be taught between fifth and eighth grade in the Commonwealth of Massachusetts. While researching child development is vital to ensure that the workshop satisfies the emotional, social, and developmental needs of the children, such curriculum guidelines are crucial to ensuring that the academic content of the workshop for Camp REACH is appropriate for the grade level of the campers.

Topic	Learning Standards[15]
Number Sense	*Numbers and Number Relationships* • Represent and use equivalent forms of numbers, including integers, fractions, decimals, percents, exponents, and scientific notation. • Apply ratios, proportions, and percents. • Investigate and describe the relationships among fractions, decimals, and percents. • Represent numerical relationships in one- and two-dimensional graphs. *Number Systems and Number Theory* • Explain the need for numbers other than whole numbers • Know and use order relations for whole numbers, fractions, decimals, integers, and rational numbers • Use operations involving fractions, decimals, integers, and rational numbers. • Demonstrate how basic operations are related to one another. • Create and apply number theory concepts, including prime numbers, factors, and multiples. *Computation and Estimation*

Number Sense (cont.)	• Compute with whole numbers, fractions, decimals, integers, and rational numbers. • Develop, analyze, and explain procedures for computing, estimating, and solving proportions. • Select and use an appropriate method for computing among mental arithmetic, paper-and-pencil, calculator, and computer methods. • Use computation, estimation, and proportions to solve problems. • Estimate to check the reasonableness of results of computations and problems involving rational numbers.
Patterns, Relations, and Functions	*Patterns and Functions* • Describe, extend, analyze, and create a wide variety of patterns. • Describe and represent relationships with models, tables, graphs, and rules, using sentences and algebraic expressions. • Analyze functional relationships to explain how a change in one quantity results in a change in another. • Use patterns and functions to represent and solve problems. *Algebra* • Understand and apply the concepts of variable, expression, and equation. • Represent situations and number patterns with tables, graphs, verbal rules, and equations and explore the interrelationships of these representations. • Analyze tables and graphs to identify properties and relationships. • Demonstrate an ability to solve linear equations, using concrete, informal, and formal methods. • Describe the strategies used to explore inequalities and nonlinear equations. • Apply algebraic methods to solve a variety of real-world and theoretical problems. • Construct expressions or equations that model problems. • Explore and describe a variety of ways to solve equations, including hands-on activities, trial and error, and numerical analyses.
Geometry and Measurement	*Geometry* • Identify, describe, compare, and classify geometric figures. • Explore and describe the properties of points, lines, and planes. • Visualize and draw geometric figures. • Explore and describe transformations of geometric figures. • Represent and solve problems, using geometric models. • Apply geometric properties and relationships. Develop and explain the concept of π. • Develop and explain the concept of the Pythagorean theorem. *Measurement* • Select appropriate units and tools to measure to the degree of accuracy required in a particular situation. • Describe the meaning of perimeter, area, volume, angle measure, capacity, density, weight, and mass. • Develop and describe the concepts of rates and other derived and indirect measurements. • Develop and apply formulas and procedures for determining measures to solve problems.
Statistics and Probability	*Statistics* • Collect, organize, and describe data systematically. • Construct, read, and interpret tables, charts, and graphs. • Make inferences and convincing arguments that are based on data analysis. • Evaluate arguments that are based on data analysis. • Develop and explain why statistical methods are powerful aids for decision making.

Statistics and Probability (cont.)	*Probability* • Model situations by devising and carrying out experiments or simulations to determine probabilities. • Construct a sample space to determine probabilities. • Describe the power of using a probability model by comparing experimental results with mathematical expectations. • Make experiments that are based on experimental or theoretical probabilities and determine their reasonableness. • Develop and explain an appreciation for the pervasive use of probability in the real world.

2.7 Women in Science and Engineering

The scientific and engineering workplaces have been and continue to be considered by many a male domain. The male to female ratio at WPI supports this. Both the undergraduate and graduate student bodies are comprised of 78% males and 22% females.[18] This section reviews statistics regarding this perception. Programs such as Camp REACH and the others previously discussed are making great strides to break the barriers that have been raised to keep women from the technological workforce.

2.7.1 Statistical Analysis

To see the statistical discrepancy between the numbers of men and women in science and engineering, one can consult many different surveys. For example, in a study by the National Science Foundation, they found that in 1995 there were 41,471 more bachelor degrees in engineering awarded to men than women, producing almost a five to one ratio of men to women engineers.[19] In other science fields, the ratios were similar; two and a half to one for computer science degrees, four and a half to one for physics degrees, etc. The only scientific fields where women received more degrees than men did were psychology and biological science. Also, in comparison to 1985, the number of women receiving engineering and computer science degrees awarded was less in 1995, though the total number of degrees awarded for both of those fields in

1995 was significantly less. One more interesting point is that, while the number of women receiving bachelors degrees increased by over forty-seven thousand between 1985 and 1995, the number receiving degrees in mathematics, computer science, and engineering decreased during this time period

Another set of interesting statistics is compiled by AWSEM, or Advocates for Women in Science, Engineering, and Mathematics. One statistic that really stood out among the others was that girls "consistently match or surpass boys' achievements in science and mathematics".[19] We found this statistic to be disturbing because it indicates that women are not less skilled in science and mathematics than men, but they are still a minority in the professional engineering world. Also, only 16% of scientists, 10% of engineers, and 4% of computer scientists as of 1990 were women, meaning that for every 25 computer scientists, on the average only 1 was female. In addition, as computers begin to play a larger role in the fields of science and engineering, according to the United States Labor Department, 75% of tomorrow's jobs will involve the use of computers, but the enrollment in training courses related to computer skills is only 33% female.[20]

2.7.2 Societal Issues

Many advocates of women in science and engineering argue that the biggest reasons for these gender gaps are not genetic, but societal. Girls and boys are not born with the idea that only boys can be engineers. It is the societal influences that create stereotypes such as a beautiful woman can not be a physicist, for instance.

One article that presents the argument that society is to blame for the gender gap in science and engineering is an article from the winter 1998 edition of the Association for Women in Science magazine entitled, "Perceptions of Women in Physics: Is There Something Wrong with This Picture?" The article uses as an example a comic strip called "The Lockhorns". In this particular comic, a man walks dejectedly away from a beautiful woman upon finding out that she is a physics professor. As the article discusses, this points out two major stereotypes: that physicists are neither female nor attractive, and that beautiful women can not be intellectual. Many individuals probably would read those two statements and think that they are totally absurd, however those attitudes are quite prevalent in modern society, as the article goes on to describe. The particularly interesting segment of this article was the discussion of a young, attractive, intelligent woman who was interested in astrophysics. She had loved astrophysics since she was a child, but other than the author, who was her teacher at the time, everywhere she went for advice people told her she wasn't supposed to be an astrophysicist. Neither of her parents had gone to college, and her mother felt that a girl should be more worried about finding a good husband than astrophysics. Even her guidance counselor suggested that she was too attractive to be an astrophysicist. Despite the actions of the author, some other supporters, and the Society of Women Engineers, the girl eventually succumbed to the pressure to conform and wound up being impregnated by a Navy castoff that had treated her very poorly. A gifted mind wasted because of the beliefs of others around her that put so much pressure on her to be what they expected of her and not let her do what she wanted to do with her life.

One more article about how society has caused this discrepancy is an article written by AWSEM entitled "In Their Nature". This article describes a variety of reasons why girls are less encouraged to become scientists, and which people cause each particular problem. A major culprit is the parents, who are probably the most influential people on a child's opinion of what they should and should not consider for a career.[21] For example, when parents are purchasing toys for their children, they will tend to buy boys things that are more geared towards learning about mathematical and scientific skills, such as a chemistry set, while they will buy girls toys more inclined towards building social skills, like dolls. Also, like the girl in the previous story, many parents will encourage a girl to learn skills that will make her an effective caretaker of a household in the future, like sewing and cooking, while boys are more likely to be encouraged to use computers and learn about mathematical and scientific topics.

The other major group that has a large influence on girls losing interest in science and mathematics is teachers. Teachers are supposed to treat boys and girls in their classrooms with equal opportunity to experiment and learn, but studies have shown that boys are more likely to be called on in class, less likely to be chastised for speaking out in class with their opinions, and more likely to be chosen to participate in scientific demonstrations. Boys are also encouraged to use scientific equipment and computers more often than girls are, even if the girl expresses interest in using the equipment. The net result of this is the girls not having the opportunity to participate in the subject matter, and thereby losing interest.[21]

2.8 Scientific Background for Workshop

We have selected to design a robotics workshop for Camp REACH. The robot which the students will construct is designed to pick up paper clips and drop them into a cup. In order to do this, the robotic arms will have electromagnets attached to them, and the arm's movement is controlled through a hydraulic system consisting of two water-filled syringes connected by a piece of tubing. The following is the scientific background behind the main principles of physics employed in this workshop.

2.8.1 Electromagnets

Electromagnetism is defined as the study of electricity and magnetism, and the interactions between these two things.[22] When a current is passed through a conductor, it creates a charged area around that conductor known as an electric field. Along with this electric field, a magnetic field is also created around in that same area. A magnetic field can also be created by a permanent magnet, such as a refrigerator magnet. This magnetic field can be used for two purposes: to alter the path of a moving charged particle, and to magnetize a piece of metal. The particular usage of electromagnetism explored in this project is the magnetic field created by a solenoid. A solenoid is simply a wire wound around a cylinder, usually in the circular orientation. The interesting property of a solenoid related to magnetic fields is that the strength of the magnetic field increases as the density of coils on the cylinder increases. The formula for the strength of the field is:

$$B = \mu_0 n I$$

where B is the strength of the magnetic field, μ_0 is the constant $4\pi \times 10^{-7}$ Tesla * meters/Amperes, n is the number of coils per unit length, and I is the current running through the wire. From this formula, we can determine that there is a linear relationship between the number of coils per unit length and the strength of the magnetic field. This formed the basis for the experiment in our workshop.

2.8.2 Compression and Expansion

Compression is the act of making an object more compact by or as by pressure. Expansion is the act of enlarging, dilating, stretching, or making larger in volume.[23] These are the principles behind hydraulics, the system which creates motion in the robot in our workshop.

The syringe systems which move the robot rely on having a non-compressible substance inside them. The syringe systems are two syringes with their open ends connected with a piece of rubber tubing. The tubing should be attached when one syringe is full of fluid and in the fully open position, and the other syringe should have its plunger fully inserted inside the syringe. Because of this arrangement, when the full syringe is compressed, the fluid inside places pressure on the opposite plunger, causing the other syringe to open. When the plunger of the second syringe is attached to the robot and the syringe is secured in place, this allows the hydraulic syringe system to make the robot move.

In order to determine the compressibility of the fluid inside the syringe, one must study its density. If a material is very dense, the molecules are packed close together and cannot get much closer. Therefore, such materials are not compressible.

A substance's phase of matter affects its density. A substance has more energy in the liquid phase than in the solid phase, and even more in the gaseous phase. Energy is required to break intermolecular bonds, so the more energy a substance has, the more of its atoms are free to move at random. As internal energy increases, the molecules (or atoms if the substance in question is a pure element) eventually all become free and then move faster in proportion to the increased energy. When all the molecules become free to move anywhere in relation to the other molecules, the substance is completely in the gas phase, and the molecules spread to fill the container they are in. As a result, gases are very compressible because the molecules are separated from each other and can be moved closer together. Liquids and solids, however, are not compressible because the molecules are held a fixed distance from each other by intermolecular bonds.

3.0 Methodology

3.1 Research

3.1.1 Child Development and Behavior

Our research into child development and behavior was collected primarily from print sources, contrary to our web-based research into Camp REACH and other camps. A search of several area public libraries, however, failed to yield useful sources of information on children in the intended age range. Worcester State College Library was then found to have the most comprehensive collection of information on children of this age group, as the college offers a degree in elementary education, and this material is necessary for this coursework. This collection also yielded most of the sources of information on teaching methods and methods of teaching evaluation that were used to develop the literature review of these topics.

3.1.2 Camp REACH and Other Programs

To find out more about Camp REACH and other simple programs, we chose to use the web as our major research vehicle. We read the entire Camp REACH web page to better understand the philosophy of the camp and to get an idea of what kind of ideas for workshops would work well within not only the time structure of the camp but also the general tone of the two weeks. To help us to gather some ideas and to learn about other programs that we could use to compare to and derive ideas from, we started at the links page at the Camp REACH web page and branched off from there, finding a number of program that were similar in design and/or ideology to Camp REACH offered throughout the country. One of the other major "hub" sites we used to gather information about the other programs we discovered was the SciCentral Women and Minorities in Engineering page, which not only pointed us towards some other similar programs, but also to organizations like AWSEM and AWIS which offered large amounts of information about the issues of why girls would lose interest in science and what sort of things were being done to help combat the problem.

3.1.3 Curriculum

In order to ensure that the workshop does not teach over the campers' heads or teach them concepts which they have already covered in school, we set out to obtain sixth-grade curriculums for schools in Worcester County, the area in which the majority of Camp REACH campers reside.

We sent letters to the main offices of the school districts in Boylston, Northboro, Paxton, Shrewsbury, Spencer-East Brookfield, Uxbridge, and Worcester requesting copies of their curriculums. Unfortunately, none of the districts responded with their information.

We met with Joyce Gleason, science coordinator for Worcester Public Schools, to discuss the statewide science curriculum. She also supplied us with copies of the Massachusetts mathematics and science curriculums.

3.2 Brainstorming Possible Workshops

After learning about the previously existing workshops for Camp REACH and studying which fields of engineering were undergoing the steepest decline in female interest, we sat down to brainstorm some possible workshop ideas. Since we are, in terms of majors, a civil/environmental engineer, a computer scientist, and a management engineering major who has previously been both a biotechnology major and a mechanical engineering major with a concentration in materials science, we first tried to think of ideas within our own fields of expertise. Some of the ideas we came up with were water treatment, wastewater management, materials analysis, image processing workshop, algae analysis, a physics lab/experiment, and others. As we did not want to limit the workshop solely to topics with which we are familiar, we listed out all of the majors offered at WPI and tried to determine at least one project in each category. This resulted in ideas such as color-related projects, either the psychological effects of colors or optics, optical illusions, nuclear technology, fire protection engineering, robotics, and general circuitry. We also tried to think of projects we had done when we were the approximate age of the Camp REACH campers, which yielded ideas such as a hydraulic robot, a magnetic car, and bridge building.

We made preliminary cuts from the list of possible topics for various reasons. We anticipated too many parental concerns about nuclear engineering and fire protection engineering simply for safety reasons. Water treatment and wastewater management were discarded because they involved showing a camera shot of a pipe in a sewer system showing all of the deposits along the walls of the pipe, and there would most likely be a lack of interest from the girls. Physics was eliminated simply because none of us wanted to work with physics. Building a bridge was expunged because the workshop on sandcastles is civil engineering related, and we hoped to create a wide range of topics covered at Camp REACH. Similarly, algae analysis was removed because there already exists a biology related DNA-testing workshop.

The following pages are the detailed evaluation forms which we used to make a final decision between the ideas we deemed worthy of initial development.

Workshop Topic Evaluation

Workshop Title: Robotics
Area of Science/Engineering: Mechanical Engineering/Electrical Engineering

Appropriateness of Content

Prerequisite knowledge for workshop: Existence of atoms/molecules, general understanding of electricity

Degree to which prerequisite topics are covered prior to seventh grade*: 1 2 3 4 ***5***

Topics taught in workshop: hydraulics, electromagnets

Degree to which topics fit seventh grade curriculum*: 1 2 ***3*** 4 5

Overall appropriateness of content: 1 2 3 ***4*** 5

Appropriateness for Camp REACH

Facilities required: a room with enough tables so that each group has room for each member to be close enough to participate

Are these available on campus? ***Y*** N

Estimated time required: 6 hours

What variables may affect outcome of workshop: bad connections, air in the syringe system, leaky syringes, magnet cores can become permanently magnetized

To what degree is there a chance this project will fail? V. High High Avg ***Low*** V. Low

Overall appropriateness for Camp REACH: 1 2 3 ***4*** 5

Budget Feasibility

Equipment needed: batteries, wire, plastic/wood for robotic arm, syringes, tubing, screws/bolts/nails, paper clips, cups

Estimated cost per camper/group of campers: $15.00

Estimated campers per group: 3

Total estimated cost: $150.00

Overall budget feasibility: 1 2 3 4 ***5***

Overall Rating: 13 /15

*Based upon the Massachusetts Mathematics Curriculum Framework and Massachusetts Science and Technology Curriculum Framework published by The Commonwealth of Massachusetts Department of Education.

Workshop Topic Evaluation

Workshop Title: Water Quality
Area of Science/Engineering: Environmental Engineering

Appropriateness of Content

Prerequisite knowledge for workshop: existence of microorganisms, knowledge of particles in solution

Degree to which prerequisite topics are covered prior to seventh grade*: 1 ***2*** 3 4 5

Topics taught in workshop: concentration, safe levels of contaminants

Degree to which topics fit seventh grade curriculum*: 1 ***2*** 3 4 5

Overall appropriateness of content: 1 ***2*** 3 4 5

Appropriateness for Camp REACH

Facilities required: chemistry lab

Are these available on campus? ***Y*** N

Estimated time required: half day

What variables may affect outcome of workshop: if the water samples are too similar, the results will be marginal and the girls may not get the point

To what degree is there a chance this project will fail? V. High ***High*** Avg Low V. Low

Overall appropriateness for Camp REACH: 1 2 ***3*** 4 5

Budget Feasibility

Equipment needed: test tubes, testing equipment (depends on specific test we perform), water samples from different sources (ex. bottled water. tap water, pond water), microscopes

Estimated cost per camper/group of campers: unknown, but very low expense – test tubes borrowed, water free

Estimated campers per group: 2

Total estimated cost: low

Overall budget feasibility: 1 2 3 4 ***5***

Overall Rating: _10_/15

*Based upon the Massachusetts Mathematics Curriculum Framework and Massachusetts Science and Technology Curriculum Framework published by The Commonwealth of Massachusetts Department of Education.

Workshop Topic Evaluation

Workshop Title: Image Processing

Area of Science/Engineering: Computer Science

Appropriateness of Content

Prerequisite knowledge for workshop: basic computer use (familiarity with mouse operations, etc.)

Degree to which prerequisite topics are covered prior to seventh grade*: 1 2 3 4 5
Unknown – computers not mentioned in curriculum framework

Topics taught in workshop: Cut & paste graphics, use of Adobe Photoshop tools (crop photos, blur, alter colors, layering photos, etc.)

Degree to which topics fit seventh grade curriculum*: 1 2 3 4 5
again, unknown

Overall appropriateness of content: 1 2 ***3*** 4 5 (assuming most have used computers)

Appropriateness for Camp REACH

Facilities required: computer lab (preferably movie lab)

Are these available on campus? ***Y*** N

Estimated time required: 3 hours

What variables may affect outcome of workshop: stability of campus computers

To what degree is there a chance this project will fail? V. High High Avg Low ***V. Low***

Overall appropriateness for Camp REACH: 1 2 3 ***4*** 5 (already computers @ camp)

Budget Feasibility

Equipment needed: computers

Estimated cost per camper/group of campers: nothing

Estimated campers per group: 2

Total estimated cost: nothing

Overall budget feasibility: 1 2 3 4 ***5***

Overall Rating: _12_/15

*Based upon the Massachusetts Mathematics Curriculum Framework and Massachusetts Science and Technology Curriculum Framework published by The Commonwealth of Massachusetts Department of Education.

3.3 Elimination and Decision Process

We began by developing several characteristics that we considered essential to the development of a successful workshop. These criteria were designed to streamline the process of selecting a topic, and included the following items: the workshop should use a facility at WPI that the girls would not otherwise be exposed to, it should expose the girls to an area of engineering that does not have an adequate female representation. A list of topics was brainstormed (listed above) taking into account these two characteristics, and possible workshops for each topic were discussed. When a list of possible workshops was completed, a worksheet with a uniform evaluation system was completed for each workshop idea. The ability of a workshop to hold an audience's interest is difficult to predict and even more difficult to describe numerically. While this was a largely subjective process, we relied upon camp staff of previous years for input.[12] Their experiences working with girls that attended the camp in past years provided us with insight as to what areas of engineering the girls would be most interested in. It was felt that areas of biotechnology and an introduction to the Internet were already covered thoroughly in the camp, and that a workshop in an area of civil or mechanical engineering would be well received.

The first item evaluated was curriculum suitability. The Massachusetts mathematics and science curriculums were reviewed in order to determine if a suitable workshop could be developed that fit well with what the girls had just completed in the past year without being repetitious. We also hope to challenge them with some new material, but not so much that the workshop became overwhelming.

Facilities and time feasibility were also examined. Since none of the workshop ideas required facilities that could not be made available to the girls during the camp, this was not a factor in our decision. Time feasibility, or how long the workshop would take to complete, was, however, carefully examined. An interview with Camp REACH's director indicated that the girls' average attention span was about 40 minutes. With this in mind, a workshop needed to be devised that was suited to sub-topics that could be implemented in forty- to fifty-minute periods. It seemed that a workshop that incorporated experiments that introduce and develop the concepts needed for the final workshop task would be well suited to this division into forty-minute tasks.

An additional point to be evaluated was how reliable each workshop's results would be, because in past years workshops have been conducted in which definitive results depended on fair weather or other uncontrollable variables. This led to an unsatisfying experience for the girls involved, in which even groups who had completed each part of the workshop successfully failed to obtain the desired results.

The third item evaluated was budget suitability. For each workshop idea introduced, an attempt was made to make a preliminary list of materials that would be necessary in order to carry out the workshop for the number of girls in the camp. If the materials necessary to conduct the workshop seemed to fit within a budget of two to three hundred dollars, then the idea was awarded a high score in this category.

3.4 Workshop Development

Once the topic of the workshop was finalized, we began the design process for the actual kits for each robot that the campers will construct, as well as brainstorming for what experiments to have them perform prior to the robot construction, and how to schedule the workshop to best keep their attention. The following sections detail the plans for the workshop as they stand currently, however the design phase is still in progress, and these plans are subject to change.

The workshop begins with a tour of the WPI Robotics Lab. It also includes an experiment in which the campers test the strengths of various electromagnet configurations to determine what makes the most effective electromagnet. After a break for lunch, the girls construct robots, which are controlled by water-filled syringe and tubing systems. The electromagnets from the morning's experiment attach to the end of these robotic arms and are used to pick up paper clips and drop them into cups. This illustrates the ability of machines to perform work.

All information necessary for holding this workshop, such as the worksheets, a materials list, and construction instructions, can be found in Appendix II.

3.4.1 Robotic arm Design and Construction

To begin the design phase, the project team defined the capabilities that were required in the robotic arm assembly. The arm must have two ranges of motion: the entire assembly must pivot, and the top of the arm raise and lower. The motion must be caused by a set of syringes; and that the end of the arm must have a provision for the attachment of a nail or screw to facilitate the construction of an electromagnet. Once these properties were set, rough dimensions were established and material was obtained.

The material selected was a high-density polyethylene plastic. While wood was originally considered as a possibility, this plastic was chosen based on the input of WPI lab technicians who felt that this material would be better suited for the robotics project. The plastic is more stable than wood at the scale at which we were working, as imperfections in the wood would probably lead to splitting and checking of the parts. Also, this plastic could be threaded to accept a bolt if necessary.

A layout was established using the plastic sizes available, and a working prototype was constructed. This prototype was deemed acceptable by the project team once a refinement of the pivoting assembly was made, and the six assemblies necessary for the trial were constructed.

3.4.2 Materials

After some discussion and comparison to a similar project, we came to the agreement that the materials necessary for the body of the robot are a square or rectangular piece of wood (or plastic) for a stable base, two bars of wood for the movable arms of the robot, and connectors for the joints. The materials necessary for the hydraulic motion system of the robots are four syringes and two pieces of rubber or plastic tubing which will fit onto the syringes and connect them. The electromagnet construction requires the use of a battery, a switch, some sort of screw or metal rod for the magnetic part, and a length of wire sufficient to connect all the parts and wrap around the screw or rod. Also, supplementary materials not required for the construction of the robot are paper clips and paper cups.

3.4.3 Experiments

We brainstormed experiments which would demonstrate the principles of physics and engineering which are present in the robotics project, such as electromagnetism, open and closed circuits, forces, and moment arms. We collectively decided that the force and torque experiments would be the least likely to hold the girls' attention, and focused our efforts on developing an experiment about electromagnets, which will also include the concept of open and closed circuits, since they will need to turn their electromagnets on and off. This experiment will lead the girls through the process of building an electromagnet and allow them to determine the properties of an electromagnet that will make it as effective as possible.

3.4.4 Worksheets

When the design of the workshop was finalized, we designed several worksheets using either Microsoft Power Point or Corel Presentations, common programs which we have at our disposal on our own computers. All necessary background information is presented in a vocabulary list for the project. There are worksheets which detail the experiment process and provide space for the girls' to enter the results of their experiments in a manner which will make the conclusions to be made very clear. There is also a worksheet or set of worksheets detailing the process of building the robot and connecting the electromagnet and hydraulic system. There is a separate worksheet detailing the materials required for this workshop should the girls want to replicate the robot at home. The worksheets in conjunction with demonstrations during the workshop should allow for us to get the instructions through to every student, whether they are word-oriented in learning or picture-oriented.

3.5 Testing and Evaluation Methods

The robotics workshop developed was tested by ten camp alumni on Saturday, November twentieth. The respondents to a letter sent out to the list of alumni were invited to come to WPI for the day, during which a trial of the workshop was conducted. When the girls arrived in the morning, there was a brief introduction as to the purpose of the workshop, and then the material was presented, as it is to be during the camp itself.

As it is planned to include a tour of WPI's Robotics Laboratory in the actual workshop during the summer, one was arranged for the morning of the trial, thanks to the generosity of the lab director. If during Camp REACH, this tour is not possible, it is suggested that several members of WPI's FIRST (For Inspiration and Recognition of Science and Technology, an organization which hold national robotics competitions annually) team or several representatives of the robotics industry give a brief demonstration of a working robot. Contact information for the FIRST team can be found on their website. After this demonstration, the girls worked through the preliminary experiments of the workshop for the remainder of the morning, with a short break for cookies and juice in between which kept the girls happy and attentive. These experiments included learning about open and closed circuits and determining the most effective configuration of an electromagnet, as well as a demonstration showing the difference in compression between a liquid and a gas. After lunch, the final activity, the construction of the robotic arm, was conducted.

Devising a method with which to evaluate the effectiveness and educational value of this workshop is an essential part of the project. The educational content of the workshop can be analyzed rather objectively, so it is the manner in which it is communicated to its intended audience that becomes that subject of scrutiny. It must be determined how effectively the workshop developed conveys the subject matter, as well as how the workshop holds the attention of the students.

Any input from the project advisor was recorded and entered into the results of the trial, in the manner of direct observation, as will the team's observations during the trial. The use of a recording device, such as a video cassette recorder, while providing a permanent record of the workshop trial, would introduce the concern that the students' behavior would be modified by the presence of such a device. Also, recording these minors may be considered a violation of privacy, and would require clearance from every participant's parents or guardian.

Student opinion was the chief indicator of success. An open forum discussion was conducted, as well as a questionnaire distributed in order to obtain the advantages of both. Since research indicates that an impartial third party is necessary to obtain unbiased opinions from the students, one of us refrained from participating in the presentation of the workshop material. This person occupied himself solely with observing the students during the workshop, as well as administering the questionnaire and moderating any forum for discussion. During the open discussion, the two teaching members of the team left the room so as to facilitate open discussion. If the campers were dissatisfied with the workshop, it is important to know if it is due to the workshop content or the inexperienced teaching techniques used.

We recognize the need for both objective questions and short answer questions. We addressed this need by asking numerically scaled objective questions on the questionnaire and obtaining responses to open ended questions during the open discussion forum.

3.6 Refinement

After the trial of the workshop was conducted, we were left with a volume of feedback in the form of colleagues' observations, notes from the forum discussion conducted by the third group member as well as the questionnaires filled out by the girls. We performed a full statistical analysis in order to obtain an accurate evaluation of our performance and workshop content. The results of such analysis were then applied to the workshop to make any feasible modifications directly suggested or derived from comments made in any of the feedback.

The modifications that were made as a result of the girls' feedback were the revision of the directions for assembling the robot and the addition of compression experiment rather than a demonstration. These changes are reflected in the packet of handouts for the workshop. Also, we have learned that the nails we were using for electromagnet cores quickly became magnetized, thus affecting the performance of the robots. We suggest that when the workshop is used in the actual camp, the magnet core be tested ahead of time in order to find a nail or screw which will not become permanently magnetized so readily. As it is impossible to predict the resources that will be available to any person who may wish to conduct this workshop, at best we can make suggestions as to the properties required for the core. The core should be a nail, screw, or bolt which is not pre-magnetized and should contain iron in its composition so as to be able to be magnetic.

4.0 Evaluation Analysis

4.1 Trial notes

The following is the notes that were taken by the observing member of the team during the trial of the workshop. The only change that has been made to these notes from their original form is that they have been checked for spelling errors.

Robotics lab tour:

Manufacturing Techniques-Hands-On Training
Girls showed some mild interest, but in general they were kind of bored at the beginning part.
Interest in manufacturing: not that much, no one asked question during this part.

All have computers at home

Computer technology: some interested to learn the terminology, others a little bored

Lost interest a bit learning about the school and what classes are offered, etc.

Learning about different types of machines was interesting--practical uses of robots, etc.

Robotic arm welder--did a little dance, Cournoyer showed them an example program written by his daughter, they seemed a bit intimidated seeing the large arm move without anyone "controlling" it at first, but once he explained it was a computer program they were impressed.

Interested to see the works of the students, and what they have done (golf robot, ski project, robot welder)

Computer stuff--a couple interested, others kind of disinterested

Circuit board--crowded in to see

Demonstration of light placing program--all moved so they could see, interest in at least watching that

Chernobyl incident--real life example, they seemed to be interested, one actually spoke up for the first time

A couple interested to at least peek at the C++ code behind the workings of the light placing robot, most didn't even look (sigh, us poor CS's)

Robot competition story--they chuckled a bit at the thought of other robots beating up the robot as part of a competition

Story of Dean Kaven--Interest, some seemed to enjoy the thought of coming to school, deciding it wasn't for you, but instead designing something with a real-life application and making money

Learning about robot building for this year--interested, maybe some thought about trying that out when they are in high school??

Driving the robot down the aisle--obviously the most fun part, ended the tour on a high point, something we should definitely try and do with our workshop if at all possible

Demonstration:

Should remember to ask them about what they know, instead of the lecture format

Did something with electromagnets at Camp Reach--used them to run a motor

Seems to me like three is too big for this part at least--only so much that can be done at one time, so some are left playing with staples to kill the time, etc. The usual group dynamic of leader/watcher happened a couple of times, so we should make a conscious effort to make sure all parts of the group are experimenting and learning.

Learned somewhat about circuits in fourth grade but very basic--no others have learned about it yet

One group commented that using fingers was kind of difficult--perhaps provide pliers in the future?

Make sure nails don't get pre-magnetized in testing next time---lowers the impact, could possibly warp the results of the experiment if something that has five coils can hold as many as something that has thirty since it is pre-magnetized.

Definitely seems that the two person groups are more involved, people in the three person groups are just sitting and watching far too much while the strongest personality in the group basically take command and do everything.

Six hours WAY too much time. This could be done with similar effectiveness in probably two less hours.
1 hour-tour
30--electromagnets
--robot building

Possibly introduce a resistor--not sure about the theory but would possibly prevent the batteries from becoming basically a first-degree burn waiting to happen. Another possibility is multiple batteries so they can alternate--basically prevent sitting and waiting for battery to cool off.

Mike agrees that two is a better number.

Jo feels good about her speaking today.

Perhaps do individual activities for the electromagnetic stuff. Materials wouldn't be that expensive and making each one do it themselves would most likely be more rewarding that having one work and someone else basically write down the data.

After about 25 minutes, groups started to finish--maybe we need to encourage them to experiment on their own. If we give each person an individual kit, then maybe they could try combining them to increase the power, though I'm not sure the magnet theory concurs.

Started to discuss water versus air, one group seemed to understand very basically why water is better than air.

I think we need to use fresh nails, CLEARLY state that a new nail should be used for each experiment, because the coils/power relationship is becoming blurred because of the pre-magnetization.

People seemed surprised about the results, because they didn't get results that corresponded to the experimental theory behind it.

People were interested in keeping the robots--will send home, how will they deal with the more specialized molding?

Air vs. water--should be about 15 minutes probably

They knew the definition of hydraulic, force, need to tighten up this part and exactly what we want to talk about.

They began losing interest, and I almost got the impression that at least a couple of them stopped taking it seriously a bit at this point. A teacher doing this would probably keep tighter reins on it, though talking wasn't rampant, it was there. It shouldn't be military school or anything like that, but should try and keep some discipline.

They definitely enjoyed the electromagnet part better than this part, learning the chemical theory behind it not too interesting--perhaps design an experiment to go with this??

Passing the two examples around was interesting for about 30 seconds, but something that would involve everyone simultaneously would definitely be better.

Possible experiment--have them trying to lift different weights by compressing the syringes, have them compare like water, air, and maybe another liquid or two. Also, maybe use the term "density" in the context of not just comparing air and water, but also water and another liquid.

Another possible experiment--build miniature "cannons", let them test which compressor fires better, have them try to hit a target area perhaps, let them experiment with use of air, water, other liquids, combination, etc.

Suggestion: short attention spans, need to keep them busy
robotic lab tour-they really enjoyed driving the car

Robot building:

Almost all of them wanted to try to do it themselves without us explaining how. Explaining about real life engineers and relating it to building it themselves seems like a good thing to keep in the final workshop.

Reword directions if we're going to let them experiment--specify which part we are referring to for each part, so they understand more what to do. The directions were "confusing".

Perhaps pictures of what each part we refer to by name is?

Also, we should sand the plastic, make it smooth, uniform.

One wants bigger groups for this part, more opinions. Perhaps individual during the experiment part, and then move into larger groups for this part.

We should definitely add pictures to match the technical names, unless you want everyone asking what an I-bolt, etc, is. Perhaps at the beginning we go through and tell them what the name of each part is so they know.

The instructions on the syringe and the pivot are unclear. We should try giving this to some people and having them try to build it based on our directions.

9th grader had no trouble with the pivot, everyone else had some difficulty.

Once group 2 got the basic arm assembly working, they thought it was "cool". Good sign?

The stop screw in the base plate should be clearly indicated as solely a stop screw and not anything that needs to have something attached to it.

One epoxy failure-had spare. Find better means of attaching syringes or make sure have plenty of extra ones.

If we're going to let them build it basically by themselves, we should try and make the pivot assembly a lot tougher, so it won't break.

At some points, it seemed like two was too few, at some points three was too many. Probably go with three and accept that at some points there might not be enough for all three at the same time. Also, maybe make some steps so they can be done simultaneously.

Should probably illustrate the correct method for filling the syringe, because filling them both is important and perhaps not obvious at the moment.

Also, maybe more than one water container because, in the camp, there will be more people and having just one place is inconvenient if they all finish around the same time.

Group 1 thought the arm was "awesome". We didn't totally screw up! Woohoo!

Everyone seems to think that the working product is quite cool. We just need to make the process of building it tighter and prevent loss of interest.

Also, making the electromagnet an actual part of the robot would probably help, rather than it basically being a quick tack-on to the arm.

Building process took about 35 minutes total to get everything working. If we do an explanation at the beginning it might stretch to 45, but not sure.

General sentiment about the robot was it was cool, the major problem at the moment is dealing with the on/off function of the electromagnet and getting a nail that doesn't instantly become a magnet.

Group one seemed to accept the magnetization of the nail and try to deal with that instead of complaining that it didn't work like it was supposed to in the directions. Good sign? We can hope all the girls at the camp will be like that, thought it's obviously not a certainty they will be.

Perhaps add a competition element to the end, but we should get a more dependable nail that won't instantly become magnetized itself and also need to improve the reliability of the robot itself.

One suggested the race, some seemed possibly excited about it, and others were hesitant because they didn't have confidence in their robot.

Maybe if we can't find a solution to prevent the batteries from heating up, we should wrap them in something that won't heat up.

Group 3 thought that it was really easy to assemble, and that when it is assembled it is neat.
Perhaps add some variations so groups don't get stuck. They said that the directions should a little more specific, but not too much so that there is still an element of experimentation and discovery. They would be interested it perhaps having a longer

workshop. Could we add on to this, or would that be a separate project? They didn't think that it was too simple, and it was neat to see. One group said that three was too big, because someone would get left in the corner, so there was a general consensus that two was the right group size, because then there's enough to do, but not too much. I think 45 minutes is the right amount of time to build and use the robots.

Robotics tour: they wanted more hands on stuff, less standing and listening. Ask Cournoyer to do less talking, more demonstration, tour definitely sparked interest, gave them background, gave them an incentive to build them, otherwise wouldn't see the purpose behind the building process

Electromagnetic: more visual, less blah blah blah, two people a group appropriate, do something about the battery heating up, maybe talk about the basics of electricity, how it powers things, but don't be too specific

Compression: less talk, they like the cannon idea (surprise surprise), they were definitely bored during this part

Robot: Make the directions more specific, less specific help, let them experiment and learn themselves, include pictures of specific parts, because they can't differentiate between screws. They liked the final product after learning about the real life uses for robots, but if they hadn't learned about that they wouldn't have been as interested. They said it would be boring without the tour. Doh!

Also, one girl suggested that we add some variety to the robot designs.

4.2 Questionnaires

The following ten pages are copies of the actual questionnaires that the girls who attended the workshop trial filled out.

Workshop Evaluation Form

Please rate each item on a scale of 1-5 with 5 being the most positive and 1 being least positive.

	1	2	3	4	5
Was the material in this workshop interesting?			X		
Were you interested in robotics prior to this workshop?				X	
Are you more interested in robotics now?					X
How much did the tour of the lab spark your interest?					X
How much did the experiments spark your interest?				X	
How much did building the robot spark your interest?				X	
Was the material at an appropriate seventh-grade level?			X		
How appropriate were the facilities for the workshop?					X
Would you be interested in learning more about robots?					X
Do you feel this workshop would be a positive part of the Camp REACH experience?					X
Do you feel the ideas in this workshop were communicated well by the instructors?				X	
Did you find the definitions in your packet helpful?					X
Did you feel comfortable participating in the group discussion part of the evaluation?			X		

Workshop Evaluation Form

Please rate each item on a scale of 1-5 with 5 being the most positive and 1 being least positive.

	1	2	3	4	5
Was the material in this workshop interesting?					✓
Were you interested in robotics prior to this workshop?		✓			
Are you more interested in robotics now?				✓	
How much did the tour of the lab spark your interest?					✓
How much did the experiments spark your interest?			✓		
How much did building the robot spark your interest?					✓
Was the material at an appropriate seventh-grade level?				✓	
How appropriate were the facilities for the workshop?					✓
Would you be interested in learning more about robots?				✓	
Do you feel this workshop would be a positive part of the Camp REACH experience?					
Do you feel the ideas in this workshop were communicated well by the instructors?					✓
Did you find the definitions in your packet helpful?					✓
Did you feel comfortable participating in the group discussion part of the evaluation?					✓

this was a wonderful workshop

to ✓

- especially when they asked us what certain things were

Charisse ← *not me* *46 of 65*

Workshop Evaluation Form

Please rate each item on a scale of 1-5 with 5 being the most positive and 1 being least positive.

	1	2	3	4	5
Was the material in this workshop interesting?				X	
Were you interested in robotics prior to this workshop?		X			
Are you more interested in robotics now?					X
How much did the tour of the lab spark your interest?					X
How much did the experiments spark your interest?		X		~~X~~ *no*	
How much did building the robot spark your interest?					X
Was the material at an appropriate seventh-grade level?			X		
How appropriate were the facilities for the workshop?			X		
Would you be interested in learning more about robots?					X
Do you feel this workshop would be a positive part of the Camp REACH experience?					X
Do you feel the ideas in this workshop were communicated well by the instructors?			X		
Did you find the definitions in your packet helpful?		X			
Did you feel comfortable participating in the group discussion part of the evaluation?				X	
		6	*9*	*8*	*25*

25
9
8
6
46

1999 camper

Workshop Evaluation Form

Please rate each item on a scale of 1-5 with 5 being the most positive and 1 being least positive.

	1	2	3	4	5
Was the material in this workshop interesting?				✓	
Were you interested in robotics prior to this workshop?			✓		
Are you more interested in robotics now?					✓
How much did the tour of the lab spark your interest?			✓		
How much did the experiments spark your interest?				✓	
How much did building the robot spark your interest?					✓
Was the material at an appropriate seventh-grade level?					✓
How appropriate were the facilities for the workshop?				✓	
Would you be interested in learning more about robots?					✓
Do you feel this workshop would be a positive part of the Camp REACH experience?					✓
Do you feel the ideas in this workshop were communicated well by the instructors?				✓	
Did you find the definitions in your packet helpful?			✓		
Did you feel comfortable participating in the group discussion part of the evaluation?					✓

1999

Workshop Evaluation Form

Please rate each item on a scale of 1-5 with 5 being the most positive and 1 being least positive.

	1	2	3	4	5
Was the material in this workshop interesting?		✓			
Were you interested in robotics prior to this workshop?			✓		
Are you more interested in robotics now?					✓
How much did the tour of the lab spark your interest?				✓	
How much did the experiments spark your interest?					✓
How much did building the robot spark your interest?					✓
Was the material at an appropriate seventh-grade level?					✓
How appropriate were the facilities for the workshop?				✓	
Would you be interested in learning more about robots?					✓
Do you feel this workshop would be a positive part of the Camp REACH experience?					✓
Do you feel the ideas in this workshop were communicated well by the instructors?					✓
Did you find the definitions in your packet helpful?				✓	
Did you feel comfortable participating in the group discussion part of the evaluation?					✓

(the driving the robot was interesting)

Workshop Evaluation Form

Please rate each item on a scale of 1-5 with 5 being the most positive and 1 being least positive.

	1	2	3	4	5
Was the material in this workshop interesting?				✓	
Were you interested in robotics prior to this workshop?		✓			
Are you more interested in robotics now?				✓	
How much did the tour of the lab spark your interest?				✓	
How much did the experiments spark your interest?		✓			
How much did building the robot spark your interest?				✓	
Was the material at an appropriate seventh-grade level?			✓		
How appropriate were the facilities for the workshop?			✓		
Would you be interested in learning more about robots?				✓	
Do you feel this workshop would be a positive part of the Camp REACH experience?					✓
Do you feel the ideas in this workshop were communicated well by the instructors?				✓	
Did you find the definitions in your packet helpful?		✓			
Did you feel comfortable participating in the group discussion part of the evaluation?					✓

Workshop Evaluation Form

Please rate each item on a scale of 1-5 with 5 being the most positive and 1 being least positive.

	1	2	3	4	5
Was the material in this workshop interesting?				☺	
Were you interested in robotics prior to this workshop?		☺			
Are you more interested in robotics now?			☺		
How much did the tour of the lab spark your interest?	☺				
How much did the experiments spark your interest?			☺		
How much did building the robot spark your interest?				☺	
Was the material at an appropriate seventh-grade level?				☺	
How appropriate were the facilities for the workshop?				☺	
Would you be interested in learning more about robots?			☺		
Do you feel this workshop would be a positive part of the Camp REACH experience?			☺		
Do you feel the ideas in this workshop were communicated well by the instructors?		☺			
Did you find the definitions in your packet helpful?		☺			
Did you feel comfortable participating in the group discussion part of the evaluation?				☺	

Workshop Evaluation Form

99

Please rate each item on a scale of 1-5 with 5 being the most positive and 1 being least positive.

	1	2	3	4	5
Was the material in this workshop interesting?				X	
Were you interested in robotics prior to this workshop?			X		
Are you more interested in robotics now?					X
How much did the tour of the lab spark your interest?			X		
How much did the experiments spark your interest?					X
How much did building the robot spark your interest?					X
Was the material at an appropriate seventh-grade level?					X
How appropriate were the facilities for the workshop?					X
Would you be interested in learning more about robots?					X
Do you feel this workshop would be a positive part of the Camp REACH experience?					X
Do you feel the ideas in this workshop were communicated well by the instructors?			X		
Did you find the definitions in your packet helpful?	X				
Did you feel comfortable participating in the group discussion part of the evaluation?					X

Workshop Evaluation Form

Please rate each item on a scale of 1-5 with 5 being the most positive and 1 being least positive.

	1	2	3	4	5
Was the material in this workshop interesting?				✓	
Were you interested in robotics prior to this workshop?				✓	
Are you more interested in robotics now?				✓	
How much did the tour of the lab spark your interest?			✓		
How much did the experiments spark your interest?					✓
How much did building the robot spark your interest?					✓
Was the material at an appropriate seventh-grade level?				✓	
How appropriate were the facilities for the workshop?				✓	
Would you be interested in learning more about robots?				✓	
Do you feel this workshop would be a positive part of the Camp REACH experience?					✓
Do you feel the ideas in this workshop were communicated well by the instructors?				✓	
Did you find the definitions in your packet helpful?		✓			
Did you feel comfortable participating in the group discussion part of the evaluation?				✓	

Workshop Evaluation Form

Please rate each item on a scale of 1-5 with 5 being the most positive and 1 being least positive.

	1	2	3	4	5
Was the material in this workshop interesting?				✓	
Were you interested in robotics prior to this workshop?		✓			
Are you more interested in robotics now?			✓		
How much did the tour of the lab spark your interest?			✓		
How much did the experiments spark your interest?				✓	
How much did building the robot spark your interest?					✓
Was the material at an appropriate seventh-grade level?					✓
How appropriate were the facilities for the workshop?				✓	
Would you be interested in learning more about robots?			✓		
Do you feel this workshop would be a positive part of the Camp REACH experience?					✓
Do you feel the ideas in this workshop were communicated well by the instructors?				✓	
Did you find the definitions in your packet helpful?					✓
Did you feel comfortable participating in the group discussion part of the evaluation?				✓	

4.3 Statistical Analysis

The questionnaire provided at the workshop consisted of thirteen questions which were to be rated on a scale of one to five, with one being the most negative response and five the most positive. Out of a possible total of 650 points, the workshop received 514. This gives the workshop a score of 79% approval from the students who participated in the trial. The mean response overall was 3.95, the median was four, and the mode was five. The breakdown of each question is as follows:

1. Was the material in this workshop interesting?

   Responses: 2,3,4,4,4,4,4,4,4,5

   Mean: 3.8

   Median: 4

   Mode: 4

2. Were you interested in robotics prior to the workshop?

   Responses: 2,2,2,2,2,3,3,3,4,4

   Mean: 2.7

   Median: 2.5

   Mode: 2

3. Are you more interested in robotics now?

   Responses: 3,3,4,4,4,5,5,5,5,5

   Mean: 4.3

   Median: 4.5

   Mode: 5

4. How much did the tour of the robotics lab spark your interest?

   Responses: 1,3,3,3,3,4,4,5,5,5

   Mean: 3.6

   Median: 3.5

   Mode: 3

5. How much did the experiments spark your interest?

   Responses: 2,2,3,3,4,4,4,5,5,5

   Mean: 3.7

   Median: 4

   Mode: 4.5

6. How much did building the robot spark your interest?

   Responses: 4,4,4,5,5,5,5,5,5,5

   Mean: 4.7

   Median: 5

   Mode: 5

7. Was the material at an appropriate seventh-grade level?

   Responses: 3,3,3,4,4,4,5,5,5,5

   Mean: 4.1

   Median: 4

   Mode: 5

8. How appropriate were the facilities for the workshop?

   Responses: 3,3,4,4,4,4,4,5,5,5

   Mean: 4.1

Median: 4

Mode: 4

9. Would you be interested in learning more about robots?

    Responses: 3,3,4,4,4,5,5,5,5,5

    Mean: 4.3

    Median: 4.5

    Mode: 5

10. Do you feel this workshop would be a positive part of the Camp REACH experience?

    Responses: 3,5,5,5,5,5,5,5,5,5

    Mean: 4.8

    Median: 5

    Mode: 5

11. Do you feel the ideas in the workshop were communicated well by the instructors?

    Responses: 2,3,3,4,4,4,4,4,5,5

    Mean: 3.8

    Median: 4

    Mode: 4

12. Did you find the definitions in your packet helpful?

    Responses: 1,2,2,2,2,3,4,5,5,5

    Mean: 3.1

    Median: 2.5

    Mode: 2

13. Did you feel comfortable participating in the group discussion part of the evaluation?

Responses: 3,4,4,4,4,5,5,5,5,5

Mean: 4.4

Median: 4.5

Mode: 5

4.4 Comparison to Previous Camp REACH Workshop IQP's

As we previously mentioned in the methodology section, we are not the first group to design and implement a workshop for Camp Reach as an Interactive Qualifying Project. To provide an extra evaluation reference for our project, we decided to compare our workshop to the positive and negative aspects of these prior student projects. We thought this would give us the chance to notice not only what we accomplished, but also to see what other groups did well that we were weak in, so we could make improvements that may not have come up during the test run.

4.4.1 Price of Heating Your Home

The first project we compared ours to was The Price of Heating Your Home, by Michael Burzycki and Timothy Webb. The workshop they designed involved building a miniature "house", then wiring a circuit board and connecting it to a computer. The computer had a program written specifically for the workshop running on it, and the girls would test different insulators by using the program to create a test environment and then examining the test data.

This group did notice faults within their workshop during the test run. First, they noticed they were having trouble keeping girls interested through the entire workshop, especially during the lecture part of the workshop. In our workshop, we tried to avoid this by giving the girls very basic explanations of the scientific concepts behind our workshop, and answering any additional questions the girls may have. Second, the group was concerned about not having anything for the girls to take home from the workshop so they would remember it. We also considered this, but the materials involved in building a new robot are a rather large investment of not only supplies but also time. Therefore, we decided we would give the girls a set of plans for the robot to take home with them in case they wanted to try and recreate the robot again. The other major negative this group noticed within their project was they had too much to do in the time frames they had allocated. In our project, we tried to allocate extra time for each of the activities, so that if a group is having difficulty or if the girls are really enjoying the current activity there is plenty of time to make sure everyone is where they need to be.

This group's workshop also used a number of positive ideas in their workshop design and implementation as well. One thing they did was they made their workshop rather challenging, though certainly not impossible. Though this produced a certain amount of frustration among the girls when things were very difficult, the girls also got a very good feeling once they were able to get the problem solved, and they got to experience the fruits of their labor. We thought about making our workshop very challenging, but we decided that we wanted to avoid causing the girls any major frustrations, so we kept it simple. Another positive of this group's workshop was the incorporation of several different fields of engineering into the project. This group was able to combine civil engineering, electrical engineering, material science, and computer science into one workshop. Our group definitely though this was an excellent idea, which is why we tried to do the same thing in ours by using electromagnetism combined with robotics.[2]

4.4.2 Forensic Science Discovery Workshop

The second project we compared ours to was Forensic Science Discovery Workshop, by Kimberlee Mix and Kerri O'Connor. The workshop involves the creation of a fictitious crime. The girls go to the "crime scene", collect evidence, and then perform a series of chemical and biological experiments to try and determine who the criminal is.

One major aspect that stuck out about this project was that the group really ran into no difficulties during their test process. The only minor problem they had was the fingerprint gathering did not work out during the actual test run, though they were able to modify it so the girls could enjoy at least moderate success during this part of the workshop. We strove to have our workshop run this smoothly, and while it did not, we feel we learned a lot from the successes and failures within our test run.

A big part of what makes this group's workshop a good model is the fact that it takes advantage of facilities that are unique to WPI. The girls do a number of chemical tests using actual scientific techniques like gas chromatography, using the labs in Goddard Hall. Using a facility unique to WPI was definitely a major goal for our workshop, which is why we have a tour of the robotics lab at the beginning of our workshop. Another positive aspect of this group's workshop was that all the activities were done in groups, but there was still enough work for everyone in the group to do. During our testing, we noticed that in the group of three there seemed to be a member sitting doing nothing, while in all the groups of two there was enough work to go around, so we decided to make two the set group size for our workshop. The third successful part of this group's workshop was that almost all of the activities succeeded. In the other workshops, the designs were very ambitious, but sometimes this would result in the girls having a lot of frustration, and losing interest in the workshop. In the forensic workshop, there was very little of this, as almost every test produced useful results. In our workshop, we endeavored to create a workshop where the girls would always have a working robot at the end.[3]

4.4.3 Summer Radio Workshop Design for Camp

The final project we used for comparison was Summer Radio Workshop Design for Camp by Linda Cappuccia, Kristomus Iwo, and Nilufer Saltuk. For their workshop they had the girls split into groups and, after explaining the basics of radio, had the girls build their own radios out of pre-bought kits.[24]

One problem this group noticed was that they thought that if the girls had seen a pre-made radio, they would have found putting it together much easier. We dealt with the same issue with our workshop. However, we decided that if the girls saw a pre-made product, they would be tempted to simply copy it rather than read the directions and try to understand them. Also, this group ran into the problem that the materials did not always work for the project. For example, during their test run, one of the radios that were constructed produced a sound that was too quiet for the girls to hear.

A quality of this workshop that we wanted to emulate in ours was that the girls got a lot of hands-on experience. In this group's workshop the girls got the opportunity to assemble a relatively complex electronic device with their own wits and occasional help from the instructors. We tried to do that within our own workshop by just giving the girls a list of directions and the necessary parts and letting them try to build the robots themselves. Another positive from this workshop was they used a pre and post evaluation sheet for the girls, which allowed them to gauge how much their workshop changed the girls opinion. We only used a post-evaluation in our test run, but we would definitely consider adding a pre-evaluation in the future.

5.0 Logistics

5.1 Budget

The following budget is based on the costs incurred in our trial workshop. Obviously, these prices are variable depending on where the merchandise is purchased, and the current price of the goods at the time the workshop occurs. Also, the availability of scrap materials from different on-campus facilities may affect the total cost of the workshop. The estimated costs below are per kit, so the final cost will be fifteen times that amount, as the trial run determined that two-person groups provide for the most enjoyable and educational experience.

Material	Estimated Cost
Plastic	$3.33
Screws, Bolts, and Nuts	$0.75
Syringes	$4.50
Battery	$2.50
Battery Connector	$0.28
Wire	$0.50
Magnet Core	$0.10
Total	**$11.96**

By this cost analysis, the final cost of the camp workshop would be $179.40, assuming the average of thirty girls attend the camp.

We will also incur costs for the production of the handouts for the campers. We anticipate approximately eight pages of handouts per camper, at an assumed average of five cents per copy, the worksheets for the camp would cost $12.00 assuming thirty girls attend the camp.

5.2 Timeline

The following is the approximate timeline used for A-term and the proposed schedule of events for B-term. This timeline was designed at the onset of the project and the exact dates may not, in some cases, precisely reflect the stage of the project we were at on any given day, although the timeline is never more than a day off from real life occurrences at any point.

A-Term

Aug. 26-Sept. 17	Set system for documenting research, look at old Interactive Qualifying Projects, research both child development and school curriculums.
Sept. 18-Sept. 24	Review findings, combine information to brainstorm possible topic ideas, set criteria for evaluating ideas
Sept. 25-Oct. 1	Finalize decision on workshop topic, begin setting experiments/activities
Oct. 2-Oct. 14	Write drafts, revise, and finalize progress report

B-Term

Oct. 27-Nov. 10	Design specific activities, plan for materials needed, etc.
Nov. 11-Nov. 17	Develop handouts/worksheets/apparatus for activities
Nov.18-Nov. 21	Prepare facilities for testing and test workshop
Nov. 22-Nov. 28	Review feedback/refine workshop/adjust handouts if necessary

6.0 Conclusions

Our principle goal for this project was to create an effective, affordable, and enjoyable workshop that could be used as a part of Camp REACH. In our work on this project, we learned about the philosophies behind Camp REACH, about effective teaching methods, and about evaluation techniques. Using this knowledge, we designed a workshop that uses multiple disciplines of engineering. After our design was complete, we tested our workshop by conducting a trail run with ten Camp REACH alumni. Using their feedback, we altered the workshop into an experience we feel would be a beneficial part of Camp REACH.

In terms of achieving our goals for this project, we feel that we were able to achieve almost everything we planned for at the beginning of the project. Based on the evaluations we received from the nine girls that participated in our trial of the workshop, we feel that we did produce a workshop that was both effective and enjoyable. The materials used are not expensive, making the workshop a viable addition financially to Camp REACH. And, in doing our workshop, we learned a lot, especially about the issues involving women and engineering, and how it is a problem that should be addressed.

For future groups that may design workshops like ours for Camp REACH, we advise you to remember that the girls who will be doing these workshops are young, and have short attention spans. A workshop with lots of hands-on work and as little lecturing and dictation as possible is very likely to be well received by the girls, as we learned from reading and hearing their feedback. But, remember that your principle goal in this is to educate and stimulate the girls' interest in science and engineering.

Endnotes

[1] Gagne, Stephanie, Robert Grelotti, Chi-Yan Tsang, and Elisabeth Wagner. Design of an Engineering Camp for Girls. 96C025I. 1996. Demtery, C.

[2] Camp REACH Program Highlights. Worcester Polytechnic Institute. 4 September 1999 http://www.wpi.edu/~reach/program.html.

[3] Burzycki, Michael A and Timothy Richard Webb. The Price of Heating Your Home. 97CO33I. 1997. Demetry, C.

[4] Mix, Kimberlee Sue and Kerri O'Connor. Forensic Science Discovery Workshop. 97CO55I. 1997. Demetry. C.

[5] Personal communiction. Nicoletti, Denise. September 1999.

[6] 1997 Camp REACH Discovery Workshops. Worcester Polytechnic Institute. 4 September 1999. http://www.wpi.edu/~reach/97workshops.html.

[7] Women in Technology. Vermont Technical College. June 1999. 5 September 1999. http://www.vtc.vsc.edu/wit/index.htm.

[8] Women in Science and Engineering Programs: K-12 Programs. University of Michigan. 6 September 1999. <http://www.umich.edu/~umwise/k12.htm>.

[9] Role Model Project for Girls. WomensWork. 5 September 1999. http://www.womenswork.org/girls/about.html

[10] Human Development: A Social Work Perspective. Specht, Riva and Craig, Grace J. New Jersey: Prentice Hall, 1987.

[11] Who's Easier: Boys or Girls?. Stich, Julia. *Parents*, January 1998: pp. 70-74.

[12] Children's Friendships. Rubin, Zick. Cambridge, MA: Harvard University Press, 1980.

[13] Personal Interview. Adams, Amy A. 21 September 1999.

[14] Teaching Effectiveness: Its Meaning, Assessment, and Improvement. Mohan, Madan and Ronald E. Hull. New Jersey: Educational Technology Publications, 1975.

[15] Mathematics Curriculum Framework. Massachusetts Department of Education. 1996.

[16]. The Recognition and Evaluation of Teaching. Eble, Kenneth E. Salt Lake City:Project To Improve College Teaching, 1970

[17] Science and Technology Curriculum Framework. Massachusetts Department of Education. 1996.

[18] Discover WPI!: A Statistical Profile of the University. Worcester Polytechnic Institute. 5 March 1999. 7 October 1999. http://www.wpi.edu/About/Intro/introstat.html.

[19] In Their Nature: Compelling Reasons to Engage Girls in Science. Advocates for Women in Science, Engineering, and Mathematics. 10 September 1999. http://www.awsem.org/gnature.html.

[20] AWSEM Gender Equality: Facts in Brief. Advocates for Women in Science, Engineering, and Mathematics. 10 September 1999. http://www.awsem.org/gender.html.

[21] AWSEM Homepage. Advocates for Women in Science, Engineering, and Mathematics. 10 September 1999. http://www.awsem.org.

[22] [22] University Physics, Ninth Edition. Freedman, Roger A. and Hugh D. Young. New York: Addison-Wesley Publishing Company, 1996.

[23] Webster's New World College Dictionary, Third Edition. New York: Macmillan general Reference, 1986.

[24] Cappuccia, Linda, Kristomos Adisurya Iwo, and Nilufer Emineand Saltuk. Summer Radio Workshop Design for Camp. 96E013I. 1996. Nicoletti, D.

Appendix – Guide for the Conductor of the Robotics Workshop

The following text shall serve as a complete guide for anyone who wished to replicate the robotics workshop we have designed, be it for Camp REACH or other programs.

1. Who?

This workshop has been designed with an intended audience of girls entering seventh grade. The planning for appropriate content for the grade-level was done with respect to the Massachusetts curriculum. If this workshop is being utilized outside of the Commonwealth of Massachusetts, please refer to section 2.6 to compare your curriculum to that of Massachusetts.

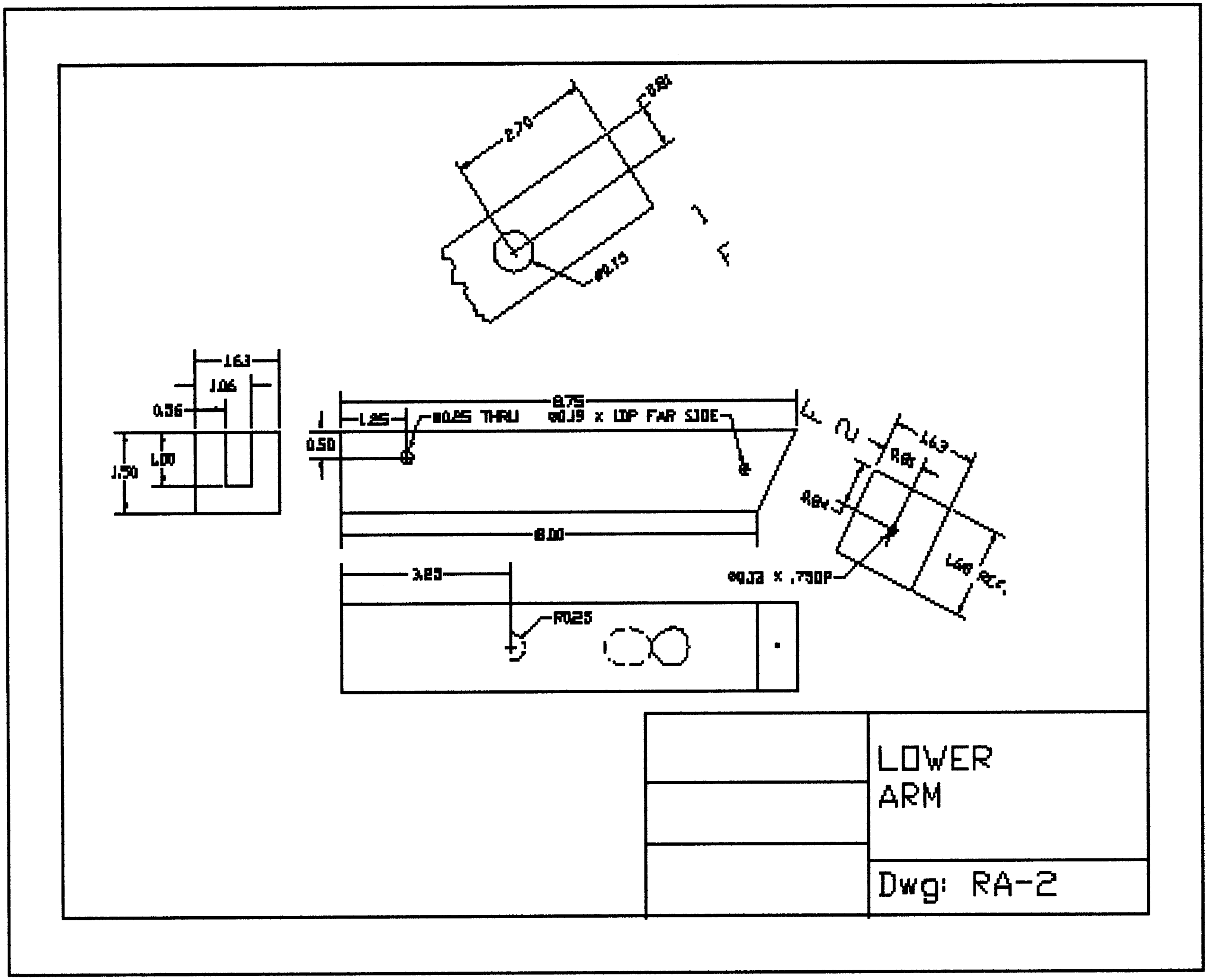
2. What?

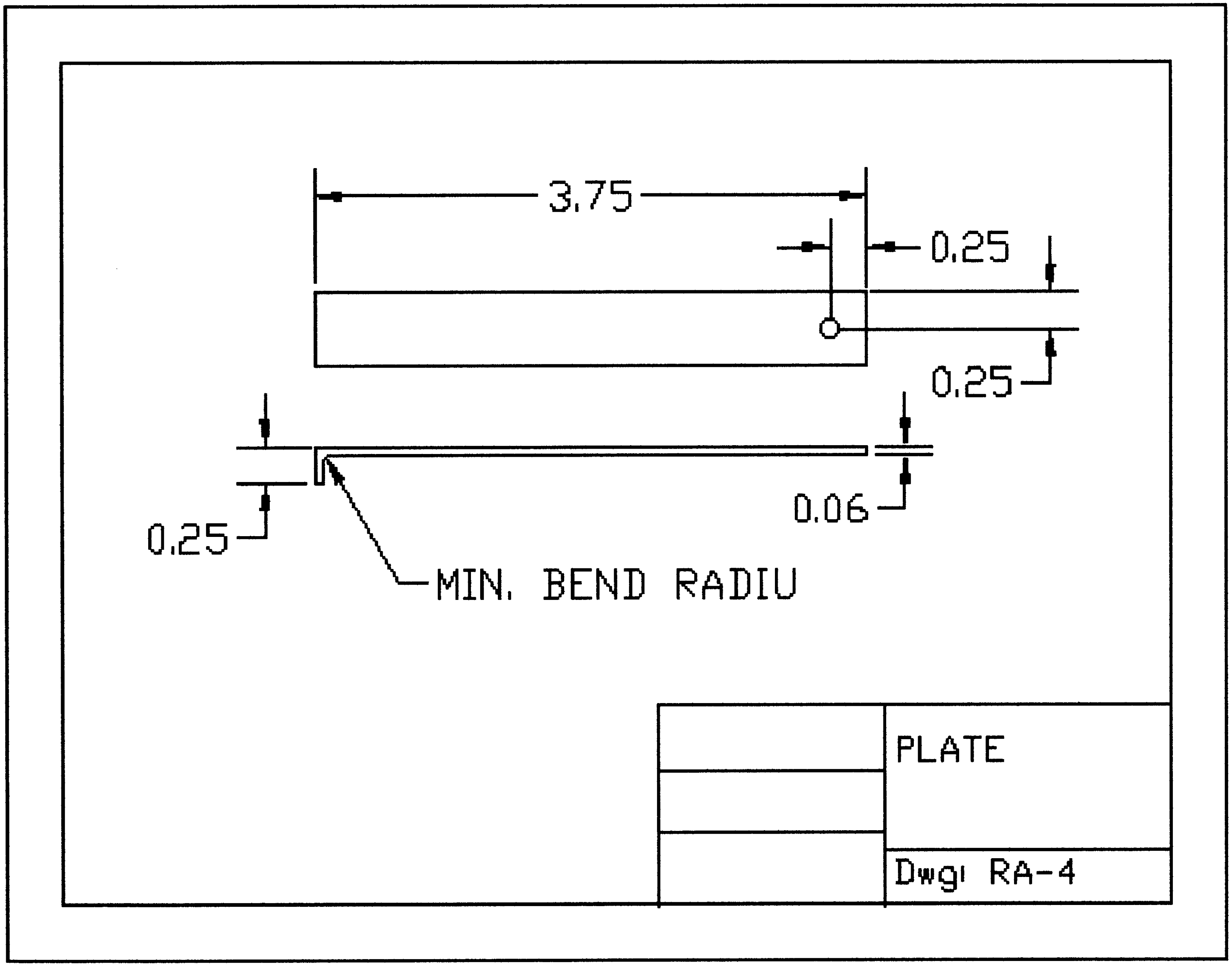
The materials needed for each student or group of students are as follows:

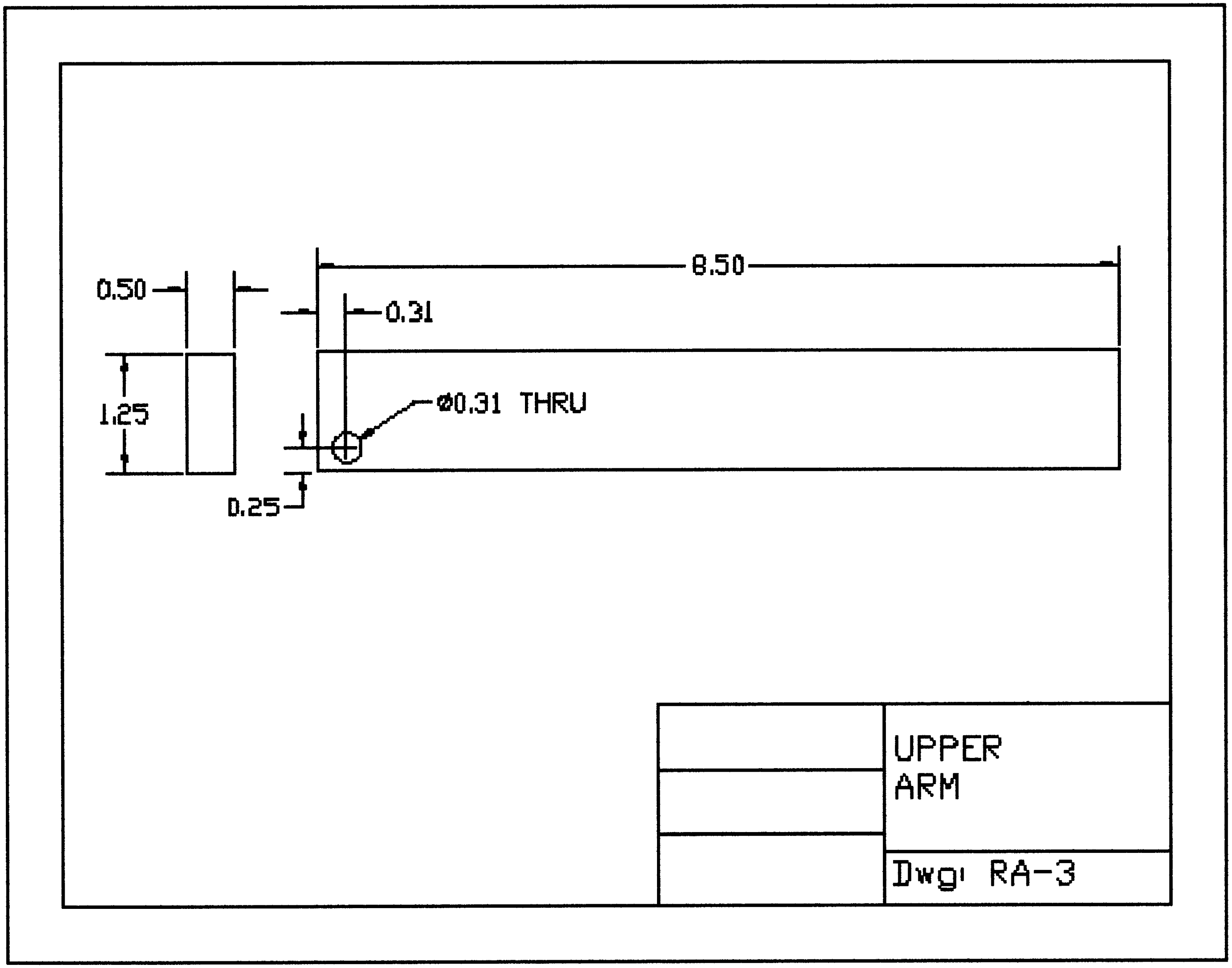
1) Base (1)
2) Lower Arm (1)
3) Upper Arm (1)
4) Plate (1)
5) 2 ½" Eye Bolt (1)
6) #6 Drywall Screw (1)
7) 1/8" x ½" long Phillips Sheetmetal Screw (2)
8) 12 cc Syringe (4)
9) 1/8" x 1" long Phillips Sheetmetal Screw (1)
10) 1/8" diameter Surgical Tubing (2 feet)
11) ¼"-20 x 3" Bolt (1)
12) ¼"-20 Wing Nut
13) Epoxy
14) 20-30 paper clips
15) plastic/paper cup
16) 9-volt battery
17) battery connector
18) wire
19) electrical tape
20) magnet core (nail, screw, bolt)

3. How?

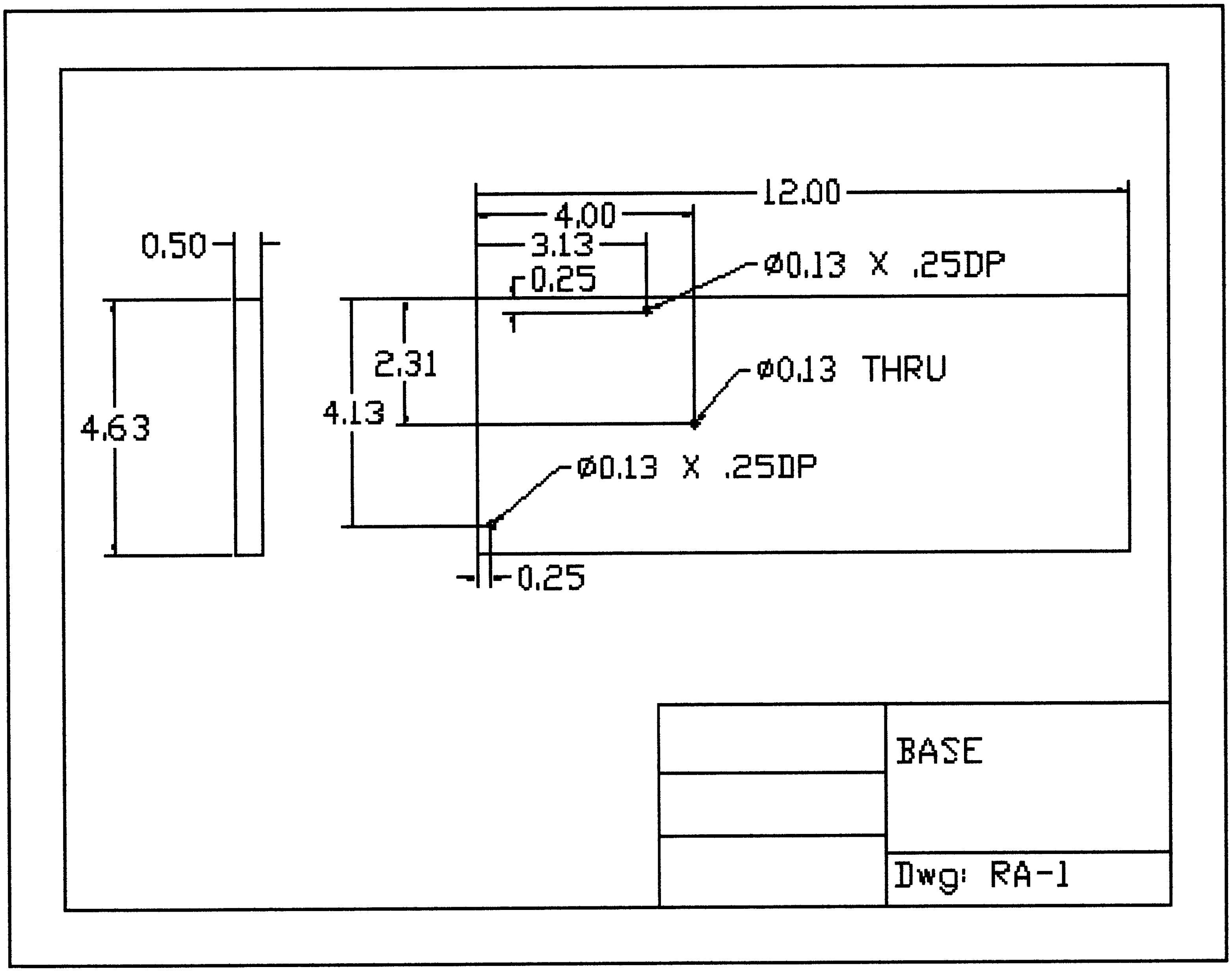
The following are the plans for the base, upper arm, and lower arm of the robot.




3.75
0.25
0.25
0.25
0.06
MIN. BEND RADIU
PLATE
Dwg: RA-4



0.50
8.50
0.31
1.25
Ø0.31 THRU
0.25
UPPER ARM
Dwg: RA-3


12.00
4.00
3.13
0.25
0.50
Ø0.13 X .25DP
2.31
Ø0.13 THRU
4.63
4.13
Ø0.13 X .25DP
0.25
BASE
Dwg: RA-1

4. Where?

The facilities required for this workshop are a room equipped with enough space and tables to seat each student close enough so that all in a group can participate and learn, yet not so close that they are crowded and do not have sufficient room to work. Approximately 4 feet of table space per pair of students is ideal.

5. General Tips

1) A provision must be made to attach the recommended electromagnetic core to the end the end of the upper arm.

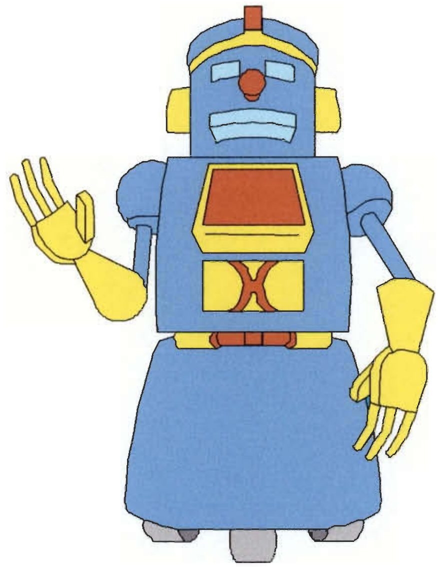
2) The sheetmetal plate must be epoxied onto one syringe in order to allow it to serve as the pivot syringe in the assembly. The plunger of this syringe must also have a slot cut into the side of it to accept the eyebolt, and a hole drilled into the top of it to accept a screw. (#7)

3) The recommended group size is two students. With three, the least assertive one usually became excluded and the other two did all of the work.

4) If the workshop plan is altered, make sure to plan a lot of hands on activities and demonstrations. Simple lectures do not hold the attention of the students.

6. Worksheets

The following pages are the worksheets that have been developed for distribution in this workshop.



Camp REACH Robotics Workshop

by

Sean Bradley
Michael Paonessa
Johanna Tenczar

Workshop Schedule

- 8:30 - Arrival, Icebreaker activities
- 9:00 - Tour of WPI Robotics Lab and Demonstrations
- 10:00 - Snack break
- 10:15 - Experiments
- 12:00 - Lunch
- 12:30 - Robot assembly and practice

Definitions of Terms

Battery - a cell or series of cells which stores an electric charge and is capable of producing a current

Charge - the state in which a particle is not electrically neutral

Circuit - a path over which current may flow

Closed Circuit - a circuit which forms a complete circular path; current will flow

Open Circuit - A circuit which is interrupted; current will not flow

Current - the flow of electrical charge through a conductor

Electricity - movement of electrons or other charged particles

Electromagnet - device in which a magnetic field is generated by an electric current

Force - a physical power or strength exerted against a power or object

Hydraulic - operated by the movement and force of a liquid

Magnet - a piece of certain materials (ex. iron) which attracts like material

Piston - a mechanical part which fits tightly into a cylinder and moves up and down within the cylinder by the force of a fluid such as steam or water

Pivot - a point, shaft, pin, etc. on which an object turns

Robot - a device which performs certain tasks by responding to preset controls or coded instructions

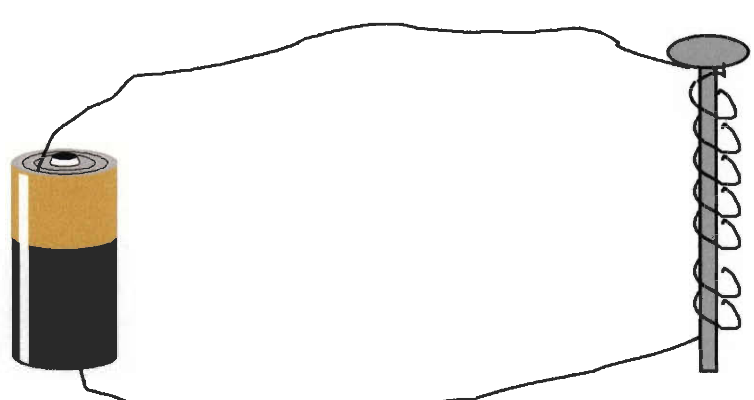
Switch - a device used to open, close, or divert an electrical current

Electromagnets

Electromagnets are comprised of a metallic rod, such as a screw, which is wrapped in a coil of wire which is connected to an electric circuit. When the circuit is closed, the current flows through the coil, creating a magnetic field around the screw. The power of an electromagnet can be changed by the number of coils wrapped around the core. In order to build the most effective robot possible, it is necessary to test an electromagnet to determine its optimum configuration. You will test three different coil sizes and two different battery strengths. You will test how many paper clips each setup of the electromagnet can pick up and hold. Enter your results into the table below. Whichever configuration holds the most staples is your optimum, and is what you will use later in building your robot.

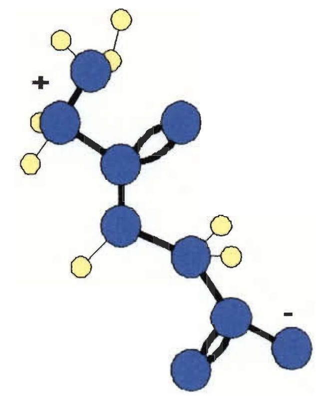
# Coils	Battery 1	Battery 2

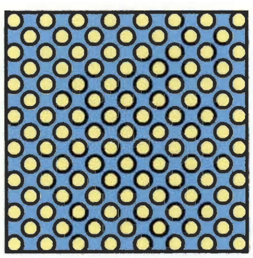
To assemble your electromagnet, you will need a battery, a battery connector, a nail, and some wire. First, take a long piece of wire and connect each end to one of the wires in the battery connector by twisting the two exposed wires together and securing them with electrical tape. Wrap the long wire around the core the designated number of turns WHILE THE BATTERY CONNECTOR IS NOT ATTACHED TO THE BATTERY. Leaving the battery connector off is a safety measure which will stop the electricity from flowing when you connect the wires. Be careful when touching the battery and do not leave it connected too long as it will heat up quickly.



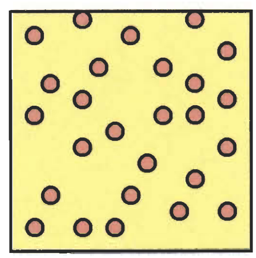
Why use water to control the robot?

Every piece of matter is made up of atoms and molecules (groups of bonded atoms). These particles are constantly in motion. The degree of their motion is dictated by how much energy they hold, as is their state of matter (solid, liquid, or gas). Solids hold the least energy and move the slowest, while gases hold the most energy and move the fastest. Also, because particles in the gas phase have so much energy and move so fast, they are more spread out than in other phases. Particles in solids are arranged into specific, orderly structures, and only vibrate slightly within their fixed positions.

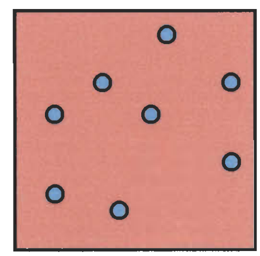




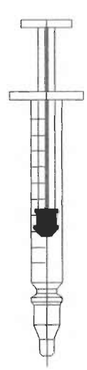
SOLID



LIQUID



GAS



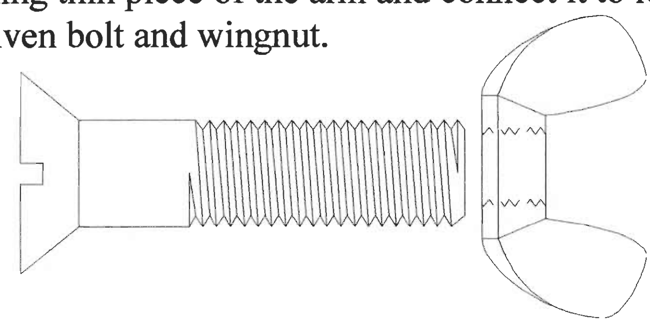
You will be using pairs of water-filled syringes to control your robot. It is simply not possible to teach you to set up a computer-controlled robot in one day. There will be one pair of syringes for every joint of the robot. In order for your robot to move, you will either push down or pull out the plunger of the free syringe, while the other syringe will be connected to the robot itself. The two syringes will be connected by a piece of tubing. Because the particles in gases are very spread out, gases can be compressed easily. Compression is when a pressure is applied to something to squish it into a smaller volume. A liquid is not as compressible as a gas, so when pressure is applied to it, it squishes a little, but then all of the particles get packed close together, so the liquid begins to move. Filling the syringe systems with water allows you to make the robot move, because as you push the plunger on the liquid, it pushed out the plunger on the other syringe and in turn pushes on the robot, forcing it to move. Pulling the robot back works on the same principle. Just as liquids do not compress much, they do not expand much, either. By pulling out the plunger in the free syringe, it creates a small vacuum, forcing the water back into the first syringe, and pulling in the plunger on the second syringe, pulling the robotic arm back with it.

Robot Assembly

•Insert long black screw through hole in base. Twist thich arm piece (screw hole is in the end cut at an angle) onto screw. So the arm swivels freely.

•Insert a syringe into the large angled hole in the thick arm (which should now be upright in base). The outlet of the syringe should protrude through the back of the arm.

•.Take the remaining thin piece of the arm and connect it to lower, thicker part of arm with the given bolt and wingnut.



•.Take the eyebolt (all ready screwed into the thicker part of the arm) and attach it through the plunger on the syringe with the metal attached to it (there is a hole cut in the plunger to accept it). Make sure the rounded part of the plunger faces up when they are connected.

•.Screw down the metal plate attached to the syringe to the hole in the corner of the base.

•.You should have one screw left. Thread this screw partway into the base (leave it sticking up) in the one remaining hole. This screw does not attach anything to the base, it only prevents the syringe in the base from extending too far.

•Compress the two syringes already in the assembly fully. Attach a piece of surgical hose to each of the two remaining syringes. Compress these two syringes attached to the tubing, and then fill the whole assembly with water.

•.Finally, attach the other ends of the surgical tubing to the two syringes in the robot assembly.