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Raising Interest in Science and Technology in the United Kingdom

An Interactive Qualifying Project Report
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Abstract

There is concern about the continuing decline of enrolment in technological universities and the shortage of scientists in the United Kingdom. Students' lack of interest in science and technology is presumed to be an underlying cause. We used interviews, surveys, and detailed observations of existing science workshops to discover effective ways of stimulating children's interests in science and technology. We then applied these concepts to the design of two new workshops aimed at motivating students to pursue careers in science and technology.

Executive Summary

There is a deep concern about the continuing decline of enrolment in science and technology institutions in the United Kingdom. Students' lack of interest in science and technology is presumed to be an underlying cause. This lack of interest comes from numerous sources, specifically the children's negative stereotypes of scientists and weak science programs in schools. Science and Technology Regional Organisation (SATRO) develops and promotes programs that are designed to stimulate interest and excitement for science and technology in today's youth. SATRO runs workshops in many local schools in London that attempt to get children to think about science and engineering as possible career opportunities. There is a need for SATRO to obtain more educational resources and improve existing resources to achieve its goals as an organisation.

The objective of this project was to assist SATRO in fulfilling its mission of raising the level of interest for science and technology in children as well as to gain an understanding of what types of teaching techniques work best in keeping students engaged in a science and technology workshop. Our goals consisted of assessing SATRO's current science and technology teaching resources, for example the Balloon Buggy and Robotics workshops, as well as evaluating the Techno Games CD-ROM. The final goal of this project was to take the information acquired from the analysis of existing resources and then apply that knowledge to create additional teaching resources for SATRO and other organisations to use in stimulating excitement for science and technology.

Our initial research consisted of the examination of past projects and workshops that were intended to stimulate interest in science and technology. Through this research we discovered many programs that have been effective in getting children excited about science and technology. It was hoped that a comparison between these programs and the programs we assessed in this project (Balloon Buggy and Robotics workshop) could be used as an evaluation tool.

We then made observations of SATRO's Balloon Buggy and Robotics workshops to gather information regarding children's interests and methods of encouraging them to pursue careers in science and technology. Both of these workshops, which follow the material in the national curriculum, are intended for year-five and year-six students. In order to complete the evaluation we first observed eight workshops (three Robotics and five Balloon Buggy). In each workshop we observed the instructors' attempt to keep the children involved at all times by having the children lead much of the discussion and by keeping them occupied with hands-on activities. The two workshops are structured differently, suggesting that a great deal could be learned by observing the differences between them. More specifically, the Robotics workshop has a lot of teacher interaction to keep the children on task throughout the workshop, whereas the Balloon Buggy workshop needs very little additional instruction after initial discussion and presentation of the subject material.

Our primary objective in observing these first workshops was to use them as a learning tool. We sought to become acquainted with the workshop environment and deepen our perception of the attitudes and roles of the people involved. In particular, we wanted to familiarise ourselves with their basic structures before we attempted to collect significant data, thus insuring a strong basis for our subsequent observations. From these

workshops we obtained very little hard data, but we revealed a primary and common method for the assessment of these workshops. It became evident after the first of these workshops that it would be impossible to accurately measure and represent the effectiveness of stimulating interest in science and technology from the observation of sessions alone. The large numbers of immeasurable variables are inherently apparent, and they clearly limit the possible outcomes of an assessment of the Robotics and Balloon Buggy workshops. From these initial workshops we were able to determine the measurable dependent and independent variables that could be used to represent a subjective assessment of the workshop. We created a list of all measurable, recognizable and relevant variables from our many attempts to record significant data from these early workshops. This list enabled us to narrow the scope of the project by revealing the possible questions that could be answered from the measurement of these variables. The questions gathered are as follows. How effective was the workshop in teaching the concepts to the children? Do the children stay continuously interested in the activities? At what point (or aspects) of the workshop do they start to lose interest? In addition we could identify any misunderstanding or problems the children had during the workshop. We also conducted interviews with Peter Chamberlain and Bernie Holloway of SATRO in order to deepen our understanding of the ways that the workshops are run and to also determine which methods are most effective.

To develop a true understanding of a workshop environment, we needed to observe them from multiple perspectives (i.e. student, teacher, and outsider). The analysis of the different perspectives of each of these individuals provided unique information that could not have been easily gathered from one alone. In order to do this we created a number of evaluation tools. The first of which was a teacher evaluation worksheet. We decided to run several sessions of this workshop ourselves (five balloon buggy and two robotics). As a teacher running these activities, we wanted to obtain as much data as possible, but it proved to be very difficult to do because the process of running these workshops occupied the majority of our time, leaving little time to record our observations. Hence, the self-evaluation worksheet was designed to be completed after each workshop ended. This evaluation tool measured general information on each class and, more importantly, described the structure of each workshop and how it was conducted (for example, with students working in pairs or individually, with different amounts of instruction given to the students when performing tasks, etc.).

For our final observation, our "capstone" observation, we constructed a very structured protocol for gathering data. At this session, we divided the students into groups of three to five pairs per observer so that we could obtain more specific data regarding the student's reactions to the workshop. Within this protocol we each completed evaluation worksheets during the workshop. These worksheets allowed for structured methods of recording questions asked to the students, number of hands raised for each question, time spent on/off task, and the approach each group took to complete the tasks.

From these methods we were able to recognise and develop teaching approaches based upon the independent variables determined. These concepts can be used to keep students engaged during a science and technology related workshop. The amount of creative freedom is dependent on age level and discipline of the child. A limiting factor in determining the amount of creative freedom that a student should have is their ability to recognise and apply him or herself to complete the primary goal or the task of the workshop. The ideal flow of instruction of a workshop is when the introduction and initial discussion are able to specify all of the tasks of the workshop in a clear and concise manner. Because of the nature of some workshops this structure is not possible. Additional instruction sometimes needs to be inserted into the task portion of the workshop in order to aid the children's understanding of the concepts taught or to guide them into another task session. The amount of instruction given to the students in these workshops is directly related to the amount of creativity allowed. In the development of a new workshop a trial and error method can be used to determine the optimal point where the children are pushing the limits of their abilities to comprehend the concepts involved. Depending on the nature of the workshop there are different advantages and disadvantages to having students work either as individuals or in groups. Students, when working alone, tend to have a greater sense of accomplishment than when working in groups. On the other hand, when working in groups, students can accomplish more difficult tasks by working as a team.

Classroom environment is also another limiting factor on the attention span of the children. When children are gathered together in a hall or sitting in an open space in a classroom it is easier to keep them engaged in discussion rather then when they are sitting at their seats. Classroom management becomes increasingly difficult when children are constantly taken in and out of engagement because of gaps between sections of the workshop formed from lack of preparation. Having a class that is well disciplined is an important aspect of running a successful workshop. Some children will stay engaged in a poorly structured workshop when others are difficult to control in any setting. If the instructor is unable to keep the children's attention then it is almost impossible for the students to get anything beneficial from the workshop. With a larger number of helpers, a workshop can run more smoothly than with one instructor alone. It is very difficult for one teacher to satisfy all of the needs of several groups of students when they all have different questions that need to be answered. The amount of preparation is also very important in running a workshop. The student's ability to understand the concepts presented is a determining factor for what a child can get out of a workshop. Lowering the learning curve for these students in many cases hinders the primary goal of the workshop. The teachers ability to know, implement, and expand upon the teaching concepts above is essential to provide a stable atmosphere for the children to work in. These concepts were then applied to the development of the flow of the workshops that we would create.

To continue the assessment of existing resources, we evaluated the Techno Games CD-ROM on behalf of SATRO for the BBC. The purpose of this evaluation was to determine the CD-ROM's potential as a teaching resource. First, we informally interviewed the Techno Games team members from the Barking Abbey Comprehensive School. We also interviewed the team leader, Steve Barlow, and surveyed the students in order to obtain suggestions for improving the Techno Games CD-ROM. These interviews and surveys were aimed at gaining their opinions on the CD-ROM as a whole. From these interviews and surveys we learned that the Techno Games CD-ROM is effective as a teaching tool. We also gathered recommendations to improve the CD-ROM. The students suggested that they would like to be able to build a robot and then compete with that robot in an event like that of the Techno Games events. In addition to the students' comments, the leader of the team suggested that more engineering be included. These comments have been forwarded to the BBC for consideration.

The second phase of this project involved the creation of original resources for SATRO. This effort concentrated on development of two workshops, Programmable Interface Controllers (PICs) and tunnelling, in which we used the results of the Balloon Buggy and Robotics evaluations to develop effective ways to present the material that keeps the children engaged and interested in the workshops.

The workshop on tunnelling was developed for the London Canal Museum to be used during Science Week as well as for SATRO's use at local schools. This workshop was intended to give hands-on experience to children of the technical problems that occur during the construction of tunnels. The workshop consists of an opening discussion, three hands-on activities, and a conclusion discussion on the concepts learned. The workshop opens with a discussion on why tunnels are made and how they affect our lives. The children are then given the opportunity to attempt to build a tunnel by digging through wet sand in front of the rest of the class. Having the tunnel collapse will lead into a conversation on different shapes of tunnels and why the arch is the strongest structure. The students are then divided into groups and given a pre-cut set of wooden pieces that form an arch when assembled. Each group of students receives a different set of blocks which separately will form different size arches. Students discover that arches with fewer blocks are easier to construct. This leads into a conversation of why real tunnels could not be made this way. The concept of a framework that is used to support the arch while it is being built is introduced and discussed with the students. In the third part of the hands-on section, each student constructs their own tunnel using small bricks and mortar around a plastic framework. The workshop is concluded with a discussion on the Islington tunnel and how its construction relates to what was learned in the workshop.

After its initial development the workshop was pre-tested with an after-school club with eight year-six students at the Prior Weston Primary School. The results of the pre-test demonstrated that the children were actively interested in the activity and gained a basic comprehension of the concepts. We established this information through a post interview with the teacher of the class and a post survey of the students. From our self evaluation of the workshop we determined a number of minor technical problems in the workshop. There were modifications made to the technical aspects of the workshop, and then we pre-tested for a second time at Saint Mary's Primary School with a full class of twenty eight students. Due to the large size of the class, this pre-test class was very difficult to manage while trying to intersperse higher level discussions within the hands-on portions of the workshop. Once the children left the carpet (where we had the opening discussion with them) and went back to their seats, they became distracted and did not pay attention to instructions. A solution to this problem is to give the children a much deeper instruction initially which outlines everything that they will be doing in the workshop. This would give the children a much better idea of what to expect during the rest of the workshop so that they would be less likely to lose interest or become distracted. After the workshop, we discussed the outcome of the workshop with the teacher of the class. He gave us valuable information on the flow of instruction and preparation from his recommendations of how the workshop should be run. This information was gathered not only by discussion but a teacher evaluation survey as well. From these two pre-tests and our own experiences of running and observing other workshops we made modifications to our workshop and created a leader's guide that gives step-by-step instructions for running the tunnelling workshop. The guide assumes minimum knowledge of the subject matter and gives suggestions for possible discussions.

For the other portion of the project, we developed a four week robotics workshop for the Warren Comprehensive School that demonstrates the uses of Programmable Interface Controllers (PICs). This workshop was developed for year-eight students and fulfils the National Curriculum requirements for systems and controls. The workshop that we developed was intended to teach the children about the basics of systems and controls, while at the same time giving them a background in programmable chips. Although most of the concepts covered will be delved into later (possibly as a key stage 4 project), the topics covered now may influence their thoughts about science and technology as a career. Keeping children interested in new material can be accomplished by having an understanding of the prerequisite knowledge, but challenging them at the same time with new concepts. The flow of the workshops is designed to first introduce the students to concepts and teach them the basics of the programming software. Week by week, the idea of telling the students how to accomplish a problem is phased out and is left to creativity while only having a few guidelines to accomplish. This is meant to teach the software so that they get familiar with it. As they become more familiar with the concepts, they can explore the wide range of activities and programs that they can create using the concepts that they have learned. By having the children develop their own project as a final test, we are giving them a wide range of creativity and freedom in design. Also, by having a "competition" for the best design to be put in the corridor in an interactive display, we are encouraging them to do their best, without having them strive for the best grade. The concept of friendly competition towards a goal that gives them recognition will act as a major role in getting the students to use all of their creativity and knowledge of systems and controls.

The Canal Museum workshop and the PIC module lesson plans are the primary deliverables of this project. The teaching concepts learned from the evaluations of the Balloon Buggy and Robotics workshops were incorporated into the design of these deliverables. With these two workshops and the assessment of the Techno Games CD-ROM, and Balloon Buggy/Robotics workshops we hope to aid SATRO in fulfilling their mission of raising the level of interest for science and technology in today's youth.

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We, Kimberly Barger, Kevin Brown, Keith Hammerschlag, and Scott Leslie, claim that we equally participated in the writing of this report. All writing, proofreading, and editing were performed equally between all of us.

Introduction

There is a deep concern about the continuing decline of enrolment in science and technology institutions in both the United Kingdom and the United States. Students' lack of interest in science and technology is presumed to be an underlying cause. This lack of interest comes from numerous sources, specifically the children's negative stereotypes of scientists and weak science programs in schools. Science and Technology Regional Organisation (SATRO) develops and promotes programs that are designed to stimulate interest and excitement for science and technology in today's youth. SATRO runs workshops in many local schools in London that attempt to get children to think about science and engineering as possible career opportunities. There is a need for SATRO to obtain more educational resources and improve existing resources to better achieve their goals as an organisation.

There has been a decline of qualified individuals able to fill the available jobs in science and engineering fields. In the past five years the UK has experienced a decline in enrolment of 6000 students in the fields of engineering (UK DfEE, 2000). With the advancements and rapid growth of science and technology fields in past years, it has become essential for today's society to comprehend the latest technological advances. Educators believe it is important to introduce children to science and technology at a young age in order to create a solid base for the rest of their educational development. It is hoped that these children, once motivated, will proceed to become more technologically aware and capable and possibly pursue careers in the fields of science and technology.

The objectives of our project were to assist SATRO in fulfilling its mission of raising the level of interest for science and technology in children as well as to gain an understanding of what types of programs and teaching techniques are most effective doing this. Our goals consisted of making an assessment of some of SATRO's current science and technology teaching resources as well as the creation of additional resources for SATRO and other organisations to use.

We evaluated past programs that were intended to stimulate interest in science, namely SATRO's Robotics and Balloon Buggy workshops. These evaluations consisted of detailed observations of the ways these programs were taught as well as the children's reactions to them. From the teaching methods gathered in these observations, we developed two new workshops that could be used to educate children and promote their interest in science and technology. One of these workshops teaches the use of Programmable Interface Controllers (PICs) as a tool for controlling an electronic system. The other is an interactive workshop on the technical aspects of tunnel building for use at the Canal Museum of London. Both of the workshops are very different insofar as one focuses on aspects of computer science and control systems and the other on aspects of mechanical and civil engineering. They are similar, however, in that they both attempt to expand children's perception of what science and technology has to offer them. These workshops were then tested and their effectiveness was evaluated using the same methods used to evaluate SATRO's existing programs.

The main deliverables in this project were divided into two main areas. The first involved evaluations of existing science and technology programs. This consisted of the evaluation of the BBC's Techno Games CD-ROM as a teaching tool for children involved in the Techno Games program, as well as the construction and application of an assessment tool for measuring the effectiveness of SATRO's current workshops. The second area consisted of the development and assessment of two new science and technology educational workshops. The first of these was the workshop on building tunnels for the Canal Museum. This workshop will accompany a display on the Islington Canal and be displayed during Science Week. The second workshop was designed for the Warren Comprehensive School and demonstrates the uses of PICs to year-eight students in a series of four laboratory modules wherein students obtained a basic understanding of electronic control systems by programming a PIC. Armed with the knowledge developed in our previous assessment of existing SATRO activities, we were able to incorporate many of these teaching techniques for keeping children interested into the design of our own workshops. The insights and educational resources that we developed will assist SATRO in its mission of sparking children's curiosity about science and technology.

Science and Technology Education

Scientists and their Importance

When we look at the invaluable resources that science and technology have given us, we see the world transformed on virtually every level. The contributions of the scientific method, research and development, testing and hypothesis have given us numerous discoveries. Scientists and engineers are the people behind these inventions and advancements, and without future generations like them, advancements that have yet to be made may never be developed. It is essential that these future generations are willing and able to take the place of the inventors of today to ensure for a better tomorrow.

Jobs in Science- and Technology-Related Fields

Science is an expanding field with more opportunities for employment opening all the time. The number of scientific and technological jobs has grown over the past few decades. The demand for professional is greater than what the current output of technological universities can supply. According to a National Science Foundation projection, there will be a global increase of almost two million science and engineering related jobs within the next decade. This is approximately a forty-percent increase from the current demand (National Science Board, 2000). The United Kingdom stands out as one of the countries making the smallest increase in the number of scientists it has produced over the past 20 years (National Science Board, 2000). Reaching students at an earlier age is an important step for the United Kingdom to improve on its output of future scientists.

Science and Technology as Majors

In order to increase the number of scientists produced in the United Kingdom, it is useful to first look at the number of graduates coming out of colleges and universities today. The numbers of undergraduates pursuing degrees in science and technology related fields have been declining over the past several decades. In the United Kingdom, enrolment in engineering fields has had a decrease of 6,000 graduates from 100000 (six percent of the current enrolment), and the physical sciences have had a decrease of 2,000 from 57000 over the past five years (three and a half percent of the current enrolment) (UK DfEE, 2000).

In the United Kingdom 34% of students graduating with bachelors degrees are currently earning science and technology related degrees. Even the US has only 32% of its bachelor degrees recipients obtaining their degree in engineering and technology areas (National Science Board, 2000). Many Asian (Singapore 100%), Middle Eastern (Israel 51%) and other European Union (France 71%) nations have far more than 50% of their university's graduates in science and technology related fields (National Science Board, 2000). In order to understand why fewer students are graduating with degrees in science/technological fields compared to these other countries, we must first understand why so few high school seniors and college freshmen choose not to enrol in these majors.

Incoming College Freshman/High School Seniors

There are approximately 5% fewer students percentage-wise going into science and technology majors as freshmen in college than there has been 40 years ago, resulting in a smaller number of graduates in these fields (UK DfEE, 2000). One possible cause of this is a poor preparation in high school to meet the demands of such majors. If we look at the results of such high-school exams for seniors such as the Third International

Mathematics and Science Study (TIMSS), we can see that the high-school seniors in the UK rank "average" internationally in science and mathematics knowledge level. In order to become a leader in scientific and technical education the UK must take steps to ensure they have sufficient numbers of scientists and engineers in the future. (National Science Board, 2000). One of the underlying causes of this lack of scientists is lack of information concerning what scientists actually do for a living. In order to improve these perceptions of science and technology related majors, children must be influenced at an early age, when these perceptions or stereotypes begin to occur.

Stereotypes of Scientists

An important aspect of getting children interested in science and technology is to understand the stereotypes that children have about science and scientists. Exploring these stereotypes will hopefully lead to ways of changing their views and, in the process, get more children interested in science.

A study of fourth and fifth graders from Pennsylvania in the United States attempted to determine students' perceptions of scientists. The study involved one fourth grade class and two different fifth grade classes. Each student was asked to draw a picture of what they thought was a typical scientist. The drawings were scored using the Draw-a-Scientists Test-Checklist (DAST-C), adapted from a study about students' perceptions of scientists conducted in 1983 (Finson, Beaver, and Crammond, 1995). Scores rate each drawing according to the stereotypes present or absent in the drawing. The most common stereotype was that scientists are white males who work indoors in a laboratory setting. The fourth grade class was then visited by a female chemical engineer and the fifth grade students by a male physicist. Both scientists led the class in discussions of what scientists and engineers do. For instance, the engineer described herself as a person "who designs and builds materials" and she performed experiments with the students, such as making silly putty. The physicist did an experiment demonstrating chemical reactions between sodium metal and water. According to the teachers, the students enjoyed meeting the scientists and performing the activities.

After the visits by the scientists the teachers resumed their lesson plans and had no follow up visits from the scientists. After four weeks they asked the students again to draw a scientist and describe his or her work setting. The post-visit drawings showed an increase in female images and fewer scientists wearing lab coats and glasses. It appears that the visits did have an effect on the students' perceptions and gave them the chance to see scientists as real people rather than white males who work in laboratories. Introducing young girls to female scientists may have a positive influence on their choice of careers in science and engineering. Overall, classroom visits such as these are a good way of attempting to get children interested in science and engineering.

Gender Gaps Between Males and Females

According to the Council for School Performance, there are several theories regarding the cause of gender gaps in education. It is believed that these gender gaps, which are more prevalent in the fields of math and science, are caused by unfair treatment and lower expectations of girls at an early age. Many teachers have lower expectations for girls than boys in math and science because they are often viewed as "male" subjects.

In the last year of secondary school, girls usually rank lower then males academically, especially in mathematics and science, even though studies prove that in general males and females start their first year of schooling at an equal academic level.

During the seventh year of school, girls' scores and achievements in mathematics and science start to drop. Adolescence has proven to be the starting point for the gender gaps that increase as the students get older and progress through school. The Wellesley College Centre for Research on Women found in 1992 that the gender gap in mathematics is closing slightly, but the gender gap in science is not (Council for School Performance, retrieved November 12, 2001 from www.gsu.edu).

Because we anticipated working with Barking Abbey, a school for females only, we needed to be sensitive to the fact that girls may subconsciously think, for the most part, that math and science are for males, not females. In approaching the girls with our lesson regarding Techno Games, we had to remember that these girls may have had preconceived stereotypes in their minds. We were concerned that many of the girls might have been disinterested, and their aptitude for mathematics and science limited due to the lower expectations of their teachers. To grab the interest of these girls we anticipated needing to explore specific aspects of a lesson that appeal to females.

Secondary- and Primary-School Science Education

For there to be a significant and positive impact on the perceptions that students have of science and technology, there must be an influence on students during their primary and secondary school years. For the Third International Math and Science Study (TIMSS) test scores given in math and science, the United Kingdom has not met the international guidelines in both subjects for the fourth and eighth grade levels (National Science Board, 2000). The UK has fallen below most countries in math and science testing at primary school levels, including the United States, who is currently at the half way mark of all competing nations (26 in total). The lack of understanding of key concepts at such a critical level of development can attest to the decline of knowledge and interest later in their secondary schooling. Test results are an indicator that the general knowledge of science and mathematics for these students in the United Kingdom needs to be improved upon. A better understanding of basic science concepts will hopefully provide them with a broader view on the world of science and technology.

Science curriculum in the school system

Goals of science and technology education in primary and secondary schools

The goals of a good science curriculum are to "educate students who are able to experience the richness and excitement of knowing about and understanding the natural world; use appropriate scientific processes and principles in making personal decisions; engage intelligently in public discourse and debate about matters of scientific and technological concern; and increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their career" (National Research Council, 1996). According to the National Research Council, these basic goals are the standards of what a literate person should learn and understand after finishing the 12th grade.

Renner and Safford's model of an ideal science curriculum

Renner and Safford have developed a model for an ideal science curriculum. This model gives a good representation of when an average child is ready to understand and apply certain concepts by dividing the curriculum into three student age levels.

As Renner says the teaching of processing skills and the structuring of concepts are the primary goals in the level one curriculum. At this age (5-10 years old) students have limited in their abilities to deal with abstract ideas (John W. Renner and Don G. Stafford, 1972). At this age level, activities that force students to test general statements on basic properties aid in their development of abstract thinking. Skills of data collection are also taught in level one, such as measurement, observation, prediction, isolating variables, and space-time relations. Children develop skills needed to organize and interpret information such as physical properties, relative position, and motion (John W. Renner and Don G. Stafford, 1972).

The model suggests in level two, children (11-14 years old) have the tools for inquiry and the maturity to begin to understand formal operations. "Inquiry" is a teaching method that is used to engage students in "minds on" as well as "hands on" activities. Functioning as scientists, students actively ask questions, evaluate data, and draw conclusions (Dailey, 1999). This is a critical age in a child's educational career because much of the child's success or failure in their education rests on what happens in this stage. The Commission on Secondary Education said about this age group that "Certainly, if any period of growth leads itself to change through education, the period of early adolescence, with its emphasis on exploration and discovery, is especially amenable to change." In the Renner and Stafford model the main purpose of science education in level two is to get the student to understand formal operations as well as to explore a range of scientific areas to broaden their conception of science. This is accomplished by collecting data, organizing the data into general patterns, making and testing predictions, imagining models to explain patterns in nature, and making and testing predictions. Renner says at this stage the child goes through a transition from concrete operations to formal operations. This transition should be nurtured by a gradual increase in the degree of abstractness in problems given as the student progresses (John W. Renner and Don G. Stafford, 1972).

From the model in level three, students (15-17 years old) should begin to understand general concepts of science in a conceptual scheme. Students can obtain this conception through class discussions and actual investigations and experiments they have made. Stafford suggests that students should be given the freedom to do their own research in order to help them start thinking and openly discussing the problems they have recognized. Also, the models states that students in this group could benefit from a history of science to help them understand how science and society interact (John W. Renner and Don G. Stafford, 1972).

Ways for teachers to implement the curriculum

In a school system one of the most important factors in developing a child's interest in science and technology is the teacher ability to convey the material to the student in an exciting manner. "When a schools science program relies completely upon textbooks and other media (even if these materials are properly prepared), the program is probably making a greater contribution to the development of reading ability than a greater contribution of scientific literacy"(John W. Renner and Don G. Stafford, 1972). It is the job of the teacher to implement these resources in order to get the students motivated and interested in the course material. The learning environment created by the teacher is an essential part of the learning process. The student should feel comfortable enough with the teacher to confer with them about issues on a project.

Implementing new teaching strategies

New strides are being taken in schools to find better ways of teaching children. Dunn and Dunn state that a learning style is a biologically and developmentally determined set of personal characteristics that make identical instruction effective for some students and ineffective for others (Dunn and Dunn, 1992). This theory suggests that individuals begin to concentrate, process, and remember new information in very different ways. The Dunn and Dunn learning style model is defined in terms of an individual's reaction to 21 elements classified in five categories of stimuli (environmental, emotional, sociological, physiological, and psychological). This is a hands-on style of learning, whereas traditional teaching is a direct instruction in science, which includes lectures, discussions, textbooks, and written activities (Searson and Dunn, 2001). This style of learning (hands-on) is the type that is used by SATRO in their workshops and will be incorporated into the resources we will create.

A recent study has been made to evaluate the Dunn and Dunn learning style model compared to the traditional learning style approach. The comparative study of the two teaching styles consisted of three third grade classrooms where students in two of the classes were taught with the hands-on approach and the third class (the control group) was taught with the traditional method. All three classes were pre-tested and post-tested on the subject matter that was taught. The results showed that sixty-five percent of the students taught with the hands-on method scored a 3 or 4 on the higher-level cognitive science achievement post-test compared to only ten percent of the students taught traditionally. This suggests that the hands-on teaching method is superior to the traditional method.

Cooperative Learning

Cooperative learning is a method of helping students to understand and extend to the real world what is being taught in the classroom. This is very valuable in getting students interested in science. One way of accomplishing this objective is to perform some type of experiment that relates to the material that was discussed in class. The Robotics workshop that SATRO runs in local schools is a good example of this type of learning. This workshop deals with simple circuits and closely follows the National Curriculum guidelines. This approach not only helps the students to understand the material better, but it also helps to increase their interest in science by making it fun and exciting.

The following sixth grade class describes an example of this type of approach. The teacher began with an assignment of writing about the most dangerous situation the students had ever been in and how they dealt with it. This was followed by reading an article about the conditions of the Antarctic called "Danger on the Ice" as well as "Shipwreck at the Bottom of the Ocean." The students became interested in how the ice slowly crushed the ship, which led to experiments. The class split up into groups and each investigated their own question. One group chose "What effect does the number of D-cell batteries have on the time it takes a wire to slice through the ice?" Another group studied the question "Which substance will melt ice quicker, vinegar or ammonia?" This approach is just another one of the ways intended to make science more appealing to young students. It is hoped that once these children develop an interest at a young age it will influence their career decisions later in life.

Non-Curriculum based science and technology programs

Several school systems have neglected certain aspects of the child's science educational development. This neglect can be a combination of lack of teacher experience and not enough science in the curriculum. The result of this neglect is fewer and fewer children pursuing careers in science and technology. Ways of correcting several of the issues derived from this neglect may be accomplished through national curriculum reforms and many new and effective, informal science education programs. A few examples are provided below as well as in Appendix AA.

Efforts to raise interest in science and technology occur not only in schools, but outside of schools as well. There are many organisations and museums that offer programs, workshops and camps that focus on this area. These programs enhance the regular curriculum-based education that the children are already receiving in the classroom. Techniques that have been successful in these organizations may also succeed in other teaching and learning environments. Some of these methods may also be applicable to our own project.

The Science and Technology Regional Organization (SATRO) has developed many programs and workshops that stimulate children's interests in science and technology. Since SATRO started its Balloon Buggy workshops about a year ago, they have been run numerous times in 58 different schools. Approximately 3220 children have participated in the program. (Retrieved November 12, 2001 from www.londonsatro.org.uk,).

From the popularity of the Balloon Buggy program, it is apparent that the methods used to present and perform this program are an effective way of getting a positive response from students and teachers. It is presumed that the children become interested in the Balloon Buggy program because it is fun. The activity provides a lesson in science, but the children are not aware that they are learning a lesson. This program also provides insight for teachers as to some of the effective ways of getting children interested in science.

Camp Reinventing Engineering and Creating New Horizons (REACH) is a summer program for girls in Massachusetts in the USA who have completed the 6th grade and who are "interested in learning more about careers in engineering and technology". (www.wpi.edu/~reach, November 2001) This camp offers hands-on workshops, an opportunity to design a project for a community organization, field trips, as well as follow-up programs during the school year. The goal of Camp REACH is to raise self-esteem and enthusiasm in the fields of engineering and technology. Since 1997, girls from all over Massachusetts have participated in this program. ("2002 Reach Staff" retrieved November 16, 2001 from www.wpi.edu/~reach/staff.html)

This camp not only teaches and enforces lessons in science and engineering, but it is also geared toward young girls. Generally, more men than women have studied science and technology fields. Camp REACH helps to fill the gender gap in these studies. Because Camp REACH allows the girls to work on a community project, these girls also gain a valuable advantage. It allows them to work in a team on a hands-on project, giving them real world experience at a young age. Educating children in a classroom is often effective, but when the information is applied to something concrete, rather than abstract, lessons can be easier to understand. Examples of such projects include making a bridge that will sustain a certain weight, building a tunnel that will not cave in on vehicles travelling through it, and constructing a skyscraper that will withstand a simulated earthquake. All of these examples teach an aspect of science (more specifically, engineering) but also pertain to real life situations.

The Science Education Leadership Fellows (SELF) Program is a partnership among Houston-area schools, the Houston Independent School District (HISD), and Baylor College of Medicine. The program was established in 1999 as a type of teacher-scientist partnership, the goal of which is to increase the interaction of these two groups that normally would not have much contact.

The SELF program seeks to enhance science education by having elementary school teachers work with scientists. In 1999-2000 sixteen teachers and eight scientists were selected to work together. Each teacher completed sixty hours of professional development, which included experience in science laboratories. The development focused on science content knowledge (esp. biology and chemistry), new teaching resources, leadership skills and teamwork. During the following year each teacher also conducted one or more science events at his or her school, such as a science festival.

This program helps teachers by giving them experience in the laboratory. One sixth-grade teacher commented on the program: "This program helped me understand more than any book ever could. The firsthand experience in the laboratory was valuable, not only because I actually saw what some 'real' scientists do in a lab, but also because I can now describe the work of scientists better to my students". (Moreno, 2001)

The SELF program also promotes the interaction of scientists with elementary school students. During 1999-2000, each SELF scientist participated in the classroom activities of two different SELF teachers. The scientists developed activities, which they taught, for each class. Some of the lessons included "Living vs. Nonliving Things" (first grade) and "Bacteria are Everywhere" (fifth grade).

Teachers reported that their students have responded positively to having a "real scientist" in their classroom. They also reported that the students have shown increased enthusiasm in science, not only as a subject area, but also as a possible career. Teachers also noted that students were excited to have a teacher who had participated in scientific research and who could tell them about the challenges and rewards of science. This approach is very similar to what is done at SATRO as they go into classrooms as neighbourhood engineers to run programs and workshops. This reinforces the idea that these types of workshops are very important at getting children interested in science and technology

Promoting Science Through Competitions

Students may become more actively interested in various fields of science through competitions. They introduce young students to a variety of areas within the fields of science and engineering, and an early introduction to these activities may help to develop a lifelong appeal of science.

Competitions can often be used to spark motivation. "When children are motivated to experiment, they begin to think and act like a scientist, and this can lead to a love of science" (Cropper, 1998). In addition to this, competitions can serve as an excellent way to develop scientific skill.

Robotics Competitions

Many corporations that are interested in promoting science and technology to school age children around the world use popular robotics competitions. Although robotics competitions may all sound alike, they usually involve different "goals" for each robot to complete, or they involve using new techniques. These competitions give the children not only a basic understanding of electrical and mechanical engineering; they teach children many other values that can not necessarily be taught in the classroom. As well as teaching science concepts, the competitions encourage cooperation through teamwork, leadership roles, and problem solving techniques (USFIRST, 2001). These skills are not readily taught through the classroom until much later in life, but they are brought into full view for the young students, giving them vital experience early in their life and education.

Robotics competitions such as the Bot Ball tournament highly encourage the number of competitors at the events (Bot Ball, 2001). The organisers of competitions such as these are aware that more schools competing results in more students working and brainstorming to try and develop new ideas. The people at Bot Ball and many similar organizations realize the great potential behind the robotics competitions and what they represent to the future of the scientific community.

FIRST Robotics

The organization "For Inspiration and Recognition of Science and Technology" (FIRST), started in 1989, has had a single focus: "to excite more young people about the fun, accessibility, and importance of science and engineering". FIRST is a non-profit organization founded by inventor and entrepreneur Dean Kamen to interest and inspire students in math, science, and technology. FIRST works toward these goals with programs such as the FIRST Robotics Competition, the FIRST Place Science and Technology Centre, and FIRST Lego League.

The FIRST Robotics Competition is an annual design competition. Ten years ago, the FIRST Robotics Competition began with 28 teams and a single 14x14 playing field. Today more than 500 teams participate nationwide. This competition brings together young people and professionals in teams to create a remote-controlled vehicle for a sport-based playoff, the objective of which changes each year. Each team starts off with the same kit of parts and uses its creativity to design and build a vehicle capable of performing a demanding task (retrieved November 10, 2001 from www.usfirst.org).

In addition to creating a "robot", this competition gives students another important benefit -- namely, the chance to work with professionals in the field of engineering. Before they sign up for FIRST, many of the students have never met an engineer. FIRST gives them the chance to work with some of the best engineers in the country. Teams are composed of high school students, industrial engineers, and sometimes, university students. This competition can be a career moulding experience. The student speaker commented that before he joined the FIRST team, he didn't know what he wanted to do, and now he wants to be an engineer. This is just one example of how a competition like this can be a life changing experience.

FIRST LEGO League

The FIRST LEGO League (FLL) is another program developed by FIRST with a partnership from the LEGO Company. It began in 1998 with 2,000 students and has grown to 20,000 (estimated) for 2001. The goal of this program is "inspiring curiosity among 9-14 year olds in science and technology".

Each year there is a new challenge announced. These "challenges" concern a current scientific or technological problem. Teams are composed of one to two adult coaches and up to ten children between the ages of nine and fourteen. These robots must be "fully-autonomous" and capable of completing various missions developed over eight weeks. The teams use many types of LEGO parts including motors, sensors, and software of MINDSTORMS or ROBOLAB, along with a FLL kit of parts. The FLL season ends with one-day tournaments around the United States where teams are judged in areas such as research, design, teamwork, and creativity (retrieved November 10 from www.usfirst.org).

This type of learning environment encourages hands-on "experiments" and builds many skills the students will find valuable later in life. FLL coaches report that "team members learn skills such as conflict resolution, critical thinking, problem-solving, personal development, and time management". FLL coaches surveyed in 2000 reported that FLL increased the students' interest in and enjoyment of science and technology, as well as their understanding of the application of these principles in the real world. This information supports the idea that children are interested in hands-on "building" type projects.

Techno Games

Techno Games first came out on the British Broadcasting Network (BBC) in 2000. This TV program was developed by the same people who devised the United States hit show Robot Wars, where robots battle each other in a ring. Although Techno Games is the sister show to Robot Wars, it focuses on a different concept. The idea behind Techno Games is for teams of students, families, or community groups to build and compete robots in quasi-Olympic events such as high jump, gymnastics, and long jump. Techno Games is part of a movement to motivate and interest children in science and technology. Techno Games follows the official creed of the Olympic Games which states that the most important thing is not to win but take part.

Students and individuals who compete in Techno Games develop their problem solving and teamwork skills. Students often get to work with professionals from different science and engineering fields who serve as role models and can encourage students to go into science and engineering fields themselves.

Techno Games not only passes on the excitement of technology to the individuals who work and compete in the games, but it reaches children of all ages who watch the show on television. It and the many other television programs like it serve as a medium to help bridge the gap between science and technology and children today.

PIC Micro-controllers

One of our main objectives in this project is to deliver a "PIC" workshop and lesson plan to the Warren Comprehensive School. This workshop is designed to introduce the student to the Programmable Interface Controller (PIC). A PIC is defined as basically a tiny black box that has lots of inputs and outputs. It is possible to teach the box what relationships you would like to have between the inputs and outputs. To accomplish this, there must be a PC in which the instructions can be written (Lancaster, 1997). The advantages of the PIC over other types of chips for educational purposes are tremendous. First of all, the PIC is readily available in smaller quantities. At four to seven dollars apiece, this makes them economical as a teaching tool for several or even just a few students. In bulk quantities, however, as would be needed for any school workshop, the price of the individual chip drops to below a dollar. Secondly, the PIC is elegantly simple to program. There are only a few commands in the PIC instruction set, but they are very powerful and easy to use (Lancaster, 1997) -- ideal as a teaching tool for students with a wide range of learning abilities. Finally, the PIC is a very low-power device that is easily battery operated. Using this aspect of PIC's, it will be possible to create a workshop module that will run off batteries. The module will also be portable so that the students may use it more easily.

Tunnels

One of the deliverables for our project is an interactive workshop on tunnels. The workshop will incorporate concepts such as how tunnels are built and specifically canal tunnels (Islington Tunnel). To properly run a workshop such as this it is necessary to have a background on tunnel construction techniques as well as canals. A history of tunnelling and a description of the three types of tunnels is located in Appendix BB.

Canals in England

Since our workshop will be run in the canal museum, information on canals will be important in the development of our workshop. Relating tunnels in the canals to our workshop will be important and give the children a way to relate the workshop to the real world.

The development of a large inland water-transport network was, perhaps, the most important factor behind the industrial revolution in England during the eighteenth century. At first glance, the use of inland water transport in England, where rivers are not large compared to elsewhere in Europe, seems unusual. In a country no part of which is further than about 100 kilometres from the sea, road transport would seem to make more sense.

However, transport was the key to the development of these midland and northern industries, and the roads of the period were inadequate, particularly in the steep valleys. They were incapable of carrying the vast quantities of heavy materials needed to supply the growing demands of new factories. In the south of England, boats had used the wide, slow-flowing rivers for centuries, though mills on these rivers often made navigation hazardous. Further north, the rivers were faster flowing, making it more difficult for boats to use them. Instead, canals were built to overcome the difficulties of road and river transport. Thus it was that the construction of canals during the eighteenth century allowed the industries in northern and central England to develop.

It was not until 1793 that an Act was passed to authorize the Grand Junction Canal from Braunston on the Oxford Canal, to Brentford on the river Thames west of London. London was not joined directly to the national canal network until 1801 with the opening of the Paddington Arm of the Grand Junction Canal.

The Regent's Canal was built to link the Grand Junction Canal's Paddington Arm, which opened in 1801. James Morgan was appointed as the canal's Engineer. It was opened in two stages, from Paddington to Camden in 1816, and the rest of the canal in 1820. To build the canal cost £772,000, twice the original estimate. A number of basins were built such as Battlebridge basin, opened in 1822 where the London Canal Museum now stands. The main centre of trade was the Regent's Canal Dock, a point for sea borne cargo to be unloaded onto canal boats. Cargo from abroad, including ice destined for what is now the museum, was unloaded there and continued its journey on barges.

By the 1840s, railways were taking traffic from the canals, and attempts were made, without success, to turn the canal into a railway at various times during the 19th century. Then in the latter part of the World War II, traffic increased on the canal system as an alternative to the hard pressed railways. Stop gates were installed near King's Cross to limit flooding of the railway tunnel below, in the event that the canal was hit by German bombs.

By the late 1960's commercial traffic had all but vanished. The canal has since become a leisure facility with increased use of the towpath, which has been opened up to the public. Boat trips are regularly available, especially between Camden and the picturesque Little Venice in west London, where the canal meets the Grand Junction near Paddington.

Islington Tunnel is the major engineering work of the Regent's Canal. Islington Tunnel is 960 yards or 886 meters long. Tunnels were built by the process of sinking shafts at intervals to the required depth, and then lowering men and equipment down to dig, and, it was hoped, meet. Accurate survey work was essential in order to locate the shafts in the correct place and dig them to the correct depth. There were delays caused by water encountered when digging the shafts. The tunnel cost nearly £40,000 to build, a great deal more than had been anticipated.

One of the main problems with the tunnel was that it was only wide enough for narrow boats to pass inside. When larger barges met inside, it caused arguments until finally, in July 1822, two men were hired to regulate the passage in the tunnel.

The tunnel was at first operated by "legging", whereby men lying on their backs on planks aboard the boat walked the vessel through by pressing against the side walls.

This was slow, hard, and caused a great deal of delay. In 1826 a steam chain tug was introduced, one of the earliest uses of steam power on the canals. The chain was secured at each end of the tunnel and the tug pulled itself and a train of barges by winding the chain around a barrel on board. This means survived for over 100 years until the 1930s when boats with engines became commonplace.

Conclusion

This background research will serve as the basis for our project to assist SATRO in achieving its goals of enhancing young peoples' understanding of and enthusiasm for science and engineering. We next turn to discuss the methods used in this project to gather data on what captures the imaginations of young students, as well as plans for the design and evaluation of specific project and workshop ideas.

Methodology

The main purpose of our research was to promote science and technology to children. By studying and evaluating existing resources we hoped to gain an understanding of how children respond to different teaching techniques and which were most effective. We then used this knowledge in the design of two new resources aimed at engaging children and getting them excited about science and technology. These two resources were a tunnelling workshop for the Canal Museum and a four-week PIC module workshop for the Warren Comprehensive School.

Understanding What Interests Children in Science and Technology

One of the main goals of our project was to gain an understanding of which teaching techniques are most effective in stimulating children's interest in science and technology. Achieving this goal aided us in determining what makes an effective science exhibit or workshop, which we could create. This information was important when designing a project that children would enjoy and was also helpful to us when evaluating SATRO's Balloon Buggy and Robotics workshops and the BBC's Techno Games CD-ROM.

Background research was the first step in achieving this goal. We reviewed resources on effective teaching methods and the ways that children learn. Attempts at getting children interested in science through programs and workshops, particularly non-curriculum-based ones, was a primary topic of review. Focusing on these programs and projects informed us about some of the methods used in the past to promote science and technology, so that we could implement this knowledge in the design of our projects.

The next step was to record observations during the activities and workshops that we ran, such as the Balloon Buggy and Robotics workshops. We ran a total of 7 workshops. To maintain unbiased results when making these observations we developed a standard evaluation that we completed after each session, as it was very difficult to take notes while running the workshop. This evaluation was intended to help us to compare the workshops and give ideas for improvement. After completing the observations under our specific guidelines, all records were compiled and compared. These observations were intended to provide information such as ideal flow and level of instruction and pairs versus individual.

In addition, surveys of the teachers of the classes were conducted. Teacher surveys focused on obtaining their opinions concerning the intensity of interest that the children possessed in relation to (i) the students' normal behaviour in a classroom setting, (ii) whether they thought the material was appropriate for that age group, and (iii) any ideas or comments that they had on the workshop. (Appendix A) This survey was modified to include a Likert scale when we did not receive the results we expected from the first survey. (Appendix B)

After observing the Balloon Buggy workshop, we began leading them on our own. Stepping into the role of teacher we gained a different, firsthand perspective and took on the challenges of getting children motivated and interested. This helped us better appreciate what teaching methods are most effective in sparking children's interests in science and technology -- knowledge that was subsequently applied when fulfilling our other project objectives.

Although running these workshops provided valuable information, we decided to take this one step further by conducting a much more in-depth evaluation of the Robotics workshop. We chose Robotics over the Balloon Buggy because we felt its structure was more closely related to the tunnelling workshop and PIC module workshop that we designed. In particular, we felt that the Robotics workshop would provide more concrete data (than the Balloon Buggy workshop), as well as information more pertinent to the design of our tunnelling and PIC activity. For this capstone workshop, we created a much more thorough evaluation tool (Appendix C). During this workshop, our time was devoted to recording observations, while Peter Chamberlain of SATRO ran the workshop. This gave each of us (Kevin, Keith and Kim) the opportunity to work closely with specific groups of children to determine the various ways in which they approached completing their tasks as well as during which parts of the workshop the children were not on task. As observers, we divided the workshop into sections. During the session we wanted to determine two things, comprehension and engagement, in relevance to measurable behaviours that the children possessed. These measurements consisted of the number of hands raised during a section, as well as the number of correct and incorrect answers. In addition, we used a student survey at the conclusion of the workshop to assess the comprehension of the students and to determine which parts of the workshop they found most interesting (Appendix D).

Canal Museum Project

Using information gained from the Robotics workshop in particular, we developed a tunnelling workshop for the London Canal Museum. This workshop was intended to give hands-on experience with some of the technical problems that have to be solved during the building of tunnels.

The structure for our workshop was developed at a conference meeting with Margaret Gwalter (Canal Museum), Bernie Holloway (SATRO), Peter Chamberlain (SATRO), and Bob Robinson (Islington Education Board). During this meeting, we discussed the specifics of the tunnelling workshop and viewed the Canal Museum's display on the Islington Tunnel. From this conference we were able to develop the specific details for the entire workshop.

Background research was important in determining our approach to the construction of this hands-on exhibit. Our group did preliminary historical analysis on tunnel construction and methods for implementing a workshop that would stimulate children's interests. This Internet and library research provided us with historical information on various types of tunnelling techniques such as the cut and cover method, which was incorporated into our workshop.

The main constraint of this workshop was that it must be easily transportable and the lesson must be taught within an hour and a half. For SATRO's use in pre-testing, the project must fit in a standard luggage case used to transport the workshops. It also had to be fairly inexpensive and rely exclusively on reusable materials.

During the construction phase of this workshop, we tested different aspects of the project with two different groups of students in order to assess their capabilities for performing various assigned tasks and to pre-test the workshop itself. Examples of parts of the workshop that we tested included the number of pieces from which the arch was constructed, the amount of sand needed to collapse the tunnel, and the size of the tunnel constructed at the end. We gave a short worksheet (Appendix E) to each student who completed the workshop. The workshop has certain concepts that the students should have learned. The worksheet included questions on these basic concepts. We then compiled the answers by categorising them as correct or incorrect. We then analysed the data by determining the percentage of correct answers for each concept being tested. The concepts that were noted to a have lower comprehension level were emphasised more in the next pre-test. Based on these pre-tests, we modified our tunnelling project. Our workshop will be run at the Canal Museum as part of Science Week, beginning March 4, when institutions from all over the United Kingdom organise activities to promote science to children.

The final part of this project involved the creation of a leader's guide for the workshop. The leader's guide was written prior to pre-testing -- and then rewritten after pre-testing -- to more accurately describe the workshop as conducted in an actual setting. The guide is a step-by-step instruction book containing suggested teaching topics and methods of demonstrating key concepts. It assumed no prior knowledge of the subject matter.

Assessment of Techno Games CD-ROM

The British Broadcasting Corporation (BBC) has asked that SATRO evaluate the Techno Games CD-ROM, which was created by the BBC as a resource to aid in the development of a Techno Games team. We performed this evaluation on behalf of SATRO. Our team reviewed the Techno Games CD-ROM that is used by schools to teach students about robots, robot control, and methods of designing robots. As part of this assessment we visited the Barking Abbey School. They recently started a Techno Games program for year eight students, and we attended some of their weekly meetings. During these team meetings the students and the teacher reviewed ways of making parts for robots, building a robot, and adhering to the Techno Games rules. We suggested that they use the Techno Games CD-ROM to learn more about these areas. At the meetings, we obtained the students' views on its quality and effectiveness through informal questioning. While the students and teachers agreed that the Techno Games CD-ROM was helpful in assisting them to develop their respective programs, we offered advice on how to execute their program using the CD-ROM. We obtained and reviewed extensive amounts of background information on the Techno Games program and a number of similar programs through web research, observations of local programs, and interviews. In reviewing these programs, we compared their methods and determined the most effective ways of running a successful robotics program. One program of particular interest was the U.S. FIRST robotics competition. Like Techno Games, the FIRST program is designed to get students interested in science and technology by having teams design and develop a working robot that will perform a specific task in competition against other teams.

Our team attended a FIRST demonstration that was aimed at getting high school teachers and staff interested in starting a robotics team in their own school. (Appendix F) This demonstration provided us with information about the FIRST program and a sample of the different attitudes and perspectives of the people involved (teachers, students, sponsors, parents, and FIRST leaders) with a successful high school program. The observations made at this demonstration helped us understand what benefits a program like FIRST and Techno Games bring to a school.

Worcester Polytechnic Institute (WPI) has its own competitive FIRST team on campus. An interview with the head of the team, Ken Stafford, was conducted. (Appendix H) This interview was vital because of his background knowledge of the program. It provided us with information on how the WPI team has developed over the years, ways to make a good robotics program, problems they have overcome in the past, and the goals of the program. Through the interview, we also came to appreciate what aspects of a program are important when trying to keep the students interested in it, and how the program builds skills other than those needed to build robots, such as team leading and group dynamics skills.

One of the objectives of our project was to evaluate the Techno Games CD-ROM, which describes how it is run and how to build robots. We observed an existing Techno Games program conducted at the Barking Abbey School in London. By evaluating how the CD-ROM was used by the team members and team leader at Barking Abbey, who had been using it for one week when we first arrived, we were able to get informed opinions as to its effectiveness as a teaching tool. By interviewing the leader and asking for suggestions, we sought to identify improvements in the ways that the CD-ROM could present the subject matter to the students. Through interviews with the leader of the Barking Abbey Techno Games program, Steve Barlow, we sought to obtain his views on how their program had benefited from using the CD-ROM in their robot development. By observing how this school has implemented the Techno Games CD-ROM into its curriculum, we could see first-hand whether it helped or hindered the development of their Techno Games program.

By using the methods mentioned above, we have measured the success and effectiveness of the CD-ROM in teaching robotic system and design. From distributing surveys (Appendix G) and using the aforementioned methods, we gained valuable information as to how the CD-ROM could be improved, as well as what knowledge the students gained on robotic design and functionality. By questioning them and observing the concepts behind powering their robot, we could mark the use of designs and concepts covered on the CD-ROM and whether they felt that it helped to improve their design. From this information, we have developed an evaluation in the form of a report for the BBC. This gave survey results on the use and the opinions of the CD-ROM by students of the program, as well as the views of the leader of the Techno Games programme at the Barking Abbey School.

Development of PIC Modules

Another technique for grabbing the attention of students in science and technology, specifically robotics, involved the introduction of Program Interface Controllers, or PIC, modules. These modules taught the students about the basic concepts of computer memory and robot control. We started by introducing basic modules at the Warren Comprehensive, but we eventually created a four-week lesson plan of our own. Before these could be created, however, background research needed to be conducted so that we had sufficient knowledge to create useful teaching modules.

First, we read and reviewed the PIC Logicator program manual, as well as, learned how to use the Logicator software, which is used to program the PIC. Then, we practised using the software so that we would be able to teach the students and teacher how to use it.

Our background research included learning about the differences between the learning styles and interests of males and females. Because Warren Comprehensive School is a co-ed institution, we anticipated that different tactics might need to be taken to introduce the PIC modules to different learning processes, as there is between different sexes. At Warren Comprehensive School, we expected that a more general and simple module would be more successful. This would gain the attention of both males and females, whereas a more specific module that focuses on more in-depth skills and different teaching styles might sway the interest of either males or females, but most likely, not both.

We also needed to review the systems and controls requirements for key stage three in the National Curriculum. This was imperative to the development of the PIC module lessons. In order for the lesson to be incorporated into the normal curriculum at the Warren Comprehensive School, specific requirements needed to be included otherwise the lesson would have no merit. The purpose of this PIC module lesson plan is to also prepare the year eight students for the new additions to the year nine curriculum due to recent National Curriculum changes.

We had a liaison, Paul Roberts, while at the Warren Comprehensive School who, when informally interviewed, gave us a brief outline of the desired structure of the lessons. Once we gathered all of our data, we then had a rational basis for choosing, structuring and creating enjoyable, yet informational PIC module lessons. Our aim was to produce PIC modules that would increase students' interest in robotics programs specifically and ultimately increase their overall interest in science and technology.

The Evaluation and Assessment of Existing Resources

Balloon Buggy and Robotics Workshops

SATRO runs a number of workshops designed to stimulate interest in science and technology in young students. The Robotics and Balloon Buggy workshops are their most popular and most commonly run in London's local school systems. The bulk of the evaluation of SATRO's resources is focused on these two workshops. Both workshops are intended for year five and year-six primary school children and are approximately 90 minutes in length.

The Balloon Buggy workshop enforces concepts learned in key stages 1 and 2, such as pushes and pulls as examples of forces and changes that occur when materials are heated or cooled (glue gun is a good example). The students get the experience of facing real engineering problems by constructing a small balloon-powered buggy out of wood, Correx and other small materials. The workshop begins with a discussion of what engineers do, specifically designing, making, and fixing. The children are then told that for the day that they will be engineers to try to help solve a problem. The problem is introduced by showing the Shell logo and discussing petrol. Most children know that petrol is used to power cars. The discussion eventually leads to the fact that the petrol supply is decreasing. In response to this, engineers are looking for alternative ways to power vehicles and the students will be experimenting by making balloon powered buggies. A short discussion of forces is explained by blowing up a balloon and asking which way it will move when released. The explanation of the construction of the buggies is then demonstrated to show how to use the glue guns and the saws. The session ends with races to compare the buggies. After the races there is a discussion concerning the reasons some buggies were more successful than others (such as friction in the axle or the weight of the buggy).

The Robotics workshop follows the national curriculum for Key Stage two students. It teaches aspects of electrical circuits and about the use of simple switches to control a device. It is normally run in a classroom setting with around thirty students. The basic workshop sequence begins with a discussion on control systems and their uses in everyday life. Usually this leads to a conversation concerning how a thermostat uses switches to turn things on and off. Students are then given paper cut-outs and pieces of aluminium foil with which they construct their own pressure switch and then test it with a circuit board using leads to attach it. The children are split into pairs and given a robot (i.e. a buggy with a motor and battery) and are told that they can use the switch they have made to control it. The students then perform a relay race with the robots by transferring a weight (like a baton in a relay race) on the pressure switches between them. A worksheet is then given to the students to enforce the concepts that they have learned. After the children finish the first two sections of the worksheet, the teacher demonstrates how a slide switch is used and then it is explained that they are to complete a series of tasks or challenges in the third section of the worksheet. These tasks are performed with the robots. The challenges are as follows:

- Make the robot go backwards.
- Make the robot go faster.
- Make an alarm sound when it goes over something.
- Make the robot stop when it hits something.
- Make a robot stop when it hits something and make an alarm sound.

- Make the robot reverse direction if it hits something.

At the end of the session the teacher reviews how each of the tasks could have been completed and answers questions.

In order to evaluate these workshops we first observed eight (three Robotics and five Balloon Buggy) workshops that were run by three different individuals (Peter Chamberlain, Bernie Holloway, and Bob Robinson). Each of these instructors demonstrated their different personalities and teaching methods within the context of the basic structure of the workshops. In all of the workshops that we observed, the instructors each attempted to keep the children involved in the workshop at all times by having the children lead much of the discussion and by keeping them occupied with hands-on activities. The two workshops are structured differently and suggest that a great deal could be learned by observing the differences between them. More specifically, the Robotics workshop is structured so that instruction is broken up into a series of small discussions and then hands-on tasks to keep the children engaged throughout the workshop while the Balloon Buggy workshop needs very little additional instruction after its initial discussion and presentation.

Our primary objective in these first workshops was to use them as learning tools permitting us to become acquainted with the workshop environment and deepening our perception of the attitudes and roles of the people involved. In particular, we wanted to familiarise ourselves with their basic structures before we attempted to collect significant data ensuring a strong basis for our subsequent observations. From these workshops we collected very little hard data but alternatively we uncovered a primary and common goal for the assessment of these workshops. The ideal result was to recognise and develop the best teaching approaches to get and keep children engaged in a science- and technology-related workshop as well as for them to comprehend the material presented. It became evident after the first of these workshops that it would be impossible to accurately measure and represent the effectiveness of stimulating interest in science and technology from observation of sessions alone. The large numbers of immeasurable variables are apparent and clearly limit the possible outcomes of an assessment of the Robots and Balloon Buggy workshops. From these initial workshops we were able to determine the measurable dependent and independent variables that could be used to represent a subjective assessment of the workshops. We created a list of all measurable, recognizable and relevant variables from our many attempts to record significant data from these early workshops (Appendix I). This list includes such variables as:

- flow of instruction
- freedom of creativity
- introduction of concepts
- working in pairs versus alone

By examining these variables we were able to identify a number of questions that we believed we could answer. The questions gathered are as follows: How effective was the workshop in teaching the children the concepts? Do the children stay continuously interested in the activities? At what point (or with what aspects) of the workshop do they start to lose interest? In addition we could identify any misunderstandings or problems that the children had during the workshop.

To develop a more complete understanding of a workshop environment, we needed to observe the activities from multiple perspectives (i.e. student, teacher, and outsider). An analysis of each different perspective provided unique information that could not have been easily gathered from one another. Therefore we ran seven of these workshops ourselves (five Balloon Buggy and two Robotics) to obtain a teacher's point of view. We developed a method of running these workshops by a process of changing some of the independent variables each time we ran a workshop. After each workshop we would then measure the dependent variables (comprehension and engagement) through self-evaluations and teacher surveys. For example, the first time we ran the Balloon Buggy workshop we allowed each student to make his or her own buggy. As a result we did not have enough time to finish the intended activities of the workshop. In addition the children's buggies did not perform well due to poor design. From analysis of the information gathered in the first workshop we concluded that children working individually were the largest limiting factor. The second time we instructed a workshop, the students worked in pairs. This provided us with the opportunity to assess how the children performed as a result of changing the independent variables. As a teacher running these activities, we wanted to obtain as much data as possible, but it proved to be very difficult to do as the process of running these workshops occupied the majority of our time, leaving little time to record our observations. Therefore, we created a self-evaluation worksheet to be completed after each workshop (Appendix J). This evaluation tool measured general information on each class and, more importantly, described the structure of each workshop and how it was conducted. This evaluation contained important information concerning the following variables: Did students work in pairs or individually? How much direction was given to the students both before and during the workshop? Was the instruction given in pieces or all at once? Were there any restrictions on design or level of creativity? What concepts were introduced before and after the workshop? The last part of this evaluation was our self-assessment concerning the positive and negative aspects of the workshop. In addition to these self-evaluations we also developed a teacher survey to be completed at the end of each session by the teacher of the class to which the workshop was presented. These surveys contained questions concerning ideas for improvement of the workshops and sought comments on our teaching style and performance. These surveys did not provide the data on ideas for improvement of the workshop as initially intended but just small pieces of information on presentation style. All of the teachers surveyed said the children were very excited and enjoyed the workshop. We believe that the many open-ended questions in the survey provided little hard data since the teachers had little time to review and complete them as fully as we would have liked. To correct this we created a new evaluation survey containing a Likert scale. We hoped that a Likert scale would force the teacher to provide us with more definite answers.

During the capstone robotics workshop, detailed notes (Appendix K) were made concerning the children's behaviour, such as their attention span. The results from these observations showed that students tended to drift off during many of the discussions while a select few participated. We also used the modified teacher survey to obtain more specific data regarding the teacher's view of the workshop structure. Similar to the results of the majority of these teacher surveys, the opinions of the workshop had very positive responses.

The final and possibly the most important step we took to deepen our comprehension of which teaching methods provide the most meaningful and fruitful learning environment for children were discussions and interviews with experienced teachers. After many of the workshops we also conducted an informal discussion with the teacher of the class on teaching concepts. In these discussions we obtained general information on teaching techniques that we were assured would not work from their experience. These discussions often brought to light many of the limiting factors with which a teacher has to work. In many of these classes there was a broad range of children's abilities. Some children are very receptive to some teaching styles while others are not. Formal interviews were also conducted with Bernie Holloway and Peter Chamberlain. (Appendices L and M) These interviews focused on the advantages and disadvantages of different workshop structures as well as the variables that influence the success of the workshop. The information that was gathered in these interviews reinforced several of the concepts that were learned from our prior experience.

From the compilation of the information gathered we've reached some conclusions regarding the specifics of our independent variables (teaching concepts). Following is a summary of our conclusions of these variables based on the analysis of our data.

1. **Freedom of Creativity** – From our experience we concluded that when the children were given total freedom, the final results were the poorest. In the Balloon Buggy workshop when the children were given total freedom their designs tended to be mostly for appearance rather than performance. On the other hand when their creativity was very restricted by imposing a certain design structure, they were not as engaged in the workshop. This lack of engagement was evident by the decrease in

enthusiasm and motivation in comparison with the children in other workshops. In addition several of the fundamental engineering concepts were lost.

The best results occurred when the students were allowed a moderate amount of freedom. The recommended amount of freedom is dependent on age level and discipline of the child. An older and more disciplined child should be allowed more creative freedom. The limiting factor in determining the amount of creative freedom is the student's ability to recognise and apply himself or herself to complete the primary goal of the task. The best result in the Balloon Buggy workshop occurred when we allowed them the freedom to come up with their own designs; however we guided them somewhat and told them when their designs were not possible.

2. **Flow of Instruction** – The ideal flow of instruction is when the introduction and initial discussion are able to specify all of the tasks of the workshop in a clear and comprehensible manner. The hands-on or task-oriented section of the workshop is then concluded with a final discussion on what the children learned from the activity. This structure provides the easiest environment for the teacher to conduct the class. Because of the nature of some workshops this structure is not possible. Additional instruction sometimes needs to be inserted into the task portion of the workshop in order to aid the children's understanding of the concepts taught or guide them into another task session. This additional instruction tends to be much more difficult to lead and keep the children's attention. If interruptions must occur during task portions of a workshop it is import to keep their length and number to a minimum. From the results of our research we have seen students lose interest during these short

discussions. These discussions are recommended to be kept under ten minutes in length.

3. **Amount of Instruction** – We had the opportunity to see the affects of varying amounts of instruction from observing as well as running the workshops. During our research an interesting question arose. When given large amounts of instructions the students performed the tasks much more efficiently and had better physical results. Do the children obtain more from a workshop in terms of comprehension and engagement when they are guided through the entire workshop or when they are allowed to make mistakes and learn from them, not always attaining the best ultimate results? The answer to that question is a complex one much like the majority of the questions that arose while teaching.

Children feel a greater sense of accomplishment when they see a physical result from their work. This feeling of accomplishment is the most prevalent in children when they are able to achieve their task entirely by themselves. The amount of instruction in these workshops is directly related to the amount of creativity allowed. Children of an older age possessing a greater knowledge and deeper intuition can be given much less instruction than a younger child who struggles to understand key concepts of the workshop. This perception became extremely apparent to us from our observations and instruction of the Balloon Buggy workshops to children of different ages. Similar to freedom of creativity, the limiting factor in determining the level of instruction given to a student is their ability to recognise and apply themselves to complete the goal or task. In the development of a new workshop, a trial-and-error method can be used to determine the optimal point where the children are pushing the limits of their abilities to comprehend the concepts involved.

4. **Group vs. Individual** – There are different advantages to having students work either as individuals or in groups. Students, when working alone, tend to have a greater sense of accomplishment than working in groups because they as individuals can create and complete the final end result themselves. When there is a large group, there is a greater chance that a more retracted member of the group will not actively participate in the workshop. On the other hand, when working in groups students can accomplish more difficult tasks by working as a team. In many classes, students have a wide range of natural ability. If the students were to work alone some of the students might fall behind the rest. In a situation where the children are in pairs or groups, a child of lesser ability could be carried along by a stronger group member and not slow down the progress of the class.

When we instructed the Balloon Buggy workshops we originally let each student make his or her own buggy. When we did this, the progress of the workshop was slowed down and there was little time to complete everything originally intended for the workshop. There were parts of the workshop that were full of dead time when most of the students waited for slower individuals to catch up. During this "dead time," the students' initial excitement got out of control and they became very difficult to manage. When the Balloon Buggy workshop was run for students to work in pairs, this "dead time" was dramatically decreased and there was plenty of time to complete the intended sections of the workshop. When the students work in pairs or small groups, the task of managing the class can be somewhat subdued.

5. **Classroom Environment** – This factor has an impact on the attention span of the children. When children are gathered together in a hall or sitting in an open space in a classroom it is easier to keep them engaged rather then when they are sitting at their seats. In a hall, a teacher can keep children actively involved in discussion for thirty to forty minutes, but when they are at their seats in a classroom, open discussion is difficult to lead for more than ten minutes. In most primary schools students are seated at large tables with other students. This environment is good for the task portion of a workshop because the students can work together, but it is poor for a discussion session. If it is necessary to readdress the class, it is important to minimise the items that could cause distraction to the children. Physical items that the student might be tempted to play with are the largest recognisable source of distraction during discussion. The Balloon Buggy workshop is conducted in a hallway and the Robotics workshop is instructed in a classroom. Since there are fewer distractions in a hall the children are less likely to be distracted by their surroundings.
6. **Amount of Preparation** – Preparation is very important when running a workshop. If the instructor is not fully prepared before the workshop or before transitions in the workshop, "dead time" is created. Classroom management becomes increasingly difficult when children are constantly taken out of engagement of the workshop because of gaps between sections of the workshop. A possible technique to avoid these gaps between sections is to have a group of students or helpers set up the next section while the instructor continues teaching.
7. **Number of Instructors or Helpers** – A workshop can run much more smoothly with a larger number of helpers. It is very difficult for one teacher to satisfy needs of

several groups of students when they all have different questions. In addition when there is more than one person instructing the class, concepts can be presented more clearly to the student by having one instructor actively involved in discussion while the other writes or draws concepts on the board therefore, avoiding any "dead time".

8. **Student Ability** – The student's ability to understand the concepts presented determines what a child can get out of a workshop. In many cases the students are not prepared with the knowledge needed for some of these workshops. The process of lowering the learning curve of the workshops for these students in many cases, hinders the primary goal of the workshop.
9. **Student Behaviour** – Having a class that is well disciplined is an important aspect of running a successful workshop. In many of the workshops we instructed, the students were already very well disciplined and the workshop ran very well. However, in schools where discipline levels were low, the workshop structure began to fall apart. Some children will stay engaged in a poorly structured workshop while others are difficult to control in any setting. If the instructor is unable to keep the children's attention then it is almost impossible for the students to get anything beneficial out of the workshop.
10. **Teacher Experience and Ability** – This is by far the most important variable to get students engaged and keep them interested in a workshop. The teacher's ability to know, implement, and expand upon the prior teaching concepts in the classroom is essential to provide a stable atmosphere in which the children can work.

We ran and observed these workshops not only to deepen our understanding of which teaching techniques are most effective, but also to provide SATRO with an evaluation of both of these workshops. (Appendices N and O) We formatted the comparing the results from each of our teaching technique to the leader's guide and how the workshop is currently run. We also included our own comments and suggestions for each workshop.

By running the Balloon Buggy workshops using different methods in terms of structure and instruction we were able to compare them and determine which method was most effective. In the end our most effective workshop was run in a manner very similar to the way we saw Bernie Holloway run it. We recommend that the children work in groups (in the leader's guide it says to make no more than thirty buggies per class) during this workshop. We do not think there is sufficient time in the workshop to make thirty buggies. In our experience between eleven and fourteen buggies made per class was enough. We also feel that all of the instruction should be given at the beginning of the workshop. Overall, the Balloon Buggy workshop is fairly straightforward and needs very few modifications.

From observing and running Robotics workshops we have noticed that the focus is different than in Balloon Buggies in that Robotics is more of an educational workshop rather than for entertainment. We feel that the best method for discussion is to have the children seated together in a group on the floor. We recommend this method be used for the pre- and post-workshop discussions when possible. This method limits distractions and makes the children feel more involved in the discussion. We also believe that limiting the number and length of breaks (stopping to give instructions) in the workshop be kept to a minimum. Constant starting and stopping makes it difficult to keep the students attention as well as regain their attention to introduce a new part of the workshop. We think that the portion of the workshop dealing with the relay race is somewhat out of place in a workshop of this nature, as it is more of a fun exercise than a learning one. We would consider cutting down or eliminating this portion of the workshop. We would also have the demonstration of the line following robot at the end of the workshop. In our experience the children were very interested in this robot and this gave us their attention for the final discussion. Our final suggestion would be to better explain how robots are used in the real world. From our post-test survey results we found that many of the students were unclear how robots are used in the real world. Other than these minor suggestions we feel that both of these workshops are very well organised and are excellent tools to bring science and technology to young children in an interesting and exciting manner.

Assessment of the Techno Games CD-ROM

We evaluated the Techno Games CD-ROM and its use in the development of a robot in the Techno Games program at the Barking Abbey Comprehensive School. By gathering opinions from team members that are already interested in robotics, as well as from Steve Barlow, the leader of the team, and then evaluating their respective program, we have gained a better understanding of what aspects of teaching resources might keep the students interested in the subject matter.

From observing the Techno Games team meetings at the Barking Abbey School, we've learned about effective ways of maintaining the students' attention once they become interested in an activity, which can be applied to new and existing teaching resources. We knew that these students were already interested in science and technology, or at least the robotics aspect, because they have already voluntarily set aside time to devote to the Techno Games team. However, we wanted to learn to keep them engaged in the activity once they became interested in it.

At the meetings, Steve Barlow reviewed each robot design only giving constructive criticism and positive reinforcement, therefore allowing for a very positive environment. Each session included demonstrations of the machinery that would be used when making a robot as opposed to only including lectures. This enforces the hands-on and interactive methods that we have used while trying to grab the attention and interest of students. With these robot designs he also allows the students to have as much creative freedom as they like, as long as the robot is feasible. The students have shown much pride in their designs, which also gives them a sense of accomplishment because they have created their design. The enthusiasm and devotion that the team members have shown at the weekly meetings indicates that the methods used by Steve Barlow are effective in maintaining the interest of the team members. Therefore, the information gathered from these observations gave us a basis for comparison for evaluating the Techno Games CD-ROM because we had seen first-hand which methods were effective in maintaining the students' interest. We also have deepened our knowledge and experience regarding aspects of the different teaching concepts, like hands-on versus and lecture and level of creative freedom, from these observations.

From the Balloon Buggy and Robotics workshops, we have learned of effective ways of grabbing a student's attention to get them interested in science and technology, but the Techno Games programme meetings have given us new knowledge on keeping the students' interest. The methods that were used by Steve Barlow during the meetings to keep the children interested were exactly the same as the ones that were used to get them interested. In our experience, we have seen, as well as used, certain teaching concepts to get a child's attention, but from our Techno Games experience, we have learned that children will stay engaged in a science activity by further delivering material using these concepts. From the survey given to the members of the Barking Abbey Techno Games team called the "Critic's Worksheet" (see below), we learned that the two students who did not know much about the Techno Games programme were also the only ones to agree that the CD-ROM had plenty of interactive activities to use. On the other hand, all of the other students, who knew more about the programme, disagreed which means that they thought there should be more activities with which they could interact. To us, this indicates that the former students who were just learning and getting interested in the programme were satisfied with what the CD-ROM had to offer. However, the students that knew a lot about the programme thought that the CD-ROM could provide more because these students need more stimuli whereas the other members were still running on their initial stimuli. From this information, we conclude that getting the students interested in science and technology is just the initial stage of paving the way toward more future engineers. It is important for the teacher to keep stimulating the student so that they do not become uninterested and quit.

In order to evaluate the use of the CD-ROM as an effective teaching resource, we decided to also gain the feedback of the users of the CD-ROM, namely the Techno Games team members and their leader. Each student on the team was given a CD-ROM to review at home and then we informally interviewed them as a group, which gave us their first impressions of the CD-ROM. During this group interview, the members told us that they thought that the CD-ROM was very exciting because it had interesting video clips and images that stimulated them to continue looking through the information. Four of the five team members that had used the CD-ROM suggested that it could be improved by adding an interactive activity where the user could create their own robot on screen and then compete with it. When we mentioned that the CD-ROM has a link to the website http://www.bbc.co.uk/robots where you could create your own robot, they replied that they either did not use the CD-ROM while connected to the internet or that they still wished it was on the CD-ROM itself. Overall, the response that we received indicated that the students valued the information that the CD-ROM had to offer and that they enjoyed using it as well.

Because we wanted more specific and more structured information regarding the students' opinion, we incorporated the use of a Likert scale into a "Critic's Worksheet" for the team members to complete. The questions asked of the students aimed to retrieve their opinions on specific aspects of the Techno Games CD-ROM, such as the appropriateness of video clips, in an unbiased manner. The "Critic's Worksheet" also reinforced the opinions given during the interviews. At that point, six of the eight students that made up the final team had used the CD-ROM.

Also, three of these six members suggested (reinforcing the interview results) that the opportunity to build a robot and then race it should be provided. Two members said that the CD-ROM needs no improvement and offered no suggestions to make it better, and one student mentioned that there should be more games and more colourful graphics on the CD-ROM. These survey results give us a better understanding of what students want in a teaching resource.

Each week the members of the Barking Abbey Techno Games team must present a new or improved robot design. We reviewed all of the students' robot designs at each meeting that we attended so that we could monitor their progress and learn of any incorporation of design tactics that were inspired by knowledge gained from the CD-ROM between each session. Some of these designs were products of the student's imagination or experience, but some of the ideas come from the robot designs that they had seen on the CD-ROM. We examined each student's design with the objective of gauging from where the inspiration for these robot "blueprints" had come, for example, from the leader's suggestion, the students themselves, or the CD-ROM. We were particularly interested whether the source of that inspiration was the Techno Games CD-ROM. When the student successfully created a robot design using information that they learned by using the CD-ROM, we interpreted that as a measure of success or effectiveness of the CD-ROM as a teaching tool. From compiling the "Critic's Worksheet" we learned that while most of the students (five of six) agreed that the CD-ROM had many design ideas, no student took many ideas from the CD-ROM. Four of the members got some ideas and two took no ideas from the CD-ROM.

We also relied on the leader of this Techno Games team to supply information regarding possible improvements in the CD-ROM design as well as the aspects that he viewed as beneficial. Interviewing Steve Barlow, the Techno Games leader for Barking Abbey, allowed us to gain a different perspective, which comes from his years spent teaching children and using various teaching methods to grab a student's attention and keep it. His comments will aid in making the CD-ROM a better teaching tool for the Techno Games program. During the interview (Appendix P), he expressed his positive feelings towards the CD-ROM. He viewed the CD-ROM as an efficient learning tool for the students because it broke the material down into smaller, easier to understand segments, but he mentioned that it only taught the basics and did not go into depth regarding the actual engineering. From his previous experience with Techno Games, he knows how difficult some of the concepts become. He was able to foresee that there would be a lack of information when the team needed to learn about the more technical aspects of engineering. Also, he agreed with the students when they suggested that there should be some type of interactive activity, like a "robot workshop" where you can build a robot on the computer screen. In general, Steve Barlow thought that the Techno Games CD-ROM proved to be effective when used as a starting point for learning about Techno Games and the engineering of a robot.

All of this information has helped us to come to a conclusion regarding the effectiveness of the CD-ROM. In accordance with the results of the interviews and surveys, we conclude that the Techno Games CD-ROM is effective as a learning tool for beginners. Every user that we have interviewed or surveyed thinks of the CD-ROM as a high-quality resource with helpful information.

These interviews and evaluations allowed us to obtain feedback from the users, as well as suggestions for improvement to be relayed to the designers of the CD-ROM. This feedback and these recommendations will be delivered in the form of a report to the BBC (Appendix Q).

Recommendations that we have gathered to aid in the improvement of the Techno Games CD-ROM include incorporating some type of "robot workshop" where the user can build the parts of a robot, assemble those parts to create their own robot, then allow the user to compete in different events. Another suggestion is to cover the engineering of a robot more thoroughly so that when the team's robot has passed the initial stages of creation, the students can refer to the CD-ROM for even more help with engineering specifics. With these improvements, we believe that the CD-ROM will become even more effective as a teaching resource and as a learning tool.

Evaluation of Newly Created Resources

Canal Museum

One of the objectives of this project was to build a workshop for the London Canal Museum. This workshop was intended to give children hands-on exposure to the technical problems that occur during the construction of tunnels.

The workshop consists of an opening discussion, three hands-on activities, and a concluding discussion on the concepts learned. The workshop begins with a discussion on why tunnels are made and how they affect our lives. Four children are then given the opportunity to attempt to build a tunnel through wet sand in front of the rest of the class. The intended idea for this activity is that the tunnel will collapse while the children are digging though the sand. This physically demonstrates to the children the need for a support system in order to keep the tunnel stable. The collapse of the tunnel leads into a conversation on different shapes of tunnels and why the arch is the strongest structure. To reinforce the concepts discussed a diagram is drawn that shows how the forces act on an arch, rectangle and triangle shaped support systems in a tunnel. This is also shown by bending a thin piece of cardboard (or paper) into the shape of an arch and then pushing down on it.

The students are then divided into groups and given a pre-cut set of wooden pieces that form an arch when assembled. Each group of students receives a different set of blocks with a different number of pieces to each arch. Some children build the arch on the desktop while others are given wooden forms to build on. The arches come in three sizes (7, 11, and 15 pieces). The complexity of the largest arch (15 pieces) makes it very difficult and almost impossible for the student to construct. This leads into a conversation of why the arches with seven pieces are much easier to construct as well as why real tunnels could not be made this way. The concept of a framework that is used to support the arch while it is being built is introduced and discussed with the students. In the third part of the hand-on section the students construct their own tunnel using small bricks and mortar around a plastic framework. Each student makes his or her own small arch (approximately 12 bricks) on a cardboard base. The students who make their arches very well are allowed to take them home. The workshop is concluded with a discussion on the Islington tunnel and how its construction relates to what was learned in the workshop.

The workshop was pre-tested for the first time with a group of seven year-six students in a science and technology after school club at the Prior Weston School. (Appendix R) The workshop was a general success with a few minor problems. At the conclusion of the workshop we handed out a short survey testing the concepts the students had just learned in the workshop. This workshop was intended to give us more of an idea of the technical aspects such as how long the workshop would run and what the ability of the children to accomplish the tasks during the workshop. This pre-test was important in determining the technical aspects of the workshop that needed changing.

We then compiled a list of ways to improve the workshop. These methods included using more examples that the children could relate to (such as the Tube), using pictures of some of the machinery and tunnels, and using less technical terms. Amount of instruction was another variable that was inspected in this pre-test. We found that more instruction was needed in the final part of the workshop as a few of the children were confused about the support and put the mortar directly on it. We also developed ideas for improving some of the equipment used, such as the wooden bases on which the arches are built. From this information we decided to change the bases by gluing the first pieces of each side of the arch to three of the bases. We would then have three children try to build the arches using the base with the glued pieces and three others would build the arch directly on the desk. While this pre-test gave us valuable information it was determined necessary to per-test the workshop with a full class of students to examine the problems that could occur within a large group of children.

The workshop was pre-tested for a second time with a class of twenty-eight year-five students at St. Mary's Primary School. (Appendix S) This experience gave us a much clearer perception of how the workshop should be instructed both in a classroom and during Science Week at the Canal Museum. We discovered many additional teaching techniques that are needed not only to keep the attention of the students, but also to keep control of the classroom. As we learned from running Balloon Buggy and Robotics workshops, if the instructor does not have complete control of their class many of the intended lessons of the workshop can be lost. The first teaching technique deals with flow of instruction. During the second pre-test it was very difficult to manage the class while trying to intersperse higher level discussions within the hands-on portions of the workshop. Once the children left the carpet (where we had the opening discussion with them) and went back to their seats, they began to get distracted and not pay attention to instructions. One possible solution to this problem is to give the children a much deeper instruction initially outlining everything they will be doing in the workshop. This would give the children a much better idea of what to expect during the rest of the workshop so that they would be less likely to lose interest or become distracted. A suggestion we received when talking with the classroom teacher, Mr. Smith, was to use the resources of two instructors more efficiently. While one instructor is in active discussion with the class the other could be writing and drawing concepts on the board or setting up the classroom for the next section of the workshop. In addition Mr. Smith mentioned that having the children write their answers on the board allows them to feel that their answers are important and will make them want to answer more questions. The main problem that arose in this pre-test was that it was difficult to keep the children's attention between tasks. We also encountered one of the same problems as during the first pre-test. The amount of instruction given in the final part of the workshop (when the children build the arches out of small bricks) was not sufficient. Applying the mortar to the bricks should be demonstrated to the children instead of just verbal instruction.

Following the workshop we had the class teacher fill out a survey with suggestions for improving the workshop. This survey provided many helpful ideas such as an instruction sheet for each student so they could follow along and would be less likely to build their arch incorrectly. He also included a suggested outline of the entire workshop. He split the workshop into three parts; Part 1: Share Learning Objectives (vocabulary, sand demonstration, build wooden arches); Part 2: Explain and complete individual tasks; Part 3: Evaluation. In addition he provided us with some notes on classroom management issues. This survey provided many good ideas for improving our workshop.

From these two pre-tests and our own experiences of running and observing other workshops we made modifications to our workshop and created a leader's guide. (Appendix T) The leader's guide gives step-by-step instructions for running the tunnelling workshop. The guide assumes minimum knowledge of the subject matter and gives suggestions for possible discussions.

From these two pre-tests and our observations of the Balloon Buggy and Robotics workshops we have created a list of recommendations for how the workshop should be run. The first is that an outline of the entire workshop should be given at the beginning. This gives the children an idea of what to expect during the workshop so they are less likely to lose interest from not knowing what they will be doing next. Another recommendation we have is to keep discussions to a minimum when the children are at their desks (as opposed to speaking with them in a group on the carpet). This goes along with our previous comment on giving an overview of the entire workshop at the beginning. If the children do not know what they will be doing when they get to their desks, they are more likely to become distracted and loose interest. It is also very difficult to regain their attention once this happens. The final point we would like to address concerns the final part of the workshop. A demonstration of the construction for the final arch should be given. We have found this to be the most difficult portion of the workshop to explain and many children become confused and make the arch incorrectly. Providing a demonstration would hopefully avoid this problem.

PIC Workshop

We created a PIC workshop (Appendix U) for year-eight students at the Warren Comprehensive School. The lesson plans (Appendix V) that we constructed allowed for a four-week workshop on PICs and the PIC Logicator Program. These lesson plans consisted of main objectives for each lesson in accordance with the National Curriculum requirements (Appendix W), a leader's guide to assist the teacher, a student worksheet for each lesson, two homework assignments (Appendix X), and a final project (Appendix Y). We designed this workshop so that it may be used in future years, but also so that it can be modified to meet any changes in the National Curriculum standards.

During Key Stage 3 there are certain requirements that must be covered in the syllabus. As part of the challenge of making this PIC module workshop, we had to include these requirements. Some of these obligatory subjects include systems and subsystems, the importance of feedback in control systems, and how to use computers to control systems.

A contributing factor to the PIC module workshop structure was the incorporation of knowledge that was learned while running and observing the Balloon Buggy and Robotics workshops. The teaching concepts that we learned from these workshops affected the decisions that were made when creating the lesson plans for the PIC module workshop. Such concepts included the flow of instruction, classroom environment, level of preparation, and freedom of creativity.

The first lesson plan was created with certain aspects of these concepts. The students needed to work in pairs because of the number of available computers. The teacher started the workshop with a review of the students' prior lesson on inputs and outputs while they were sitting at tables. Then we gave an overview of how to create a flow sheet using the PIC Logicator program while the students were gathered around one computer. We demonstrated one specific flow sheet and then asked the students to create the same one as practice on their own computers. After completing that task we asked them to gather around the computer again so we could describe the concept of a continuous loop. Then the students went back to their computers again and we gave them a worksheet to complete with four different tasks. The first two showed the exact structure of the flow sheets and what they were supposed to look like so they could practise the construction of a flow sheet. The last two tasks forced them to create the flow sheet on their own. Each pair had to raise their hand when finished with a task so that one of the teachers could tick the corresponding box, therefore indicating that they had completed that task (the teacher had to make sure that it was constructed correctly before ticking the box). All of the pairs completed the first three tasks and eight of nine groups finished the entire worksheet. Two of the groups asked for more tasks to complete because they finished the initial four tasks with time to spare. We reserved ten minutes at the end of the workshop for a review discussion on the concepts learned during the lesson. There was ample time at the end of the workshop for an adequate discussion, in which the children were very enthused.

The flow of instruction used in the PIC module workshop was directly influenced by our experience with the Robotics workshop. Because the setting of the PIC workshop is in a classroom, just like the Robotics workshop, we were influenced to keep the flow of instruction the same. In the classroom setting, there are several ways that students can get distracted during a lecture. Therefore, we learned that it is important to give small interspersed lectures so that the students need to pay attention for only a small duration of time. This is also pertinent because there is a large amount of instruction to be delivered. The children need more than one lecture at the start of the workshop in order to absorb all of the information, therefore supporting the interspersed lecture method. From our research, we found that talking for a long period causes boredom and creates an environment where the children are more likely to lose focus.

Another concept that was considered when designing the PIC lesson plans was the influence of the learning environment on the students' interest in the subject matter. While in the computer lab, the students are seated in front of the computer where they can use the Logicator software and discuss the topics they are learning while using the program, as opposed to a regular classroom environment where only lecture occurs. Not only does this stimulate the learning of the program and concepts, but the student's attention to the subject matter is still kept by having them strive toward an attainable goal. The worksheets that we created can also be extrapolated on to challenge the students who finish the tasks with ease. In fact, some pairs of students during the pre-test finished the class worksheet very quickly and required more tasks. This allows each student to achieve despite their academic level.

The level of preparation in the subject matter was another concept that we applied from the Robotics program. The students that participated in the pre-test of the PIC lesson plan had not studied the subject that was covered in the workshop whereas in the Robotics workshop they had previous teaching regarding circuits. Because the students had little knowledge of systems and controls, we gave a brief introduction where we explained these concepts by relating them to their previous lessons on inputs and outputs. Only a small review was conducted during the Robotics workshop because of the students' prior knowledge. According to Paul Roberts, a teacher of technology at the Warren Comprehensive School, if the students do not understand even the most basic aspects of the workshop, they will not be able to follow the activity, and will immediately lose interest (personal communication, Paul Roberts, 19 February 2002). Therefore, it was important that we ensure that the students were prepared so that they saw a relation to other knowledge and that they did not lose interest.

As commented by Paul Roberts, students lose interest when there is no incentive or reward at the end of the workshop (personal communication, Paul Roberts, 19 February 2002). Therefore, the idea of a final creative project was suggested with very few boundaries imposed. The purpose of this is to implement a level of creative freedom to maintain the students' interest. When the students are all finished with their projects, to be given during the last lesson, the most creative and functional program of a PIC made by a student will be used in the PIC display case in the school corridor so that the other students may interact with it, therefore giving the creator a feeling of accomplishment and pride.

To learn what level of comprehension the students reached, we created a worksheet for each of the lessons. We formatted these worksheets so that a box had to be ticked by the teacher or one of the helpers before the students could proceed to the next task. This forced the children to prove their comprehension of each task before we allowed them to continue. During our pre-test of the first lesson plan, we used one of these worksheets and only one group did not complete the entire set of tasks. This was a good indicator that the bulk of the students comprehended the lesson.

Even though we had made the preliminary decision to run the workshop using these techniques, we still wanted to evaluate the appropriateness of this in the workshop. Time permitted that we only pre-test the first lesson plan. The Warren Comprehensive School uses a teacher's evaluation sheet which they agreed to complete in order to give us feedback on our PIC module lesson plans and the pre-test of the first workshop. From these evaluations, Paul Roberts conveyed that he thought that our lesson plan completed the task of teaching the appropriate material in a clear and concise manner. He offered a few recommendations for improvement on the format of the leader's guide.

In addition to the teacher's evaluation, we also completed a self evaluation (Appendix Z) of the first lesson of PIC workshop. The purpose of the self evaluation was to compile our feelings toward the workshop and then revise the lesson plan as we saw fit. From our perspective, we thought that the pre-test of lesson one was effective in teaching the basic concepts of systems and controls. Every student surpassed the minimum level of comprehension for which we strived and in general they were very attentive during the lectures. The children were especially pleased when they completed the flow sheet and obtained an immediate result, which enforces the idea of a hands-on workshop rather than one that contains only lecture, one of the basic teaching concepts that we have learned through the evaluation of the existing resources.

Conclusions

During this project we attempted to determine and evaluate what makes a successful science and technology educational program. We broke it down into two scientific variables (comprehension and engagement). By definition comprehension is "the act or fact of grasping the meaning, nature, or importance of understanding" (www.dictionary.com). The only known way to measure comprehension is through testing an individual's knowledge of the subject in question. This can be done in a number of different ways; survey, interview, and observation. To engage, by definition, is "to attract and hold the attention of" (www.dictionary.com). Unlike comprehension, engagement can only be measured by observation. From a scientific standpoint, observation can be a very subjective measuring device. We recognise that most of our results could be considered subjective. We conclude that in a project such as this, it is impossible to conduct a true scientific experiment and then produce non-subjective results.

During the evaluation of this project there were several trials and tribulations that hindered our development. The largest struggle in this project was to satisfy the needs of both our sponsors and the WPI Interactive Qualifying Project at the same time. From the beginning it became clear that there had been a lack of communication between the sponsors, liaisons, and students. SATRO initially wanted, as noted in both Peter Chamberlain and Bernie Holloway's interviews (Appendices L and M), a reduction in the backlog of Balloon Buggy and Robotics workshops with the addition of newly created teaching resources. From the instruction of SATRO staff we divided the workload into two groups of two. At the beginning we thought splitting into groups was a good idea but after going through the experience we discovered that it was not most beneficial to our success. As discussed earlier in the report, two of us evaluated existing SATRO workshops as well as developed a new workshop for the Canal Museums while the other two evaluated the Techno Games CD-ROM and developed a series of PIC modules all in real time. This environment thinned out our resources and hindered the creative development of both the Canal Museum workshop and the PIC modules. Coming from an engineering student's viewpoint, the teachers' perspective is far different than ever expected. The intangible teaching concepts learned could never have been recognised through mere study alone. Because of this we were ill prepared for the creation and development of new teaching resources. In an ideal situation, we would have completed the evaluation and learned existing resources prior to creating new resources. However, in reality we learned the basic teaching concepts discussed earlier in our report from the creation process as well as the assessment of existing resources.

As discussed in our results and analysis section we determined that it was necessary to view a science and technology education program through multiple perspectives (teacher, observer, and student). We have already discussed the roles of the teacher and the observer that we played in the development of this project. Our perspective as a student can be recognised when you push yourself away from the table and see the role that we play as students in this IQP program. We have discovered vast numbers of difficulties that have deeply affected our success in the program. The lack of communication (amount of instruction) in defining a common goal between the liaisons (instructors), the advisors (helpers), and us (students) early in the project provided a less admirable final result. The question arises, similar to the one in the list of teaching concepts; do the students gain more from a workshop in terms of comprehension and engagement, the measurements of success, if they are allowed to make mistakes and learn from them, not always attaining the best ultimate results? In the project we definitely made mistakes, but were they totally our fault and if not, does that make them acceptable? All we can say is that out of all the groups at this current London IQP site, we might not have the most data from our data collection methods and the most aesthetically pleasing end result, but we would argue that we learned and gained the most from this experience.

Recommendations

The most useful information that this group can give from the process of creating our final deliverables is a recommendation of how an IQP team should tackle a project such as this one.

Division of group was not a wise idea in this or any other type of IQP project. Divisions lower the amount of time that the students posses to work on critical thinking. Often decisions have to be made without complete group feedback because one half of the group is not as engaged in that part of the project.

IQP students should obtain extensive background research on teaching methods and learning styles prior to arriving to the project site. Observational research should begin immediately upon arrival. Construction and implementation of a detailed protocol of recording these observations should be made. This protocol should outline all of the indicators of the variables that are observed. In addition, a list of all of the independent variables upon which the measured variables are dependent. A large number of observations should be made and compiled for evaluation. In teaching, unlike engineering, we discovered that there are no definite answers. From an experiment like this, one can only obtain minimal results. The most valuable information that you can gather is from interviews with experienced teachers. From their extensive background in this area, they can provide more insight into the effective methods for connecting and communicating with the students. Teaching is not a science...it is about communication (personal communication, Gregory Theyel, 27 February 2002). If you cannot communicate with the students, then you fail to give them the opportunity to comprehend the lesson.

The deliverables for a project such as this should be common in nature. A gap between the themes of the deliverables creates a problem with project and time management.

Appendix A

Evaluation of Workshop

1. Was the introduction appropriate?

2. How could it be improved?

3. Do you feel the material covered was appropriate for this age group? If not, what age group would benefit from this workshop the most?

4. How was the length of the workshop? Was it too long/short?

5. How would you rate the students' enthusiasm for this workshop compared to their normal classroom behaviour?

6. Can you suggest any ways we could improve this workshop or any other comments?

Appendix B

Teachers' Survey

Strongly Agree - (SA), Agree - (A), Not Sure - (N), Disagree - (D), Strongly Disagree - (SD)

Introduction and opening discussion kept the children interested.

(SA) (A) (N) (D) (SD)

From your experience rate the quality of normal behaviour your class possesses in the classroom setting.

(Very Good) (Good) (Average) (Poor) (Very Poor)

The material covered was appropriate for this age group.

(SA) (A) (N) (D) (SD)

If not, what was not appropriate?

Was the workshop was an appropriate length?

(Too Long) (Just Right) (Too Short)

At all times during the workshop the children seemed interested in the workshop.

(SA) (A) (N) (D) (SD)

During this workshop the children were very enthusiastic compared to their normal classroom behaviour.

(SA) (A) (N) (D) (SD)

Have you had this workshop run in one of you classes before?

(Yes) (No)

Did the workshop meet you expectations? Why or why not?

Would you recommend this workshop to a teacher in another class or school?

(Yes) (No)

Can you suggest ways we could improve this workshop and how it might be presented better?

Appendix C

Robot workshop observation sheet

Location:

Number of student: Boys: Girls:

Room description:

Instructors name: Experience giving workshop:

Number of workshop helpers:

Section type	Elapsed time
#1 introduction (discussion)	
#2	
#3	
#4	
#5	
#6	
#7	

Number of groups: Sizes of groups:

How are groups decided:

Additional comments:

Questions asked by teacher:

#1____

#2____

#3____

#4____

#5____

#6____

#7____

#8____

#9____

#10____

#11____

#12____

#13____

#14____

#15____

#16____

#17____

#18____

#19____

#20____

#21____

#22____

Answers for students:

Question #	Sec. #	Number of raised hands	Correct answer	Incorrect answer

Students showing characterises of disinterest in the workshop (i.e. heads down, talking about unrelated martial, Eyes not focused on the teacher, playing, or anything indicating not paying attention)

- record activity and elapsed time
- questions asked by students

Section #

Section #

Section #

Section #

Section #

Section #

Section
Challenges sections
(problem group had, how much help did you give, question they had, point at which stopped working on task- what where they doing)
Group #1

Group #2

Group #3

Group #4

Group #5

Appendix D

Post-workshop questions for Capstone Robotics session

1. What is your favourite subject in school?
2. What was your favourite part of this workshop?
3. Do you think this workshop has changed your view of science as a possible career?
4. How far did you get in the list of challenges?
5. Draw the symbol of a battery, motor, and switch?
6. Draw a circuit.
7. What does it mean if a circuit is open/closed?
8. Do you know what you would like to do when you grow up?
9. What is a robot?
10. Give some examples of robots.
11. How does a robot work?
12. How are robots used in the real world (i.e. not robot wars)

Appendix E

Worksheet for Tunnel workshop

1. Which one of these 3 arches is the strongest?

2. Show how the forces are distributed in this arch when a weight pushes down on the top (such as a person walking on it).

3. How would you dig a tunnel through a very soft material such as mud with out it collapsing on you?

4. Why are there always an odd number of stones in an arch way?

5. If you were designing this workshop what would you change?

Appendix F

FIRST Information Session
Nashua, NH
November 17, 2001 3:00pm

The FIRST Information session was held to get teachers interested in starting a FIRST team at their respective high schools. The history of FIRST and how it has grown over the years were among the topics covered during this seminar.

There was a panel discussion composed of five different people who gave their perspectives on the FIRST program. This panel consisted of a representative from FIRST, a student from Nashua High School's FIRST team, a team leader from Nashua High School's FIRST team, a parent of a FIRST team member, and a representative from BAE Systems, the corporate sponsor of Nashua's FIRST team.

The representative from FIRST gave an overview of the history of FIRST, highlighting the founder, Dean Kamen. She also gave facts about the company and a description of FIRST's growth over its eleven-year lifetime.

The Nashua High School senior joined the FIRST team as a freshman and described his experience with the team as "fun" even though being a member requires many hours of work. The student expressed his desire to go to a university after high school to become an engineer. According to this student, before he joined FIRST he did not know what he wanted to study in college, but FIRST helped him make that decision. His job as an intern at BAE Systems in Nashua, NH also helped to shape his decision to become an engineer. He acquired this internship because of BAE Systems' involvement in Nashua's FIRST program.

A physics teacher from Nashua High School, also the team leader, offered a perspective on the FIRST program. He stressed that the teachers/team leaders, not just the students, need to commit a great amount of time to the team. He told how the students need to keep a minimum grade average to be eligible as a team member, but also mentioned that Nashua High School is thinking of starting a FIRST class for the students to implement the FIRST program into the school curriculum.

The parent perspective was offered by a programmer from Alta Vista, who has a daughter involved in the program. He and other parents offer their extra time to help the students and teachers with their robot. Through this help, he has been able to observe firsthand how the program has affected his daughter. The FIRST program gave his daughter better team skills, experience in a team setting, and of course more knowledge of science, technology, and engineering.

The fifth and final perspective came from a representative of BAE Systems, the team's corporate sponsor. He gave advice on how to gain a corporate sponsor for a team. Also, he expressed his feelings toward the FIRST program. In the summer of 2001, he and his company hired high school students from the FIRST team in Nashua as full time interns. This was the first time that they had ever done this and the representative made it clear that BAE Systems was very pleased with these interns. He credits the FIRST program for giving these students the experience and knowledge that they needed to be successful in these internship positions.

The session ended with a robotics demonstration from two different teams (Nashua High School and Merrimack High School). They simulated a competition situation.

Appendix G

Techno Games CD-ROM Critic's Sheet

We'd like to ask you to be the critics for the Techno Games CD-ROM. Help us by filling out this worksheet so we can make the CD-ROM better for you!
Please circle one answer only.

1. Before using the CD, I knew what the Techno Games programme is and what its purpose is.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

2. The information on the CD is boring.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

3. Many design ideas can be found on the CD.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

4. I got design ideas for my robot from the CD.

Many ideas Some ideas No ideas

5. The CD teaches a lot about robot mechanisms.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

6. The video clips were interesting.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

7. The CD should have more activities to interact with.

Strongly Agree Agree Don't Know Disagree Strongly Disagree

Is there anything you can think of to improve the CD?

Appendix H

Ken Stafford Interview

Kevin: What is your specific role in the WPI FIRST program and your specific background?

Ken: I am a graduate in Mechanical Engineering and Aeronautical engineering, my master's is in Aeronautical Engineering. I retired from the Air Force 5 years ago and I was hired back a year later by WPI as an engineering consultant to work with the FIRST team. I'm not sure why, except that they knew I had a lot of experience working with kids as a former commander of the Air force ROTC. I have a real interest in design and I had known something about so they asked me to come back and I came back and I worked, first year was 1999, at that time there were 6 people in the WPI student part of the team and about a dozen high school members. And we built a robot in 1999. I got to enjoy the teamwork aspect of it and the challenge of it. I was later on hired what we call the manager of academic initiatives. Which means that I am in charge of all of the student design projects on campus including the SAE race car, the SAE airplane contest, the Civil Engineer's concrete canoe and the FIRST robot. So my position for the FIRST team is that I am the leader, the advisor and the only non-student on the team. And we currently about 150 members on the team. There are about 100 WPI students involved and about 50 high school students. So for my fourth season, it has become really a twelve-month effort. We have meetings every week, twelve months a year and we actually put on about 50 shows. The last one was yesterday. We do middle schools, high schools, grade schools, libraries, anyone that wants us, museums. And we spread the good word about technology and science. I also do teach a course in high school, which I call Robotics 101 and it is designed to get high school students, they're juniors, smart on the concepts required to build robots including mechanical programming, electrical concepts and that sort of stuff.

Kevin: Is that at the Mass Academy?

Ken: Yes, that's at the Mass Academy and plus I teach a bunch of students at Doherty High School as well.

Kevin: What are the certain goals or the mission of the FIRST team right now and how have they changed over the years?

Ken: Well, first, in general, it is designed to expose high school students and younger to the rewards and fun of science and technology. So specifically, that's what every team's basic goal is to do is to expose them, not to make them into mini-engineers but to share the experiences of an engineering project by being mentored by real engineers or in the case of our team, by student engineers because they are the experts by virtue of a year or two more of education. Our basic plan is to get high school kids exposed. Now, the high school that I work with, the Mass Academy, already has high achievers in it. There's selected testing to get in there, so we don't convert anyone in our high school to be an engineer or a technician. Maybe we do, but that's not our main goal. Our team goal is to educate these students, but more than that, to get as much outreach as we can to go to middle schools, high schools, grade schools, to get kids turned on about education in science and technology. Now, we have specific goals too. We want to build a robot that really performs well. So every year we set team goals on what we want to do for the next season. The FIRST season really starts in January and officially ends in May with the national championships in Florida. This year it will start on the fifth of January, which is when the official kick-off is. So during the fall period, we establish, besides running a very taxing outreach program, quite often 2 or 3 demos a week, we also develop a team organization and set a mission and goals for that season when it starts in January. I think we have about 30 students who are assigned to leadership roles within the team, and we establish our goals for the year.

Kevin: So how is your goal different now that when it was when you first started?

Ken: Okay. When I got here, there was no team organization. There was no goal in mind other than the fact that WPI thought this was a cool way of getting WPI's name in front of a lot of students. And very truthfully, that is the reason why I am hired and paid for WPI is because it does wonderful things for the school in terms of visibility and all. So that was the only real goal we had. We had been asked by Dean Kamen particularly to sponsor a team because of the connection with WPI. And we did it because the administration thought it was good for the country, but very specifically, it was very good for WPI. So suddenly what's happened in the past 3 years, since I have been associated with it, I have made it much more student orientated, giving both WPI students and high school students more opportunity to learn and enjoy the team. Plus, we have taken it on as a mission to really spread the good word. Before, I came here, the robot was built in the six week period that it has to be built, it went to two competitions and it was sent back in a shipping container, put in storage until next January when it was opened up and parts were taken off to build the next robot. Nowadays, we keep last year's robot always operating and we start our tour schedule the weekend after we come back from the nationals. We hold out own tournament now here on campus, which has become the single most popular off-season tournament in the United States. We limit it to 30 teams and we have teams coming as far away as Minnesota to come to our event here. Even though there are about a dozen others like that in the nation, they all come to ours because we are the best. And we've become renowned as the premier place to experience robotics. This year we are offering a two-week summer residence for high school students to learn more about how to build robots and all that. So our outreach has really expanded. And the whole concept of team has just grown from twelve people in 1999 to 150 people today in the program, to doing a six week build and two contests to doing a 52 week program and 7 tournaments last year plus 40 odd other demos. So there was a major change in the structure.

Kevin: You mentioned how you did demonstrations at high schools. What exactly consists of those demonstrations?

Ken: I send out a letter in May every year after the official season is over. I send it to 100 different schools in the Commonwealth, inviting them to invite us.

Depending upon the needs of the school, for example yesterday I went to a grade school for an advanced group at Flag Street Grade School here in Worcester, and they have a bunch of students who were specifically wanting to build robots. So I gave about a thirty-five minute lecture/discussion on the history of robots and power sources and answered their questions about robots. Then normally, I'll give a fifteen-minute to hour-long seminar or discussion on technical aspects if the teachers want that. Then we always do a forty-five minute demonstration of the robot, let them actually drive the robot, answer questions by pointing and looking at the robot. So again, it's more motivational than educational, but some schools request that I go in there; I've actually taught hour-long courses at some schools and not even bring the robot if they want me to. So, it's a way of showing that WPI is interested in K through 12 education and getting people turned on by the fun of robots.

Kevin: What problems have you encountered with the program and what ways have you addressed them?

Ken: I suppose the biggest problem with FIRST Robotics and maybe somewhere with some other programs is burnout syndrome. The nature of this game is that it is so intense, not the competition, but the constraints on the building of it. You only have six weeks and really it's just an incredible ordeal. We work from 8 o'clock until midnight six days a week and on the seventh day we start at noon and work until midnight. So we are the only people up here that are working, whether the campus is snowed in or not, we are here until midnight working on the robot. So burnout is a real situation for both the kids and staff. Before I came here they would have professors that would do this for a year or two before they would burnout totally and then have to be shuffled for somebody else. Recognizing that after the first year when I was here, realizing what an incredible ordeal it is, my task was to make it more fun and to make it more social. The key to success in any kind of competitive program is just to have continuity with the membership. You don't want to have people that go one year and say, "Wow, I'll never do that again." You want them coming back with more education and more experience and more skills and all that. The way, I guess, that I have been successful in doing that is to out a large social aspect in this. It becomes almost like a fraternity or sorority. We have scheduled social events throughout the year now. We have Christmas parties. We have spring parties. I have at least fifty people show up for every meeting, which is really quite remarkable considering the student schedules here. We have a lot of fun with the program. I've given a lot of the students leadership positions within the team, which makes them feel more ownership. I think in general those have worked well. That's the biggest problem is student burnout. There are other problems, logistics problems with the nature of this game because of the fact that there is so little time to actually test your robot before you have to compete with it. The high school folks are required to be part of the team because the rules state that only high school people can drive it in competition. But the rules do not state or even recommend it necessary that the high school students have to build the robot. They simply have to observe it being built and simply have to see what being an engineer and a technician is all about. Before I came here the high school students participated in the brainstorming operation for five, six, seven days after the game was revealed, sent away their ideas to various spots on campus and to alumni of WPI, machine shop owners. They would never see the robot until it was delivered, normally three days before shipping date. They would never build any of it. They would never even see it. It was all built off campus or some parts on campus, but large portions off campus. They would never get to see it until it was basically ready to ship. They would have a day or two to drive it and then that would be it. That caused some real issues with, "Is this our robot?" or "What's our role in this job?" and so the one thing that I did was to change that. The robot is built 100% on campus now and 100% by students. We don't even employ the technicians here in the labs to build our parts. We do them ourselves. So the kids have developed a much larger sense of ownership even though it's not required by the game. The kids are really proud when they go up against teams sponsored by NASA and General Motors where it's very obvious and they talk to people and realize that it's all built on very high tech equipment, laser cutters and electro-magnetic discharge machines that build some exotic parts and the kids get to watch it being built, if they're lucky. In our case, it's all hands-on. So ownership was a major accomplishment because the kids really do belong to it and a judge comes up to a high school student now and asks something about this robot and they can tell them. They can tell them, "I cut this piece myself and I used the vertical mill to do this" and so there's a big change in terms of spirit. Those are the two biggest issues. And also the fact that it's such a condensed program, a WPI robot always looked very well made, highly technical and the feeling was always lack of experience operating it. So I have restored and talked to the students saying that there are three aspects to success. One is how well it was designed and you folks take part in that because you are in the brainstorming and actually indeed the students are running the design teams. It used to be done by engineers off campus. Secondly, one third of success is how well it's manufactured. It used to be manufactured wonderfully, professionally. Well, when we first changed over to home manufacturing, they were a little bit raw. Our 1999 robot, first time that we had ever built it on campus was a little raw, although it did end up being the number one ranked in the nation, the first time that WPI had ever had that. The kids were excited about that. So, the final third, which we have always failed miserably in, until recently, is how well practiced are you in operating it. How good are the drivers and operators? How much have you developed your strategies and tactics? It's more of the human/robot interface. That always gets pushed asunder as you are developing the best robot. The best robot becomes the enemy of the good enough robot. Instead of having a week of experience, you get only one day of experience before you go to competition. If you have a perfect robot, maybe you don't get anytime to practice it and so it really becomes the enemy of the team. So we have kind of shifted the priorities to make sure that there is equal weighting on experience, manufacturing and design.

Kevin: Can you tell us a little bit about the Mini-FIRST competition?

Ken: In 1998, there was an IQP project here. People recognized the fact that the high school students weren't buying into the program as much as they thought they would have liked to and it wasn't really developing the kind of esprit decor teamwork that they were hoping for. This was before I was involved. So some students came up with a project which was to mimic the development cycle of the FIRST Robotics program, but on a much compressed scale and instead of having high school work with industry mentors, this one was specifically high school students working with college student mentors, which is really the same as our FIRST team works, but we are unusual in that regard. And instead of building a 130 pound robot that is going to be remote-controlled and have a very difficult task over six weeks and a budget in thousands of dollars, to build something small that the kids could actually build like a science project totally on their own, maybe with a little bit of help from a WPI student, but to build it on their own under a similar time constraint and material constraint that occurs with the FIRST program. So that happened in 1998 and it was over a two-month period with the competition starting in November and they actually had the competition scheduled for January, the same weekend that the FIRST kick-off was so that people would go the tournament, finish their Mini-FIRST competition and then immediately stay there and have the introduction of the official game. That happened in 1998 with modest success. It was an IQP project that was well intentioned, but it didn't work real well because even in that period of four or six weeks, it turned out in the end that very few of the robots even moved because it's a real hurdle to get it to move. A robot normally has to do something, but it has to move to get somewhere and it can have a wonderful arm and catcher but if it doesn't really move well then it becomes unsatisfying. That was a tethered robot system where there was a big pole with tethers coming down, power supplies and all that. It turned out to be a nightmare. During the actual competition, very few of the robots worked. It was very disappointing and a lot of effort. So it was dropped. In 1999, I changed the concept to get rid of the tethered robots and provide them with a driveable chassis. The design concept is now to make this radio remote controlled, not tethered, to do a task and they then build stuff on top of it. So they build arms, catchers and hopefully get a chance to practice driving it and all that. So it takes the motion part out of their challenge. The success has been that everybody builds something and everybody is able to drive it on the Mini-FIRST board. We have a pretty good website that explains the game each year and whether or not it's successful at bringing people into the FIRST program, I don't know. Because we have 40 students a year that get involved in it. We have ten teams of four people. We have ten mini-robots. It's a fun tournament to watch. Probably about three quarters of those people do jump into the FIRST program with full gusto. Probably, just about that many would anyway. But we do it because it's become a tradition and curiously enough a lot of other schools are using that program. I get probably a dozen calls per year to send the documentation on our program to other schools so they can incorporate it into their curriculum. And I know that schools as far away as Maryland are using our Mini-FIRST program as an engineering project for their schools. So I think that we have some value out of that. Actually, it's better every year. It's really good for WPI people because they get to design it with the students. The Mini-FIRST program is as good for WPI students as it is for the high school students.

Kevin: I'd imagine you see some division in the team. Some students work harder than others. What kind of things do you do to get them actively involved?

Ken: It's an ongoing issue because we are, by some people's accounts, the most popular student activity on campus at WPI. One out of five entering freshman join our team. We normally have 100 to 120 freshman every year to sign up for the FIRST team, of which about two thirds of those students will say in a survey that they came to WPI to belong to the FIRST team. We have over forty different high school teams represented on campus now. So we get all these people coming in here. Now frankly, I'm not too concerned if they all help out or not because in the lab practically you can't use more than about a dozen people at a time. What we try to do is to find out where people want to work. Everybody comes here with some idea. Some people just come from high school teams and say it was such fun driving the robot, I love this program. And then they get to WPI and realize, they don't get to drive it anymore and maybe it's not so much fun for these people, watching other people driving. Some people get tied up with their FIRST experience in high school because they like the spirit and the jumping and the carrying on and the flirtations that go on between team members and the driving experience. They may have actually lost sight of the engineering fun with it. So, I don't really care about those people. We have this team divided up into two major divisions. There's the operations division and then there's the support division. The operations division is what you would expect an engineering company to do. There is a WPI student in charge of all operations underneath him. There is a mechanical design group and a controls design group and a human crew chief. There are three different divisions under him. Under the mechanical there are three or four divisions. There's driveline, collector, arm and that sort of stuff. Under controls is software, hardware, programming that kind of stuff. Under the human part there's scouting, strategy, training, evaluation. There's lots of room for a lot of people to work there. They don't all have to be in the lab. We have probably about a dozen people who do nothing but research the web, go to other people's sites to try to see what other people are doing. They're scouting. So basically to answer your question, they're not all visible in the lab. Those who want to work, I have plenty of tasks that may appeal to them, whether it's doing web research, and actually some people who are in to the social aspect of it just like to go to other teams and just pop in and say hello and take notes. And the teams all are agreed upon to do that. There's 600 and something teams across the United States and actually there's quite a network there of people willing to share and spread knowledge. So we have people to do that on the other side of this support organization, there's all the animation bit. There is administration which involves fundraising, spirit items, T-shirt designs, hat designs, going to pizza places and getting them to volunteer pizzas for us. There is also the graphics people which do our website and do CAD work for us. And then we have another whole concept where there's a whole group of people, about a dozen that are working on what we call the Chairman's Award group. When we think of the robotics program we think well your job is to build this robot and go and compete and do the job with everybody else. That's only one part of it. There is another part which is just to develop an animation sequence, a thirty second animation which is almost a totally separate contest and then there's a third contest which if you talk to the founder is the primo which is called the Chairman's Award. This is the documentation that you put together which supports that your team is doing the FIRST mission, which isn't building robots. It is spreading the word about how wonderful science and technology is. And so between all of those competitions and between this smattering of positions I have, I would say that we probably have about, of about 150 people that we are on the team by E-mail name, probably we have half of those that are actively involved and they are doing good work for us because we funnel them into places that they feel comfortable and they like to work. So, I have never had any problem with having enough people to do different tasks because we have so many people to choose from. So, I never have to say, "Either you perform or you're out of here" because there's always people filling those spots.

Kevin: So if there was someone that really wanted to work on the robot, would they have the opportunity to do that even though there's a certain amount of people?

Ken: Absolutely. The base of the team is we never turn down a soul who wants to join in. The difficulty is the huge commitment. If you really want to work on the robot, really want to be building the robot, it's a huge commitment. Freshmen very seldom recognize that because generally speaking, if you wanted to be in charge of one of the design groups for example the driveline and that is normally held by a sophomore that is going to take minimally sixty hours a week of your time for six weeks. Normally it means working twenty hours on the weekend and then about four hours a day for the other five days of the week. There are people that are anxious to do that, very anxious to do that. I have to remind them that I work for the provost and the provost has to have academic credentials going on there. I have to remind them that they're in school. So we've never turned down anybody. There are teams that actually have to have try-outs for people to join the team, but that's normally only restricted to the high school members. Most FIRST teams, they treat the high school membership in the team as a varsity sport and so you have to try-out to become part of that. Our school is different because the high school is so small. We simply allow the entire junior class to join which is forty-five people and of that with the high school, we probably only get about half of those people who really engage, but some of those are very, very much engaged and they are actually already holding leadership roles in the team. Most of those people who are in those roles have come from other high schools, which had FIRST teams which they were involved with as freshmen or sophomores. So, there's two different things to think about and out team is kind of unique. There is what do you do with the high school members to engage them and what do you do with the mentors to keep them engaged and productive. I have no problem with mentors because I have so many of them who want to be involved, the WPI folks and the high school folks, we have all that we can use.

Appendix I

Measurable Independent Variables

Structure of lesson

-

Groups

- How the groups are selected (i.e. chosen by students or chosen by the teacher) - if students are with their friends or not
- If groups are boy-girl, boy-boy, or girl-girl
- Elapsed time for each part of the lesson (i.e. discussion, working on challenges)
- Number of parts of the lesson
- The depth of martial presented to the class

-

How often the class is stopped for discussion

- What is the topic of discussion? (i.e. progress of workshop, behaviour related)

Instructor (Workshop leader)

- Enthusiasm (Likert scale – pretty subjective)
- Experience of the teacher (Sessions conducted)

Number of helpers

-

Amount of help given to individuals (Amount of time? or # of times?)

Students

-

Prior knowledge of material covered in workshop (pre-test)

- Year level

-

Number of students

-

Size of groups (2 or 3)

-

Ability to grasp concepts (pre-test, number of challenges completed)

Classroom environment

-

Classroom or hall

-

Too restricted in space or too open

Normal conduct of the class

- Good and manageable or poor and difficult to manage (Likert teacher survey)

Measurable dependent variables

The attention span and interest of subject in student

-

Time spent listening to the teacher

-

Time spent working on the given task

-

Time spent playing or doing other things

-

Asking or answering questions (# of questions)

Students' motivation to complete the task

-

How much of the task the child completed

-

Time spent working on the given task

-

Time spent playing or doing other things

-

Asking questions

- (number and natural of questions)

Student's comprehension of material presented (post-test)

-

Answering questions

- Worksheet

- During discussion

-

How much of the task the child completed

- Amount of assistance given by the helper (number of times and amount of time)

Results Obtained from Workshop

- How effective was the workshop in teaching the children the concepts? (pre-test, post-test, and student worksheets)
- Does the workshop keep the children interested? (time spent on/off task)
- At what point (or aspects) do they start to loose interest?
- Recommendations in presenting material to correct misunderstanding or problems the children had

Appendix J

Balloon Buggy Self Evaluation

Balloon Buggy #1
Prior Weston School (24/1)
22 Students - Year 3-4
Time for workshop: 1:45

Structure: Each student was allowed to create their own buggy. The designs of the buggies were limited to the basic design described in the worksheets. The students were stopped after completion of each part (after chassis and wheels) so that they all worked on the same part at the same time. After each part we demonstrated how to do the next part. We were very short on time, no time for adequate races or discussion of designs at the end.

Comments/Ideas: Need more time to let each student build their own buggy. Hard to keep students together, especially when each making own buggy. Children seemed very interested and asked a lot of questions.

Balloon Buggy #2
Prior Weston School (24/1)
7 Students – Year 5-6 (after school club)
Time for workshop: 1:30

Structure: Each student was allowed to make their own buggy, with no restrictions on design. We did not go through detailed instructions on how to make each part, only showed the demo car that we made. There was enough time to complete the buggies with time for discussion afterwards.

Comments/Ideas: Perhaps needed a bit more structure with design and less freedom. Some of the designs didn't work at all. Need to define time restraints better.

Balloon Buggy #3
St. Gilda's RC Junior School (30/1)
23 Students – Year 5
Time for workshop: 1:30

Structure: Students worked in pairs and completed one buggy per pair. The building of the frame was shown, however no further instructions were given except to individual groups. They were shown the model but told to make any modifications they wished, however few made major modifications. They were not stopped after each part. During this workshop we had 3 helpers (1 teacher and 2 parents). There was enough time to race, however not all groups were able to compete in them. Some groups redesigned the buggies when they didn't work. There was enough time for a very brief discussion after the races.

Comments/Ideas: We should have shown them how to build the entire car as a group instead of telling groups individually. The helpers helped keep things moving along at a good pace.

Balloon Buggy #4
St. Gilda's RC Junior School (30/1)
25 Students (Year 5)
Time for workshop: 1:30

Structure: Students worked in pairs to make 1 buggy per pair. The complete design was shown prior to starting construction and students were encouraged to come up with their own designs and modifications to our basic design. They were not stopped at all during construction. We had 4 helpers during this workshop (3 parents and 1 teacher). They were a big help. We finished with enough time to have races as well as a discussion afterwards on the different designs and what did/didn't work.

Comments/Ideas: This was by far the best workshop we have run. We saw a lot of different and good designs.

Teacher Evaluations of Balloon Buggy Workshops

1. Was the introduction appropriate?
   -Very, the questions were poignant and drew out good responses from the class.
   -Yes
   -Voice projection not strong enough for hall.

2. How could it be improved:
   -No response
   -See below, explain how to fix the triangle bits
   -Perhaps could have models of different stages already made, so aides demonstration.

3. Do you feel the material covered was appropriate for this age group? If not, what age group would benefit from this workshop the most?
   -The material was very appropriate and all benefited

-Yes
-Yes

4. How was the length of the workshop? Was it too long/short?
   -Just right
   -Fine
   -Fine

5. How would you rate the students' enthusiasm for this workshop compared to their normal classroom behaviour?
   -Exceedingly enthusiastic!
   -Very excited
   -Enthusiastic!

6. Can you suggest any ways we could improve this workshop or any other comments?
   -None. Excellent delivery and perfect execution
   -It would be nice if they could vary the design a little. Maybe give some ideas of how to do this
   -It was really well organised generally and the children had great fun taking part.

Appendix K

Recorded Observations of Capstone Robots Workshop

Location: Crook Log Primary School

Room Description: Classroom setting. Six large tables with four and six students to a table.

Number of students: 26
Boys: 14
Girls: 12

Student divided into 13 groups of 2 by teacher to have students with similar abilities to work together.

5 – Boy/Boy groups
4 – Boy/Girl groups
4 – Girl/Girl groups

Workshop Instructor: Peter Chamberlain

Workshop Helpers and Observers: Kevin Brown, Keith Hammersmith, Kimberly Barger, and the Class Teacher.

Workshop Divided into Sections

Sec. #1 – Discussion: Introduction

Sec. #2 – Task: Children making switches and testing them

Sec. #3 – Discussion: Use of a switch to make robots run

Sec. #4 – Task: Making the robots run

Sec. #5 – Discussion: Doing a relay race

Sec. #6 – Task: Relay race

Sec. #7 – Discussion: Talked about worksheet

Sec. #8 – Task: Students fill out worksheets

- Stopped for play time -

Sec. #9 – Discussion: Talked about tasks on worksheet

Sec. #10 – Task: worksheet tasks

Sec. #11 – Discussion: Discussion of what happened during tasks

Questions asked by Instructor to students during workshop

Sec. #1 - Question #1: What is a robot?
Sec. #1 - Question #2: How can you control a robot?
Sec. #5 - Question #3: What are the rules of a relay race?
Sec. #5 - Question #4: What does a person carry in a relay race?
Sec. #5 - Question #5: What could be used as a baton in a relay race with robots?
Sec. #7 - Question #6: How do the wires connect to battery?
Sec. #7 - Question #7: Do the wires have to be in a straight line?
Sec. #9 - Question #8: How would you make the buggy go in reverse?
Sec. #9 - Question #9: How would you make the buggy go faster?
Sec. #9 - Question #10: How could you use two batteries effectively?
Sec. #9 - Question #11: Would you join the two batteries positive to positive?
Sec. #9 - Question #12: What can you use to make the buggy sound a buzzer when in runs over something
Sec. #9 - Question #13: On the slide switch, which two are joined?
Sec. #9 - Question #14: Which two are joined after it something?

Question #	# of raised hands	# of correct answers	# of incorrect answers
1	~	~	~
2	5	2	2
3	2	1	~
4	1	1	~
5	7	1	2
6	3	1	~
7	2	1	1
8	9	2	~
9	6	2	3
10	4	2	~
11	1	1	~
12	8	1	4
13	2	1	~
14	5	1	1

Commits made during sections

Sec. #1 - N/A

Sec. #2
Kevin: Tables #3 – Group 7: (two boys)

Asked about pasting switches

Group 8: (two Girls)

Asked about pasting switches (if it was correct)
Table #4 – Group 9: (two Girls)
No problems

Group 10: (two Girls)
Problems with making the switch. Talk to them about paper being an insulator and fold being a conductor. (Girl noted by teacher to be special needs)

Sec. #3

Keith: Small diversion with switches (playing with testers) However paid attention when robots shown

Kim: 3/6 children looking down at pressure switches

Sec. #4

Keith: Table #1 – group #1: hooked up robot without pressure switch
Group #2: Used pressure switch first
Group #3: had problems with (worked after they were helped)

Kevin: Group #7: successful without help
Group #8 troubles hooking switch up to robot
Group #8: No problems
Group#10: Problem with making circuit (Helped them by talking about was a circuit was)

Kim: Group #11: Buggy didn't work (not hooked up right) had to be helped

Sec. #5

Keith: Groups (3,4,6) playing with robot until stopped by teacher ~1 min

Kevin: Group 10 still trying to hook up switch to robot (having some trouble)

Sec. #6

~

Sec. #7

Kevin: Students working on worksheet while he talks. Not paying attention to him.

Kim: 3 playing with buggy. 1 playing with hook. 2 watching me.

- All working on worksheet

Sec. #8

Keith: Groups (1,3): started playing with robots when they thought they were finished with worksheet. Didn't do the drawings on the worksheet.
Groups (4,5,6) when done with worksheet played with robot
Comment: More clearly define what is to be done (less time on writing!) gets boring. Maybe say faster it done – then fun (Explain Gear box)

Kevin: Group #7: Didn't know how far to go on worksheet (should we do the whole page?) had problems with thermostat question.
Group #8: Helping each other with worksheet (problem with the heater question)
Group #9: Helping each other with worksheet. (problem with the heater question) worked well together – finished early and didn't know what to do after.
Group #10: Problem with heater question
Commit: Section too long children not focusing on worksheet – playing with robot children waiting to go onto next part. All the groups (7,8,9,10) waiting too long.

Kim: Playing with buggies
One doing worksheet while the another is copying
All 6 playing with buggy instead of doing worksheet

~Play Time~

Sec. #9

Keith: Girl in group 5 stared to lose interest 6 min into discussion (task #4)
Girl in group 6 not paying attention after 7 min

Kevin: Group (7,8,10) not looking when teacher is talking
Girl in group 8 does not look entire section
Commit: most of the children seem board and disinterested.

Sec. #10 – (task section)

Group #1 – worked together
Task A-D: Completed without too much difficulty
Task E: tried to hook up pressure switch (have a lot of ideas)

Group #2 –
Task A-E: completed without too much difficulty
Task F: Peter had a discussion prior to attempting this step with diagrams (just with this group) they tried then and then went for more help. Got it with much help.

Group #3- Worked together

Task A-C: completed without too much difficulty
Task D: I told them they need slide switch to do this part. Then they got it.
Task E: completed
Task F: not completed

Group #4
Task A-C: completed without too much difficulty
Task D: Completed it eventually
Comment: girl started to play with pencil box while the boy worked on the robot

Group #5- worked together
Task A: no problem
Task B: difficulty – did it wrong – had to tell them they needed a second battery
Task C: teacher showed them how to do it
Task D: gave hints to hook up to pressure switch. Needed help

Group #6
Task A: no problem
Task B: problems - tried tester
Task C: no problem
Task D:
Comment: Boy seemed to be doing all the hands on work while the girl looked around

Comment: at one point the 3 girls in the boy/girl groups started talking while boys continued to work

Group #7
Task A: helped by explaining how electric flows for plus to minus
Task B: had to remind them about using two batteries. After completing it they spend a lot of time playing with robot. Had to get them to get back on track to do the next task.
Task C: no problems
Task D: got it with teacher help
Task E: got it with help from me

Group #8
Task A: helped by explaining how electric flows for plus to minus
Task B: showed then the circuit. After completing it they spend a lot of time playing with robot. Had to get them to get back on track to do the next task.
Task C: copied group 7
Task D: teacher helped

Group #9
Task A-B: completed without any help
Task C: got after very little help
Task D: Had to be shown how slide switch worked
Task E: completed

Comment: stayed on task until they got stuck on the last task

Group #10
Task A-B: completed without a problem
Task C: Got help from the teacher
Comment: Girl just wants to play with robot. She is not trying to figure it out any more.
Off task: Boy wants to work on robot but girl is playing with it.

Robotics Post-test Results

After completion of the Robotics workshop at the Crook Log primary school we had the students complete a post evaluation with questions ranging from their favourite subject to technical questions on circuits. The questions were aimed at measuring comprehension and engagement. Concepts that should have been taught include how to construct a circuit incorporating a battery and switched and how to represent series circuits by conventional symbols. All of the following results are based on the answers of 26 year 5 students.

Survey Results from Robotics Post-test

1. What is you favourite subject in school?
   Physical Education - 12
   Design/technology – 5
   Literacy – 3
   I.C.T. – 3
   Math – 2
   Art – 1

2. What was your favourite part of this workshop?
   Making the Buggy – 12
   Improving the Buggy – 5
   Completing the Tasks – 5
   Buzzer – 3

3. Do you think this workshop has changed your view of science as a possible career?
   Yes – 16
   No – 9
   ? – 1

4. How far did you get in the list of challenges?
   Task C – 1
   Task D – 9
   Task E – 8
   Task F – 7

5. Draw the symbol of a battery, motor, and switch.
   Correct – 13
   Part correct – 11
   Incorrect – 2

6. Draw a circuit.
   Correct -18
   Incorrect – 8

7. What does it mean if a circuit is open/closed?
   Correct - 15
   Incorrect – 11

8. Do you know what you would like to do when you grow up?
   Not Sure – 9
   Footballer – 6
   Doctor/Nurse – 3
   Mechanic – 2
   Teacher - 1
   Author - 1
   Architect - 1
   Pop Star - 1
   Actress - 1

9. What is a robot?
   Machine - 14
   Has Wires – 3
   Can be controlled – 2
   Moves – 2
   Blank – 1

10. Give some examples of robots.
    Robot Wars – 11
    Car – 6
    Computer – 4
    Blank – 4
    Fighter – 1

11. How does a robot work?
    Circuit – 8
    Wires/Battery – 6
    Electricity – 4
    Blank – 4
    Switch – 2
    Controller – 2

12. How are robots used in the real world (i.e. not robot wars)
    Left Blank – 9
    Help do things – 4

Build Cars – 2
Clean/cook – 2
Paint – 2
Driving – 2
Make Things – 1
Remote - 1

1. By asking the students what their favourite subject was we intended to determine how many students were already interested in science and technology. We also wanted to see if those students that liked science (and math) performed better on the tasks as well as the technical questions on the post-test. The overall favourite subject was p.e. (12 out of 26 said this was their favourite). This was by far the favourite as the second was design/technology (5) and literacy (3).
2. From this question we hoped to determine what parts of the workshop the children found most interesting. Twelve students said making the buggy was the best part, beating out making it go faster (5) and completing the tasks (5). This question did not reveal any surprising information, we were just looking to see what interested them and what parts of the workshop might need more time in the future.
3. This question was intended to give us an idea if, in general, the workshop did make them think more about a possible career in science and technology. We realise that this is a difficult question to ask eleven year-olds, however we were glad to see that more than half (16) said it did make them think more about science as a possible career, with one student saying it did influence him very much.
4. We wanted to know how far the students made it in the tasks to determine if there was any correlation between their comprehension of the material and how far they were able to make it in the tasks. All of the seven students who made it to the final task also answered questions five and six correctly (drawing a circuit and symbols for battery, switch and motor. This indicated a relation between comprehension of the material and success in the workshop.
5. The next question asked the students to draw the symbols for a battery, motor, and switch. This question attempted to determine students' comprehension of the material learned in the workshop. Only thirteen students answered question five correctly and eleven answered it partly correct. This indicates that many of the students do not understand the basic concepts that should have been learned during the workshop.
6. There were 18 correct responses to question six which asked to draw a circuit. This is somewhat surprising because the students must create a circuit to make the robot run. Some of the students may have been confused by the question; however the circuit was introduced and drawn during the workshop.
7. Only 15 students correctly answered the question about a circuit being open closed. This may have been because they were thinking of a switch being open and closed and not a circuit.

8. We asked the children what they would like to do when they grow up to see if any of them have started thinking about a career in science or technology. While many of the students (9) were not sure what they would like to do, six said footballer and only three students said a science related career (doctor/nurse).
9. The final four questions were also intended to test the concepts learned during the workshop. Question nine asked what a robot is. Most (14) said it is a machine. Very few gave different answers. Two said it can be controlled, which is mentioned during the workshop.
10. Many students said Robot Wars as an example of a robot, which was expected. Six students answered car, which shows that some still are not really sure what exactly a robot is.
11. This question gave the most varied responses, indicating more time should be spent explaining exactly how a robot works, although many of the responses were correct.
12. The most difficult question was the last one, with most students not really knowing how robots are used in the real world; nine left the question blank. This is an important concept as it gives the students something that they can relate the workshop to in the real world. More time should be devoted to talking about robots in and how they are used in everyday life to make our own lives better.

Appendix L

Peter Chamberlain Interview

Kevin: Alright, what is your background and experience with science and technology education?

Peter: Well I started off that I didn't know what I wanted to do, so I had the chance to take a PHd. I rheetoriced in science, and so I went up to Edinborough and spent three years there, including a year in New York, and umm, I decided that I didn't want to do pure research, but I wanted to do something which combined an interest in science with working with people. So I started teaching, and taught for about 10 years and worked myself up the ladder, then I had the chance to do some teacher training at drexller university, so umm, I spent, I'm not really sure how many years there, quite a few years there, and for various reasons when I was 50 I took early retirement from that, and one reason was that I felt I was getting increasingly detached from the classroom, and came up to London to run an educational project in the east end Newham, barking Dagenham, havery, and restbridge, that was bringing industry into the classroom, and it ran for 3 or 4 years, and the funding ran out, then I went back and did some more classroom teaching. And umm…then I started working here, so I've had a long involvement with science and technology in the classroom.

Kevin: What are some of the goals of SATRO as you see them, and what prospects do you see for the organisation in the future?

Peter: Well that's the umm…could you say it again?

Kevin: What are some of the goals of SATRO as you see them, and what prospects do you see for the organisation in the future?

Peter: To raise the profile and to get people interested and committed to science and technology in the way that I've been, because I think it can be an enabling force when you can empower people to do things that they might otherwise not do and opportunities for SATRO are limitless virtually, in that the response that we get to the workshop is very positive, the workshops and the activities are very positive, and ummm, we have the problem is that we are unable to meet those demands. That's the general position.

Kevin: What exactly do you want to get out of our project?

Peter: Out of your project? I mean you see yourself as a coherent group, and Bernie and I see the group as two very discrete entities working towards the same main by following different paths. So the one that I seem to be particularly involved with is the Canal Museum, so in the short term the gain is to develop a workshop which can be delivered umm, during science week, now then, umm, that is our short term aim, in doing so, it opens up for us, new opportunities, in that I haven't been to the canal museum before, and working with model bricks I should be able to see how children can get on with building in that workshop, so as far as that particular thing is concerned, as far as I'm concerned, that aim would have been achieved, I mean we did have a second aim, which was to that you in some ways would be able to take some of the pressure off of us and deliver more workshops, now then, that's always been slightly contentious in terms of a conflict in ends, in that your, I mean it did fit in as a legitimate part of your purpose to get, be familiar with the way children would respond in a primary school and to do some practice evaluations, but you know, that was something you were doing for your purposes, our principal aim was to just do the workshops, and it hasn't worked out quite the way it might have done.

Kevin: From your experience, in the workshops you have run, what workshop structures have worked the best, and more specifically, would the children respond to them?

Peter: Certainly if we look at the difference between primary and secondary schools, then we uhh, we get a much more consistent response in primary schools than secondary schools in that we are bringing in equipment and gear that the children haven't seen before, and so the novelty factor is very strong also the fact that many primary schools are not set up to do science and technology, so anything that we do is well received. Where as in a secondary school, they already have a science and technology department. What we've got to do is to make sure we enrich what they do already, now then, there are some, I'm thinking of one or two, one particular secondary school where the, it has so many intrinsic problems, such as discipline, that it's very difficult to be effective in, where as it's very very rare to find that situation in a primary school. So the response does depend on the age group, and I think because we're new, if they give you the chance then we're doing something different, then it's very rare to get anything other than a very positive response. But you don't have that reservation about some secondary schools.

Kevin: Ummm, you always get a positive response but you might have a higher positive response than others, in that what I'm trying to get out of that question, which you answered some, just about the structure, however positive that you go through in an individual workshop, compared to different workshops, because they're structured a little differently.

Peter: Sure, umm, yes. So...I think the parts that go best are the parts where the children are doing their own individual work rather than when they're being talked at. Now then, you can't obviously you can't just say like "get on with it make the balloon buggy" Because the whole context and justifications of doing it is spelt out in the introduction. So umm, they have to go through that, I don't think there's a short cut way of doing it, certainly as far as the robots are concerned, it divides, well the balloon Buggy is a long talk, then working, then a brief round up at the end. Where as the robots one, you have the first one which is stop start stop start, which gets a little tedious, but it's an attempt to get them up to a certain level, and when they do the tasks, they can go at different rates, which the kids probably enjoy the second bit more, although some of them do get a little bit lost in that stage, umm, but it does give some account to race ahead, which is a compromise whenever.

Kevin: Do you think children are getting more out of a workshop that gets them more excited about it, rather than a workshop that has more fundamental concepts of learning in it. Like in the Balloon buggy and robotics workshops.

Peter: Yes sure, get more out of it......I think the chances are with the robotics workshops, small amounts of children get tremendous satisfaction from solving very difficult problems, some can get rather lost in that, they will all do some basic revision and learning, so it's very appropriate for year 6 students just before their SATs, so you get a much broader spectrum of achievements in the robots one than you do in the balloon buggy, but in the balloon buggy the satisfaction of actually making it is something that all of them share, not all of them have time to finish, but the majority do, and they enjoy that, although the quality of the constructions quite good so that it doesn't make it home so they can demonstrate it, but I would've thought that you'd get a more even spread of achievement there.

Kevin: So with the more unique spread of achievement you think that they're getting more out of it in terms of what you're aiming for in these workshops.

Peter: I think we're aiming for both things really, to stimulate, I mean it's the high achievers are an important group and since our funding comes from the engineering council who change slightly, but still from that group, that are looking to recruit more graduate engineers, so the targeting of the more able, is something which they seem as important, without wishing to deny the other students, so especially in the robots one, the one I did with you the other day, the morning session, the three boys who shined in that one, because they had an understanding, but the quality of their written work is usually very poor, so the teacher was very impressed that they at least, this gave them a good opportunity to do some good work, which they did, so that was in terms of recognising the talent that they've got, so I think I've got the question that you're asking, but I think it is true, and I think it's of a lesser extent with the other one, but certainly there is some who, you wont take the special needs kids and they did as well as anyone.

Kim: The post survey was definitely worth the extra credit?

Peter: And in terms of what the teacher was saying, she was impressed by that too. So I think that's a very positive thing to recognise.

Keith: Have you noticed a relationship between the quality of the written work and the actual hands on work?

Peter: Well it's very different correlation between the two. Because the, I mean the I don't see the need to do that written work, it satisfies the needs of the educational system that they've got something written down to prove, and there is a time when the theoretical, the background thing is important and you can't do without it, but on this kind of level comes with intrinsic understanding is probably sufficient, but whether they remember, whether, in doing that piece of written work, whether they'll ever refer it again in their notes is very unlikely, it does get them in the habit of writing things down, rather than because there's any merit in doing so without influence.

Kevin: What attempts have you made in assessing the workshops that you run now?

Peter: Nothing systematic because of the intrinsic difficulty in the time it takes, so we get a occasional feedback but not, we haven't really had a system of logging the number of times when we get formal thanks for a workshop, and maybe we ought to do that, when the teacher takes on to send in or telephone in, but it's in the way in which they just informally talk to you at the end of a session is the feedback that we rely on, and maybe it should be.

Kevin: You mentioned before of the development of the robotics workshops, just, emphasise the kinds of problems that you encountered with getting the children and keeping them interested in during a workshop, that involved any other workshops as well

Peter: With that one, the main problem has been, and I think we're getting better at this, is the reliability of the equipment. If the child does something which is perfectly reasonable and it's through equipment failure that it doesn't work, then one needs to be there and respond and the teacher often comes who can't cope with the technical aspects of it, so that one person responding to the needs of fifteen groups is often pushes things quite a lot so there are irritating things like crock clips coming off the leads off the terminals, which maybe we've got to address at some time and try and find a better system, but it's just been, motors not working or faulty leads or battery failure, but it's getting much better than it was to start with, so I think that's one of the main frustrations with that workshop.

Kevin: What have you noticed, I think we've kind of gone over this, but when have you noticed children becoming off task or uninterested during a workshop, and what have you done to get them back on task?

Peter: It's when they loose, when they fail to complete the task and they're stuck there and they don't understand a task or something like that, so one of the ways of doing that is, that last one when they get the buggy to reverse, umm, I've revised that worksheet so that now there's an intermediate exercise, which will hopefully help them a little bit towards that because the number that were doing it without actually talking to them about the theoretical circuit was so small that is was you know, counterproductive I thought. So giving them the answer is something when it takes away the excitement of achieving it by oneself, but it allows many more people the answer, and that's a difficult balance, how difficult can you make the challenge, that if you start to make it easy, there's less satisfaction in actually doing it, and I don't know what the answer to that is.

Kevin: Could you tabulate what types of child does best in different workshops, and why the reasons you think that?

Peter: I think as far as answering questions, boys are really more forthcoming than girls, and it's very difficult to adjust the questioning so that the girls do get their fair share. Especially you find that with the balloon buggy one, when I start off with "today you're going to be an engineer" Some of the boys look perked up, and the girls show lack of interest, umm, so certainly, I notice the boys I think, achieve more than the girls, it isn't necessarily show itself in the manufacture of the balloon buggy, but the initial intrinsic antipathy the girls show, where the boys don't shut down. Umm, as far as the teaching of the balloon buggy, girls are as good as boys in making them. Boys tend to be more...they want to experiment more with design than the girls, and that's something that I encourage, and I think. Then with the robots, its more the boys that achieve more, then I used to, that there used to be an anxiety of letting down the opportunity for the girls, but I don't feel that as an anxiety anymore, because of the girls outperforming the boys in almost all subject of primary and secondary education, so to give the boys a chance to do well, that doesn't worry me particularly. You know, the three that I was talking about in the morning class the other day, they were the boys that normally failed, and they succeeded, so that's good. But the girls didn't fail, but they weren't so driven to accomplish the task.

Kevin: Umm, this is something we got out of the balloon buggy workshop, when introducing the level of concepts that you want to introduce prior to working with them, like more specifically the friction on the wheels. Do you think the children get more out of explaining to them the problems that they might have in the construction, and having better results, or actually facing the problems and seeing what went wrong themselves, but having less of a result.

Peter: so there are several questions there, so in the first place, the theory as opposed to practice, then the as far as the school's concerned then a major pre occupation is to teach the key stage exam, the fact exams. So I make a point in the balloon buggy workshop to use the word force by spelling it out a letter at a time. Because that's a key word that they need for the exam. But the children appreciating that isn't my concern as much as it is the teachers, and that's why I talk about the glue gun and the terms solid and melting, again a part of the exam. I use interactions rather than telling because I think that does keep the crowd with you, because you can get through that introduction rather quickly, but I tend to take half an hour or 45 minutes for it, and to keep it, and if you ask the teacher their attention span is about 10 minutes and somehow if you carry on talking for 40 minutes you'll lose them all, I try and make it interactive, I think they can get to learn all sorts of things of areas, that's why you've got questions in the time, to get a response, and be aware that in that situation the same hands go up all the time. Now as far as the actual construction is concerned, I don't know whether I give more or less instruction than you've experimented with, during the workshop I try to give as little instruction as possible and they say "how long do I make this, what should I do here" and I say "you're the engineer" and it's not too hard to get the teacher to play along with that too. Try to get them to think themselves on what they're doing and why they're doing it. Does that the question?

Keith: Do you think it's better to let them experiment not tell them the problems they may encounter but go over them afterward.
Peter: I think to let them solve their own problems, but ultimately you have to. So for minor problems, when they put the straw on they tend to squeeze it on the glue and that distorts it, now then I'd talk to them about that and say there's a specific problem and the wheels don't go around and I'd explain why.

Kevin: So you'd explain that before or after?

Peter: I might mention it before, but usually it's after, because their earliest, their ability to remember things at that stage is nonexistent. So that when a child says ' my buggy wont go around' and you have to point out that the wheels don't go around, so lets see whether we can do something about it.

Kevin: What sort of limiting factors have you seen about running a successful workshop?

Peter: Time on teacher to actually go around and meet all the needs of the students, now then that's a problem on the robot one not the balloon one, in fact, we often ask for parents helpers, I often feel that three people are all that are necessary, because you have one that makes sure that learns the words, one to supervise the glue table, and one to be just generally around, and of course the teacher, so that one of the limiting factors is that if you don't have a teacher whose got good control of them, especially at the end, it's quite painful to try and get all of them to be quiet so they can listen. But there are only a couple of times I've done it all by myself and the end session was quite unsatisfactory because the teacher didn't have control.

Kevin: What kind of structure, different structures for different kinds of age groups.

Peter: I don't think that's an intrinsically different structure, it's the way you relate to the children, so that secondary school children are young adults, and yeah, so you treat them as such, the way with the primary school you act more as a parent and less like a teacher, so the way that you relate to your own children as a parent as compared to the way you relate to young adults is different, and umm, I think its but I think there is an entity there.

Scott: I had a few questions actually, in order to stimulate the children going into those fields later in life, what kind of age is it more important to introduce workshops in, so that later in life they go into those fields

Peter: I think the evidence is increasingly that key stage 2 is as good as any other

Scott: Do the concepts stick with them

Peter: The concept of thinking about a career of being an engineer might be relatively not exactly the same way in what they may be thinking of. If you look at what they were going to be, and mark it down, the number of people who actually achieve that is utterly, the number is absolutely minimal, but some people do, if you look at your own career planning, when did you decide that you wanted to be this that or the other, umm, I have no idea how long ago you made the decision or whether it just sort of happened more or less by mistake, I think the reason for this is that, well for me, I talked to my own son about this, that there's a conflict between abilities and values, and umm, so I have an ability in science, but one of my values said that I wanted to work with people, so umm, I think that the values don't emerge till later with many people, so my son has an ability to work with numbers, so he's training to be an accountant, but he finds it incredibly boring, so when he's got his accountancies qualifications done, he's going to spend all his time just toying over figures.

Scott: The workshops to stimulate interest are more important in key stage 3 you said? For interesting students?

Peter: I wouldn't want to, because what can trigger enthusiasm is just one incident rather than a student suddenly taking ownership of the material and says "this is mine" so in the Balloon Buggy, they actually have the buggy, but likewise, it doesn't have to be owning something physically, so that when something can get that thing to work when they've done it themselves, then they've learned the idea, because they you know, other people knew it, but they take joy and pleasure in making that design.

Scott: I had a question about, I don't know how many age groups you've worked with in workshops, but do you think that there's any difference in the workshop plan structure, I know you were saying that you could only talk about a concept for 10 minutes, then project, then move on to another concepts, do you think later that you can work on concepts more then move on to projects later?

Peter: The sophistication of the argument can be much more complex with older students, but I'm not sure the attention span is any greater, you might be able to get as far as 15 minutes, but I think if you plot learning curves against the amount of time in lecture, then 10 minutes and then you have to refocus, bring them back, and then you can go back and do another 10 minutes or something like, but I think it's a general thing. My mind wanders.

Scott: The ability to talk about a concept later, maybe In like a year 10 kid, that maybe the attention span, maybe go into concepts a little more

Peter: Oh yes, you can go into concepts a little more, but the ability to concentrate on someone for more than 10 minutes doesn't go up as one gets older.

Scott: Have you noticed any difference in the, you might have already answered this, difference in a comprehension workshop versus a workshop that gets children interested in the subject matter.

Peter: I think the comprehension is a place for doing for rather, you know..so, it isn't to say that you can't get some learning there, but it's done to meet the teachers objectives, you need to for the balloon buggy with you've got to explain why they're doing it, about engineering in a culture, about the engineering process, and that's all fine, and that isn't for the teacher that's for their benefit, but it's a bit off course, but it will hopefully benefit them somehow.

Scott: I know the PIC programme that we're running, the students comprehend the subject matter, but the interest in the subject matter is what we're trying to focus on. I don't know if there's any way to structure the workshop to try and do both.

Peter: There interested in the particular, means that their open and receptive to that generality of ideas, it isn't that they are interested in PICs and nothing else. If you can suspend their interest in a particular way then you got them, I think in general, so I wouldn't worry about that.

Appendix M

Bernie Holloway Interview

Kevin: First off, what is your background experience with science and technology education?

Bernie: Ok, I'm a telecommunications engineer, scientist. First degree in electrical engineering, second degree in Telecomms systems, I've worked prior to the present job, about two of them for about, 20 years I guess, doing sort of systems design and software design. Since doing this present job, which is SATRO, I've been in different courses to make me appreciate what the National Curriculum is, what, sort of how children learn, etc. So my background is really engineering.

Kevin: So what influenced you to do what you're doing now?

Bernie: As opposed to doing engineering?

Kevin: Yes

Bernie: Hmm, interesting, this was really sort of the first step into retirement, you know, I sort of wanted a change, see something entirely different. This was going to be sort of a short term, 18 month contract, hahha, started about 10 years ago.

Kevin: What are the goals of SATRO as you see them, and what prospects do you see for them in the future?

Bernie: Well the main goal is to raise interest in science, engineering and technology. That's the general one, the department of training and industry, they provide funds for us, they have more of a specific sort of objective, in particular they want to do, is they want for every key stage, they want the have the opportunity for the children to experience some external science and technology activity. So in the business plan, what I have to do is at least offer that opportunity to every child in east London as they go through each key stage. So that means that, four key stages, so that means that a kid should have an opportunity of doing one science and technology activity during each key stage, which means like 4. In practice, that's almost impossible to achieve because of the number of children and the level of funding.

Kevin: What exactly did you want to get out of our project?

Bernie: Well your project sort of manifolded...What we were hoping was that we'd get some people to help reduce the backlog of workshops, ok..so that's what we hoping to get out of it. What we hoped you were going to get out of it, would be sort of an opportunity to develop some additional resources, that one may be of use to, that we could actually re-use, and two, one that would help you achieve your own project, which I think is to understanding how you can influence children's interest in choice when it comes down to science and technology and engineering careers.

Kevin: In the past, how have you found and developed new projects or workshops to run?

Bernie: How have I?

Kevin: How have you developed new ones?

Bernie: Ok, we have a management board and an educational working group, ok, and on the educational working group, and on the educational working group, there are teachers, well we wish we had more, but umm, we use that as one to try and establish what limits and needs are, and the robotics workshop, that's how that came about, so basically half the teachers argued and what do you have difficulty with, and they have difficulty with looking at controls, and trying to think out parts, one how to teach controls to children, and two, how to improve their understanding of controls systems. So that's how the robotics workshop came about. Other ones come about by..we're part of a national network, so we share ideas umm across country, and what'll happen if an activity will be piloted in one part of the country, and we look at the results of that and then decide whether we want to use it ourselves. And there's also national events, like this one right here which is K'Nex, which is a construction kit, I think K'NEX in the states is much better organised in terms of running national competitions than where in this country, it's been slightly off mark. But anyways in the short term, yes, we really speak to the teachers, look at the national curriculum, and then sort of try to develop something that the teachers have difficulty with in the classroom environment.

Kevin: From experience, several of these workshops have different structures to them, what kind of structures work better and the children have a better response too.

Bernie: Hmm, when we talk to the teachers, they want to make that front for the kids, they also want something where someone from outside comes in to the school that has some background experience relative to the areas national curriculum, ok, and that's what the workshops about. There are two bits, it's got to be fun for the kids, you got to engage the kids, and it's got to have something that relates to the real world, now, around them. In terms of structures of workshops, that leaves a little from what I've said already. One, you want to get them to think about the world about them. So if you take, for example, the Balloon Buggy workshop, you'd normally ask them what do engineers do. And so you'd normally set that context, but you'd make sure that that interactive part doesn't run for too long, because the attention span if you're sort of going to go more than 10 minutes, in that mode of operation I think you'll probably loose their interest. Now once you've gone through that general phase, then you're talking about sort of, very particular challenge or activity that they're going to be involved with, then trying to start to get them to think around how they're going to complete that challenge and to start to give them some indication as to what the design may be, what the problems may be, then what you need to do is you need to look at the very particular skills that they need to complete the workshop, so umm, if it's to do with making some examinations it has to show of them some particular tools that they'd have to use, just prior to when they're going to be running the workshop, and when you've done the workshop, which you'd normally hope for it to be something fun, where they actually made something that they could perhaps keep, then you've got to leave time at the end to make sure that you review what they've actually done and what problems they've had, and give them an opportunity to communicate to you and to the other children in the class that there're results because communication of their work is an objective of the workshop, it's not just the making, it's actually sort of the getting them to communicate their idea to others. So that's roughly the structure.

Kevin: Do you think that children are learning more from a workshop that gets them more excited, rather to a workshop that more includes more detailed work, or lesson plan.

Bernie: It's not our job to go in and teach the national curriculum, that's the teachers job to do that, so ideally what you want to do is you want to make sure that the children have done something prior to the workshop that sort of lays some of the foundations of what you'll need for the workshop.

Kevin: So what you're trying to accomplish from these workshops, you think the children are getting more out of it than, like out of the two workshops, like the Balloon Buggy are giving more..

Bernie: They get different things out it. The school time table in this country is getting very crowded and often when you go into a school, it will be the first time during that year that the children will have had the opportunity to actually use, hacksaws, to use...etc. So one of the reasons why we got such a demand for the Balloon Buggy is that there's not sufficient time and not enough class time or preparation time for the teachers to assemble the right equipment to allow them to get the experience of making things. So the Balloon Buggy workshop gives them that design and make activity and the use of those tools that they would not normally have the opportunity of doing within a normal time table. So that is an opportunity that the children should have, ideally it should be sort of given the advantage, but it's not, so that objective that you want to achieve quite well for the Balloon Buggy workshop, it's a different sort of structure for the robotics workshop. Where you do start covering some of the ground that would normally be covered by the teacher, and hopefully reinforcing what the teachers doing, not having to build it from first principles. So usually when we go in and do that workshop, we ask the teachers to already go over series circuits, and the way I'd normally start is to go over some of that stuff to make sure that the children are reminded about it. So the difference in workshop unfortunately, and the kids enjoy the balloon buggy workshop more than the robotics workshop, but I hope there's more concepts reinforced within the robotics workshop

Kevin: What attempts have you made in assessing the workshops that you run?

Bernie: From the workshops that you've run, I don't think there's been sufficient assessment ok. The assessment has been by implications by looking the demand and at the number of times that we're called back to run that workshop. So hopefully what you've done is helped us to carry out a slightly more structured assessment of the workshops, other workshops that we do, those at the Soanes Centre, yes there is a formal evaluation sheet. Or the outreach programmes that I do, like using the sticks machine and things like, there's a much more formal evaluation, but we're grateful that you've done some more structured evaluation of the things that we do.

Kevin: Particularly in the robotics workshop this is a generic development product testing according to Peter, he mentioned that there's been changes made to it and I've sort of want to know what sort of problems you've encountered and methods that you've used to solve what kinds of things have caused problems

Bernie: We had a lot of trouble with the robotics workshop. We started off using K'nex kits, because you had them. Then that was a little bit of a blind alley, because they were too bulky to fit into the suitcase, so that was one of the false starts, the other bit we thought we wanted to make a sensor, so I brought in the idea of a pressure switches, because I wanted them to make something, then we realised that for that particular workshop, that it would be unlikely we'd be able to afford to give the children the things that they make at the end, making a pressure switch was one of the things that they could make and take. But that aspect of it went fairly smoothly, it was an easy thing to do so we tamed that side of it. We had made to change the chassis of the used as the gears and motors. We had trouble with reliability of the geared motors, the gearing part in particular, the battery clips that we used, that caused us to change the type of motors we were using. Also, the structure of the workshop, we wanted to be able to manage differentiation, some children more able than others, so instead of it being a closed activity with the robot relay, we added a number of open ended challenges, hopefully that would allow for some differentiation between the children. That's what we've got to at the moment, we still need to improve the reliability of the equipment. Also, what we've had to do is cut down the preparation time. One, sort of get a printer to print out all the worksheets, two, to get the paper templates, get those cut out automatically, so we don't have to spend time cutting out like 60 paper templates, and that's now being produced by a company for us. Next stage on is really because we think that the robotics workshop is still quite challenging, even for the bright kids, is to make a workshop to be used in secondary schools, so what we're working on next and we'll work on very briefly is the use of a very simple programmable controller to actually control the little robots, and that will be done for secondary schools.

Kevin: What factors have you noted that cause children to become off task of the workshop?

Bernie: When things don't work. Now sometimes the in the robotics workshop, sometimes things don't work because they don't understand what they're doing. What was completely annoying is if things don't work because of faulty components. That sort of means that the leader of the workshop has to diagnose not sort of errors in standing, but errors in equipment. In that situation, there are children wanting attention and guidance and they start to have to, and that's sort of when they're getting off task, when then want help, but the leader is spending far too much time on sort of a non productive activity.

Kevin: What kind of relationships have you noticed between the success of performing tasks or the success of Balloon Buggy, the way it runs, or far they get in the robotics workshop to a verbal response, like knowing the material.

Bernie: I don't know if I got the gist of that

Kevin: Like conceptual versus hands on

Bernie: Ah, yeah, I don't think there's an easy answer to that, some kids just sort of work in a more spatial way versus a verbal way. They can sort of visualise their design, but when it comes to describing their design they're not always able to. So there's not really good correlation between the verbal abilities and their spatial awareness of their design ability. I think it's unfortunate that some children may be very strong in one aspect, but weak in another. That's particularly so in the robotics workshop, less so with the balloon buggy workshop, and some so in the balloon buggy and less so in the robotics.

Kevin: If possible, could you categorise the type of child that tends to do better in these types of workshops, the type of learning style and the type of child they are, and what type of child not as well.

Bernie: Hmmm, I think the girls tend to do better on the robotics workshop, in terms of reading the brief and understanding what they have to do and perhaps persevering with the problem, more than the boys do. Umm, that's just very generalise, the other thing that I've noticed is, most of the workshops that I've run, which isn't that many, maybe about 20 robotics workshop exceptional children tends to be the boys that do exceptional in understanding the layout of the robotics workshop, but I don't have a logical reason for. But if you look at some of the research papers on this, that in general the boys are not as good as the girls. But then if you look at the distribution of them right, then you'll probably find that they're more boys at the top end of spectrum then there're are girls, where the for the distribution of girls, the average is much higher. I think the boys sometimes have to be more active in the average, as to say that they're down more poorer than the girls are in the distribution.

Kevin: Just in the way you present the workshop, such as the Balloon Buggy, when you present concepts, like we noticed, when we focus on section, if we talk about it, then the people would have better buggies at the end. Do you think they're getting more out of them being physically told that before they do it, or testing out and finding the problems themselves.

Bernie: The trouble with that, if you leave it completely open, and don't give them some guidance, I think a much smaller percentage of the children have that enhanced learning experience. They're discovering it themselves. In that way, it lodges with them and stays with them better. But to get a more uniformity of coverage, of more children having that learning experience, you've got to give them some pointers in the beginning, because if you don't it will be either by accident or either more brighter kids that understand that experience. Not that you should tell them the answer, but you should, like if you're introducing anyone to a subject, you need to refresh their memory and give them a few pointers, so it's useful for you to lead, but not to give them the solutions.

Kevin: What are some limiting factors in having a workshop run well?

Bernie: Limiting factor....A big limiting factor is one sort of, the discipline in the school. If you go into a school and you can't even get the attention of the kids, to start with, and there's three or four kids having a punch out in the middle of the hall, which happened before, you're going to lose the kids like that. So the school has had to establish this sort of classroom management regime that allows you to come in and actually interact usefully with the children, without having that it's a hell of a battle. Next one is just sort of the physical layout of where you operate it. Does it actually allow you to run the workshop in the way that's most appropriate to the kids... what else....making sure that the school has taken notice in what the workshops target is on, so actually doing robotics, and you find that you have a year four class in front of you that's not done circuits, etcetera..., then you find you've got a hell of a struggle.

Kevin: Do you have anything else that would relate to this?

Scott: I have a couple questions to ask you. I don't know how many different age ranges that you've worked with for workshops, but have you noticed any certain age where the workshops are most effective at stimulating interest in going into those fields later.

Bernie: I've found that it's more rewarding to work with the top end of primary school, where the kids get really enthusiastic and that's enthusiasm and that interest provides an excellent basis for building on in later stages, so they're more open and receptive at that stage.

Bernie: We've done primary school being an excellent place. What you need to do is run activities that stimulate them at key stage three, which is age 13 or 14 years. Usually that one is more getting them to start solving problems more and communicate their ideas in a better way. In this country, the options that they have, what you'd be doing is influencing them before they made their selection of what GCSE they'd be taking. But in practice, if you look at what they'd be doing is very limited options anyways, so they've got to do is design and technology, so what you'd be doing is influencing a very small percentage between doing food technology and resistant materials right. But it's more worth while doing it as a reminder during key stage three so that perhaps they do do resistant material instead of food technology, then the next thing is sort of the decision of which A levels they do, that is quite important to do, unfortunately that's key stage 4, so they'll be like 15 or 16 years old, and the pressure on them at that stage is quite high, so they have to, they're just about to do their revision for their GCSE's and the school are quite reluctant to have any external distraction, so you'll find that sort of access to children at key stage 2 is quite easy, top end primary, access at key stage 3 is quite easy, because the workshops then are sort of reinforcing what they need to do for the national curriculum. Access for them at key stage 4, when they have to do their GCSE's, is more difficult, but it's when you want to influence them, when they do their A levels.

Scott: Nothing that you introduce earlier in their life, like key stage 2 workshops would be highly effective at them choosing that later in life rather than in key stage three in the same effect.

Bernie: : I think they're more receptive and they're prejudices and ideas are not fully formed at the primary school. The next one where we do workshops is 16, so like sixth form students, that are actually doing A level, and they're usually committed already, they've chosen their A levels that relate to engineering, that relate to something like history, or whatever. But if there were part of sort of doing it with them, and because some of them will have chosen something like science or math, but still weren't sure if they should go into a financial area or an engineering area, and also, generally, on a smaller number basis, you can get access to a sixth form than you can a key stage 4.

Scott: With introducing different workshops at different age levels, is there any difference in structuring the workshop, like for every key stage. Did you do any major changes in workshops going up in age?

Bernie: For primary school you're really stuck with a workshop for an hour, hour and a half, two hours tops. You're really limited to that, for key stage 3, you fall into two categories, you get the sort of short workshops of about 45 minutes, and that's when the school's got like a technology day or technology week. Then the school wants sort of like 5 sessions during a day, because they have groups of about 120 kids, they have a year group, and they want the year group to go through the same experience, so you end up having to produce a much slicker and shorter workshops in order to have the larger group have the same experience within the same school day. Then in addition to that, what they want, you might end up want to have more demanding challenges that require to have them take off the time table, maybe a half day or whole day event. So at that level, key stage 3, you end up having two main classes of workshops, big challenges, and actually three, create brief challenges short workshops, like technology day, then projects, where the kids will end up working on a project for a term or so, and then you're looking at national awards for what they've done. So key stage 4, more difficult, the whole day or half day challenge that can be the schools, you can still slip in a project that links in with GCSE's assignments, and get them engaged in a subject of their project work, as part of the GCSE's, as part of the national award scheme, that's where the press comes in too. The sixth form challenge, they tend to be the challenge, and the kids tend to go and get information about careers.

Scott: I know in key stage 2 and 3 you have to focus a brief amount of time on concepts and then move on to a workshop, then more concepts, then more workshop. Is there any difference in workshops between key stage 2 and 3 to other older workshops?

Bernie: Ok, usually there's less time to go over concepts, what we'd be doing is really presenting a challenge, more than problem solving, then there wouldn't be going over the concepts, you'd just set the concepts and have more emphasis on them communicating back to you, so there's more emphasis placed on them working together as a team and actually solving problems and reporting back at the end of the workshop, so it's more controlled, but it's more sort of like giving them a problem, and then let them delve, and then save like half an hour to let them report back to you.

Scott: Have you noticed any difference in a workshop focusing on principles as opposed to something that focuses on stimulating their interest. Sort of like the Balloon Buggy and Robotics workshop.

Bernie: The project about getting them excited about a workshop and challenges, and making them realise that the skills that they have can be applied to simulations of real world problems. And that's s very productive in getting them interested in science and technology. And we have things like robotics challenge, that isn't about principle as such, although they're reminded about principles, not by me or the workshop leader, but from an activity, but that sort of challenge is more about getting their interest and making a fun activity that makes them take up science and technology, I think that might not quite answers your question. The progressive tasks that would allow them to do a challenge is something that should be covered in school, and I wouldn't expect it in a school and to present the concepts or the steps for them to attain that project, I'd expect them to be at that level already and present them with a fun project or activity.

Scott: Ok, I think that's about it.

Appendix N

Balloon Buggy Workshop Evaluation

Objective of workshop: The workshop is intended for year-five and year-six primary school children and gives them an experience of tackling a real engineering problem.

1. **Amount of Preparation:**

- Leader's Guide: Before starting, the space should be organised so that the tools are set out at six work places and a glue table for the four hot glue guns is prepared. Newspaper should be used to protect this table surface from glue. Try to arrive about twenty minutes before the workshop is due to start. This gives you time to meet the teachers and set out the six workstations needed for a class of thirty. Each work station should have a mat to protect the bench, a bench hook, a junior hacksaw, scissors, pencil, ruler and sanding block.

- Comment: In addition to the suggested, all demonstration tools should be easily accessible to the instructor during the opening lecture. A model of a complete buggy should be pre-made and demonstrated to the class.

2. **Classroom Environment:**

- Leader's Guide: Sessions last about 90 minutes and are best run is a school hall or large classroom.

- Comment: Through observing and instructing the workshop we determined that this is the must appropriate setting.

3. **Hands-on Vs. Lecture:**

- Comment: This workshop has a good distribution of both Hand-on and Lecture learning activities.

4. **Flow of Instruction:**

- Leader's Guide: Introduce yourself and discuss the variety of things engineers do. Explain that they, acting as engineers, are to try to solve a problem. Engineers are trying to find alternatives to petrol-powered vehicles and they are going to experiment by making a 'balloon-powered' buggy. Discuss forces. Ask class for suggestions of how to fix a balloon to buggy made from LEGO. A volunteer could show their design to the class. Demonstrate the use of hacksaws and glue guns to the class. Divide the class into 6 working groups. Hand out wood to start activity. Test buggies if they are free-running. End the session with a race to compare buggies. Discuss what was learned with the class.

- Comments: This is an Idea flow of instruction for the teacher (discussion – activity - discussion). It provides an easy environment to teach because most of the workshop runs itself. The major problem in this workshop is that children can get out of control because of their excitement and high adrenalin. It becomes difficult for the teacher to get these children to calm down and listen to the teacher.

5. **Amount of Instruction:**

- Leader's Guide: Discuss forces with the children. Have a volunteer show how the balloon would go on the buggy. Demonstrate how to cut the wood strip using a hack saw and then how to use a glue gun to make the chassis. Describe how to fit the wheels, axles, bearings etc. Children may need advice on the best size for the hole in the Correx.

- Comments: Through observing and instructing the workshop we determined that the students constructed the best buggies and comprehended more of the concepts in the end discussion when the following was done.

- Suggestions: Instead of just describing how the wheels, axles, and bearing fit on the students should be briefly shown. During the demonstration of the construction of the buggy suggest hints to the students regarding engineering concepts, such as friction, stability, strength, etc., to aid in their designs. Have a completed buggy to serve as a model for students to refer to during their construction.

6. **Freedom of Creativity:**

- Comment: Through observing and instructing the workshop we determined that when the children were given total creative freedom they were too concerned with making their buggy looking attractive rather than perform well. When this happened it took longer for the students to finish their final buggies and the workshop ran short of time.

- Suggestion: Have the students draw the design they want for their buggy and show you. Give the children the material to build their buggies only after you have checked their design.

7. **Group Vs. Individual:**

- Leader's Guide: It is suggested that no more then 30 buggies be made per workshop. If there is more than this, some can work in pairs.

- Comments: When the students worked as individuals several of them fell behind and did not finish in time. A number of students finished their buggies early and had nothing to do while they waited for everyone else. When the students worked in groups all the groups finished in time. This was because in a group there may be a less able child but chances are the other child will help carry the other along.

- Suggestion: It is suggested that all workshops be run for students working in pairs.

8. Student Ability:

- Comment: In many of these classes there is a large division of ability. Several students finish much sooner then other. During the time these more able students are waiting for the others to finish they may get restless and difficult to manage. It is recommended that these children should be keep occupied by having them made modifications to there buggy or decorate it.

9. Student Behaviour:

- Comment: It is important not to let the class get out of control during any portion of the workshop. The children are often running on high adrenalin levels and become difficult to manage.

10. Number of Instructors or Helpers:

- Comment: A larger number of helpers usually mean a better running workshop. This number of helpers should not be too large, however, because of limited work stations.

11. Teacher experience and ability:

- Comment: The instructor of this workshop should have a good background in basic engineering concepts.

General Comments: Teacher surveys show that students are genuinely excited about the workshop and the teachers themselves are appreciative of what the workshop brings to the class.

Appendix O

Robotics Workshop Evaluation

Objective of workshop: The workshop is intended for year 5 and 6 primary school children and gives them an experience of different ways of controlling a robot (a buggy).

12. Amount of Preparation:

- Leader's Guide: Ideally, before starting, the space should be organised so that it is possible to run the robots on the floor. A marker board is needed and children must be able to sit at tables for written work in a workbook. Materials needed to run the session are packaged in a suitcase.

- Comment: Ensure that all robots are in working order before handing them out to the children (some may have been damaged during their transport).

- Suggestion: Improve upon the reliably of the equipment (buggy's wheels, gear boxes, and slide switches).

13. Classroom Environment:

- Leader's Guide: Sessions for classes of 32, last about 90 minutes and are best run in a large classroom. A marker board is needed and the children must be able to sit at tables for written work.

- Comment: Students loss interest in the later discussions of the workshops when seated at their desks. They get distracted with their local environment (i.e. Robots, class mates, worksheets, etc.) and do not concentrate on instructor.

- Suggestion: Have the initial discussion and final discussion on the carpet or open space in the classroom there the students can sit on the floor. This why they are less likely to get distracted during discussion.

14. Hands-on Vs. Lecture:

- Comment: This workshop has very good amount educational material in it. The topics discussed and the actual hands-on work coincides well.

15. Flow of Instruction:

- Leader's Guide: Introduce the workshop by discussing examples of control of control systems such as how you control your temperature. Go on to discuss electrical control systems. Discuss control of movement by demonstrating line-following buggy. Explain that the class are going to make a pressure switch.

Demonstrate construction. Explain that the class are going to use the pressure switches to control the movement of a buggy. Children test their switches and then hook the switch up to the buggy. Children are then grouped together to run a "relay race" between buggies. Stop the class, hand out workbooks so the class can complete the first two sides of the workbook. Discuss the six tasks to be completed that are listed in the workbook. Give time at end of lesson for children to write up what they have done. Have the children put the equipment away. Summarize what was learned in session.

- Comments: There are number of starts and stops between tasks and lecture of the workshop. In the capstone workshop there were 11 sections of task and lecture. This should be cut down in number.

- Suggestions: Remove the relay race portion of the workshop. Have the demonstration of the line following buggy at the end of workshop to keep the children interested in the conclusion discussion. (see Appendix K)

16. Amount of Instruction:

- Leader's Guide: Have the children recognize the electrical symbols on the board. Discuss what a switch does. Shown how to construct the pressure switch. Discuss the first two pages of the workshop. Discuss the tasks portion of the workshop.

- Comments: Discuss what needs to be done on worksheet. Go over a couple of the questions with the class then let them work on it. When discussing the task portion of the workshop describe the different tasks with some detail. Demonstrated the use of the side switch. Children have often been confused when to use the slide switch. Hint that the slide switch isn't used till task D. (See Appendix K)

17. Freedom of Creativity:

- Comment: There is very little creative freedom for the children in this workshop.

18. Group Vs. Individual:

- Leader's Guide: Children should work in groups for the task portion of workshop.

- Comments: Children should not work in groups any larger then three. Any more and the on or two children could get left out of the actively while the other two do the work. Due to availably of buggies and nature of workshop children working pair is the best set up.

19. Student Ability:

- Comment: In many of these classes there is a large range of ability between students. The structure of the challenges in the workshop is set up well to acuminate the different skills levels of children. Children of lesser ability can still feel a sense of accomplishment.

20. Student Behaviour:

- Comment: Behaviour management issues can be occur when children give up on a task because they can not do it. Often this is because of a mechanical failure in the equipment or a misunderstanding of what needs to be done.

- Suggestion: Be as clear as possible when describing tasks. Double check the reliably of equipment.

21. Number of Instructors or Helpers:

- Comment: The larger number of helper the smoother the workshop will run. In many of the tasks done most of the groups need a little help from the teacher. With more helper a group of children are less likely to give up if they can figure out a particular task.

22. Teacher experience and ability:

- Comment: The teacher should know the basic concepts of electrical engineering. It is important that they can communicate well with the students and get there attention effectively because of the start stop nature of the workshop.

General Comments: Teacher's surveys show that students are genuinely excited about the workshop and the teachers themselves are appreciative what the workshop brings to the class.

Appendix P

Interview with Steve Barlow

Steve Barlow is the leader of the Techno Games team at the Barking Abbey Comprehensive School of London. He currently has a team of 8 eighth year students. This is their first attempt at participating in the Techno Games competition with eighth year students.

Scott: Have you reviewed the CD-ROM?
Steve: Yes.
Scott: For how long?
Steve: Quite a few hours.
Scott: Do you think that it is helpful as a teaching resource?
Steve: It's been really helpful in terms of...if I could introduce it in the classroom I would use it (no access to CD-ROM drive in the classroom). In terms of breaking things down it is really resourceful.
Scott: Do you think that it teaches a lot about robots and how robots work?
Steve: About the basics of it, yeah. It's a really good starting point.
Scott: Do you think that the video clips help with the lessons?
Steve: Yeah. They have been really helpful.
Scott: I don't know how much the kids have looked at it.
Steve: See that's the thing because I haven't watched it with them you know, if I could have sort of guided them or talked them through it, so I'm not sure. We're gonna give them out to year twelve's because they'll like it better than a textbook and they will use it.
Scott: Do you think that the CD-ROM should have more interactive stuff?
Steve: Ummm...yeah, more stuff like on the BBC robot thing where you build your own little jitterbug thing. That would be...more of that stuff would be excellent. Especially because they make the parts as well so you're not just throwing something together and seeing it wobbling around on screen. They're understanding about the injection moulding and everything. I found it excellent, but I'm just a sad teacher.
Scott: Do you have any suggestions for anything that they could put on it to make it more effective?
Steve: We found with "Erica" ("Erica" is the swimming robot that the year nine Techno Games team created for last year's competition) we started simple and she just grew and grew and grew. So maybe a different level...they ought to have some more sort of engineering stuff on there you know. So that's what I would suggest.
Scott: Do you think that the kids have learned more concepts from the CD-ROM?
Steve: There has been improvements haven't there? I think that you're seen that. And I think that it is because of the CD. It does help out. I mean, the first time that you came they had just shells (the students began drawing what they wanted to the

robot to look like, as an assignment) Now they're actually using the right language. I figure it helps out a lot.

Kim: Do you know if the members have taken any classes on robotics before?

Steve: They haven't in school. I don't know if they have elsewhere. We don't cover mechanisms until year nine.

Scott: How long have you been involved in the Techno Games program?

Steve: We ran a year nine club last year. So it's just over a year, about a year and a half so eighteen months. The kids had great fun and it's just got bigger and bigger.

Scott: How many kids are on the team?

Steve: Well, four just quit today to do dancing or gymnastics. So how many were here today?

Scott: Eight.

Steve: Yeah, I think that's what it's going to be. There was about twenty kids that put their name down at first and I didn't want any more than about twelve, but you're going to get the dropouts and the kids that don't like it anymore so hopefully it's right around ten or twelve. It's manageable and it's not the biggest workshop in the world.

Appendix Q

Techno Games CD-ROM Evaluation

Barking Abbey Comprehensive School

27 February 2002

Per request of the Science and Technology Regional Organisation (SATRO), we evaluated the Techno Games CD-ROM to determine its effectiveness as a teaching tool. To complete the evaluation, we visited Barking Abbey Comprehensive School to gather opinions from the Techno Games team members and team leader. First, we informally interviewed the students. At that point, only five of the fourteen members had used the CD-ROM. From these interviews, we learned of their first impressions, which were positive in that they said that the CD-ROM provided interesting and useful data.

After this preliminary data, we gave the students a survey to complete (see attached for completed surveys). By this time, some team members had quit the program and there were eight final members, six of which had looked at the CD-ROM. Therefore, we were able to gather surveys from those six students. This survey was in the form of a Likert scale. A Likert scale uses standardized response categories, like strongly agree, agree, disagree, and strongly disagree, to determine the intensity of different items in an unbiased manner (Babbie, Earl. The Basics of Social Research…). The statements and the responses to them are as follows (SA = Strongly Agree, A = Agree, DK = Do Not Know, D = Disagree, SD = Strongly Agree):

1. Before using the CD-ROM, I knew what the Techno Games program is and what its purpose is.

SA	A	DK	D	SD
2	2	0	2	0

2. The information on the CD-ROM is boring.

SA	A	DK	D	SD
0	0	0	6	0

3. Many design ideas can be found on the CD-ROM.

SA	A	DK	D	SD
0	5	1	0	0

4. I got many design ideas for my robot from the CD-ROM.

Many	Some	None
0	4	2

5. The CD-ROM teaches a lot about robot mechanisms.

SA	A	DK	D	SD
3	3	0	0	0

6. The video clips are interesting.

SA	A	DK	D	SD
2	3	1	0	0

7. The CD-ROM should have more activities to interact with.

SA	A	DK	D	SD
1	3	0	2	0

The eighth and final question asked for any recommendations for improvement. The most popular response that we received was a suggestion to incorporate some type of "robot workshop" on the CD-ROM. This workshop would allow the student to make the parts to a robot, assemble the parts and then compete with the robot in a

Techno Games activity on screen. This was also suggested during the interviews. We referred the students to www.bbc.co.uk/robots because we knew that this website has a similar activity. The students expressed that they still would like to be able to use the activity on the CD-ROM because of reasons such as the inability to access the internet and the like.

The last part of our evaluation consisted of an interview with the leader, Steve Barlow (see attached for transcription). The purpose of the interview was to gain an experienced teacher's perspective concerning the appropriateness of the CD-ROM as a teaching tool. He mentioned that he thinks that the CD-ROM has successfully taught the students about the engineering of the robot. From the information gained from the CD-ROM, Steve Barlow and we have noticed many improvements in the member's robot designs that they presented at each weekly meeting. Over time, they started to incorporate more engineering into their designs instead of focusing on the personality of the robot, such as determining the perfect name or physical appearance. Because of a three week gap in between the meetings that we were able to attend (because of a half term break and other events), the students had the CD-ROM, instead of the weekly meeting with the leader and the CD-ROM, to assist them with their design. Their vast improvements indicate that the team members gained much of their information from the CD-ROM over this time because they had no classes with Steve Barlow.

Even though many advancements were made in the designs, this may be because the robot was in the initial stages of design. Mr. Barlow suggested that as the building of the robot continues, the engineering concepts become much more difficult to comprehend and the CD-ROM may not be able to help with those advanced concepts. Although he believes that the CD-ROM has value, he believes that it is mostly beneficial in the early stages of robot creation because only basic concepts of robot engineering are introduced. So his recommendation to improve the CD-ROM is to include more specific and advanced engineering information. He also reinforced the students' idea of a "robot workshop" on the CD-ROM.

Appendix R

Canal Museum Pre-test #1

Prior Weston School
7 Students (after school club)
Time of Workshop: 1:30

Structure
Pre-workshop: We began the workshop with a discussion of various tunnel types and the reasons for building tunnels (such as saving land space and more convenient, such as going through a mountain instead of over it). We asked the students how tunnels are built, such as through soft materials and under water. This led to a discussion of how the Channel Tunnel was constructed. None of the children knew exactly how it was constructed (using a tunnel boring, or drilling, machine). We also talked about the ventilation in tunnels and how people would get out in an emergency.

Part 1: In the first part of the workshop we had the children attempt to dig through a pile of wet sand. We gave the children plastic knives as tools to dig with. We let the children make their own plan for digging prior to starting. They were successful in digging a small hole through the base of the sand. We then told them it must be bigger to allow cars to pass through. When they tried to make the tunnel bigger, it collapsed on them. This was what we wanted to happen. We then had a discussion of why the tunnel collapsed (because it had no support). We asked the students what shape tunnels they had seen before and led into the fact that the arch is the strongest structure. We drew several shapes on the board (arch, rectangle, triangle) and asked if someone could show us how the forces are distributed on each of the different shapes. We showed how the forces are distributed evenly on the arch, making it the strongest structurally. We explained that wider arches were not as strong as closes arches. We also did a little demonstration using folded pieces of paper in the shape of an arch and a rectangle and what happens when you press down on the top of each.

Part 2: For the next part of the workshop we had the children try to assemble the wooden arches on the desktop. Many of the students had difficulty with the pieces slipping; however one student was successful in building the 15 piece arch by himself. We then gave the students the bases to build on. This helped and the students were more successful in building their arches. We then asked the students what went wrong when they were building their arches. We then led into the idea of using a framework to support the tunnel while it is being constructed. We also introduced the concept of the keystone and why all arches must have an odd number of stones or pieces.

Part 3: For the final part the children constructed their own tunnels using a cardboard base and plastic frame to build on. We mixed the mortar for the children. Most of the arches came out good; only one student glued his tunnel to the frame. The students seemed to enjoy this part of the workshop the most. We left the arches to dry overnight and left a small amount of mortar for the children to fill in any empty spaces after drying.

Problems: Better "sand tray" needed for first part of workshop, something with more support. Might need a little more support of the bases for the second part when they build the wooden arches.

Comments: The pre-test ran very well and the students seemed interested in the workshop. The workshop lasted and hour and a half which was our target and we had time to complete all parts. We gave out a post-workshop worksheet to all of the students asking questions on the concepts learned in the workshop. Out of the seven students all were able to identify the strongest arch from a choice of three, 6 out 7 knew how the forces were distributed in an arch as well as how to dig through a soft material (by using a frame). 3 were ale to identify the keystone and 3 mentioned building from either side with the middle stone as the last one to be put in. These results suggest that the children did learn something from the workshop as well as had a good time.

Ideas for Improvement: We asked the students what they would change if they were designing the workshop. All of the students said they would make it longer with more time for discussion. This came as a surprise as we thought we had a lot of discussion about many different concepts. One of our ideas is to buy a small toy car to be used to show how big the tunnel should be (so that cars may pass through it). Another idea was to have some models of structures (square shape, Triangle shape, different size arches) to demonstrate how the forces are distributed in this to the children. We also had a discussion with the class teacher about possible ways for improvement. His main suggestion was to get pictures of different local tunnels such as the Blackwall or Dartford Tunnels and pictures of tunnel construction so the children could better relate the material to the real world. He also suggested bringing different materials such as clay and chalk to have the students try to dig through and see which is the easiest.

Canal Museum project: Pre-test post-workshop Survey Results

Seven worksheets

Question #1: Which one of these three arches is the strongest?

All gave correct answers 7/7

Question #2: Show how the forces are distributed in this arch when a weight pushes down on the top, such as a person walking on it.

All gave correct answers 7/7

Question #3: How would you dig a tunnel through a very soft material such as mud without it collapsing on you?

-Put a frame in. Do it section by section
-You would put frames in.
-Make a very small hole with a frame inserted in sections.
-Put supports up.
-Start near the bottom and make a small hole and then make it bigger and bigger.
-Put a frame in section by section.
-Put up supports and make sure the tunnel is the same diameter all the way through.

Question #4: Why are there always an odd number of stones in an archway?

-Because you need a middle point.
-Key stone which is in the middle. To stop it from collapsing.
-There are always an odd amount of stones in an archway because you will build from both sides evenly and when they get together, you put the last key stone in.
-(No answer given)
-Because you need the key stone in.
-When you're building, you have to start from each side, thus having an odd brick.
-Because you need a key stone.

Question #5: If you were designing this workshop, what would you change?

-Make it longer! More discussion over the things you have made.
-I would make it longer
-Nothing
-Make it longer
-Longer lesson
-Make extension classes; more time. If you had more time you could discuss what went wrong.
-Make it longer.

The results of the post-test were very positive. All the children gave correct answers for the first two questions. Question four regarding the keystone gave the students the most problems. We decided to take this part out of the workshop (explaining the keystone) because it confused the children when their brick arches had an even number of bricks (this was possible because of the mortar).

Appendix S

Canal Museum Pre-test #2

St. Mary's School Primary School
28 students, 18 boys and 10 girls
Time of Workshop: 1:30

Structure
Pre-workshop: The children were seated on the carpet and we began the workshop with a discussion of various types of tunnels and the reasons for building tunnels (such as saving land space and more convenient, or going through a mountain instead of over it). We asked the students how tunnels are built, such as through soft materials and under water. This led to a discussion of how the Channel Tunnel was constructed. We then discussed and drew a few diagrams of the ventilation system in tunnels and how people would get out in an emergency.

Part 1: In the first part of the workshop we had four children come to the front of the class and attempt to dig through a pile of wet sand. We gave the children plastic knives as tools to dig with. We let the children make their own plan for digging prior to starting. They were successful in digging a small hole through the base of the sand. We then told them it must be bigger to allow cars to pass through. When they tried to make the tunnel bigger, it collapsed on them. We then had a discussion of why the tunnel collapsed (because it had no support). We asked the students what shapes do the tunnels they had seen before have which led into the discussion on why the arch is the strongest structure. We drew several shapes on the board (arch, rectangle, triangle) and asked if someone could show us how the forces are distributed on each of the different shapes. We used a magazine to represent a flat ceiling in a tunnel. When a student pushed down on it the middle of the magazine bent showing that it was weak in the middle. We then bent the magazine in the shape of an arch and then had a child push on it. This time the magazine was much stiffer and showed the students that the arch is a strong structure. We then drew three different size arches on the board and asked the students to pick which one was the strongest. Then we took a two model arches made of paper one big and one small. We showed them that the smaller of the two was stronger when you pushed down on them. We then had the children go back to their seats so we could explain the next part.

Part 2: For the next part of the workshop we told the children it was a race to for each group to complete an arch of wooden blocks. Many of the students had difficulty with the pieces slipping. The group of student with the most difficult set of blocks gave up and seemed upset. The students who had the bases to build on constructed their aches the fastest. We then asked the students what went wrong when they were building their arches. We then led into the idea of using a framework to support the tunnel while it is being constructed. During this discussion it was very difficult to manage the children and get them to listen to us.

Part 3: For the final part of the hands on section we had the children constructed their own tunnels using a cardboard base and plastic frame to build on. We mixed the mortar for the children. Some of the arches came out good, but some students completely covered their tunnel with mortar. The students seemed to enjoy this part of the workshop the most. We left the arches to dry overnight and left a small amount of mortar for the children to fill in any empty spaces after drying. Teacher decided that he wanted the children to keep their tunnels so the school bought the set of bricks.

Conclusion: We then gather the children up on the carpet and had a short discussion on what they learned and how it related to the construction of the Islington tunnel.

Problems: The Idea for a race was not a good idea. The students with the more difficult set of blocks seemed like they felt cheated and upset. There were problems managing the class when they were at their seats.

Comments: The workshop lasted and hour and a half which was our target and we had time to complete all parts. We didn't hand out the post-workshop worksheet to the students because we were not able to discuss all the material on them during the workshop. This was because the students were very difficult to manage.

Improvement: From our discussion the teacher of the class after the workshop as well as his evaluation sheet we can up with some ideas to improve upon the lesson. First of all the flow of instruction should be slightly modified. The majority of discussion should be when the children are still on the carpet. An outline of what the children are going to be doing through out the workshop should be made so that the children have something to look forward to as well as possible keeping them for going off task. The hands-on parts of the workshop should while discussion is still going on (by another instructor or a few students). During the arch building from wooden pieces section of the workshop should not be a race although it could be conducted in a simulator manger. The putting the mortar on the blocks should be demonstrated. The final discussion should focus more on the Islington Canal tunnel.

Appendix T

Leader's Guide for Tunnelling Workshop

This workshop is intended for year-five and year-six primary school children and gives experience on the engineering concepts behind tunnel building. Sessions last about 90 minutes and are best run in a classroom with a desk for each child to work on.

Pre-workshop Preparation

It is suggested that the following items be set up prior to the start of the workshop.

- Fill the bucket with wet sand (just wet enough to stand up on its own) and flip the bucket over so the sand pile is standing in the sand tray.
- Mix the mortar (Approximately one part water to four parts mortar. It should be able to be rolled in hands and should just barely stick to your fingers) and split it up into small cups for each student (or one cup for each two students0

Introduction

Begin by asking what tunnels are used for and why are they made.

- Discuss why they use the underground train system (Tube). Explain that there would no room for it above ground because of roads and building so engineers created them underground to save space.
- Ask why an engineer would make a tunnel though a mountain when then could just build a road around it or up it. Explain that it would be cheaper to build a road, but quicker and sometimes safer to go through (could mention snow on top of mountain makes it dangerous to drive).
- Mention that tunnels were used hundreds of years ago for canals. Ask if any of the students know what the canals were created for (transport of goods). Ask why they needed to build tunnels for the canals (can't make the water go over a hill or mountain).
- Discuss how the Channel Tunnel was created. Ask the students how you would build a tunnel underwater. They used Tunnel Boring Machines (Show Picture) from both sides deep below the layer of mud at the bottom of the ocean in the rock underneath. You might mention that the tunnel was dug from both sides. Ask how someone would get out of the channel tunnel in an emergency. Discuss that most tunnels have ventilation shafts but it is not possible to have vents in the channel tunnel (directly up into the ocean). Discuss that the tunnel has a third emergency shaft which allows an escape route (show picture).

Part 1

Have the children dig through wet sand.

- Choose 4 children to come to the front of the class and dig though the pile of wet sand that has been prepared before the workshop started.
- Give each child a digging devise (plastic knife or spoon will do)

- Tell them to dig a tunnel so that a model car can go through
- Children should be able to make the tunnel with a small diameter hole.
- Keep telling children to make the hole larger (until it collapses) so the car-bus-train can fit through.

When the tunnel collapses have the children sit back down for discussion.

- Ask why the tunnel collapsed and how could have it been avoided
- Discuss why the tunnel didn't collapse when the tunnel had a small diameter and why it did collapse when it had a larger one.
- Discuss how you could use a support system to keep the sand for collapsing (like using pieces of paper or cardboard)

Lead into a conversation on tunnelling through different materials

- Take loose sand and show how it falls when you try to dig through it
- Take Granite or another hard stone

Ask what different shapes of tunnels the students have seen

- Explain that the arch is the strongest shape (structurally) for a tunnel. Explain that the forces are distributed evenly in an arch (when you push down on the top). This can be demonstrated by using folded pieces of thick paper (or thin cardboard). Have one folded in the shape of an arch and the other in the shape of a rectangular tunnel. Have a student push down on the top of each and see that the rectangular one bends in the middle while the arch is much more stable (it may be necessary to put a weight such as a book on each end of the arch so the ends don't slide away). You may also wish to draw a diagram of the arch and the way the forces are dispersed out in it (see attached diagram).

Part 2

Explain that now the students will work in groups to attempt to build an arch using wooden blocks. Tell them that the sets of blocks have different numbers of pieces and some groups will be given a base to build on while others will need to be built on the desk. Mention that the building should be done by only one student (if necessary other students may help after a few minutes). Before beginning this part tell the students that after this section each student will be able to create their own arch.

When some of the arches have been completed (allow about 5 minutes of building during this part). Demonstrate the stability of the different arches by first pushing down on one built on the desk. The arch will collapse easily. Then push down on one built on the base, it will be much stronger.

- Ask why the one on the base is so much stronger.
- Ask what could be done to make the building easier (lead into the idea of using a framework or former to build on).
- Explain that it would be impossible to hold all the bricks in place while they dry so something must be used to hole them in place (Islington tunnel for example).

Part 3

Explain that now the children will be making their own arches using miniature bricks, a cardboard base, and a plastic former. Tell them that they will be building the arch around the former and not to it (this is important) because when it dries the former will be taken out. Show the cardboard base and explain how the plastic former fits into the base. Have the students tape the former to the base to keep it in place. Demonstrate to the children how to apply the mortar to the bricks using a plastic knife. Each student will need 12 bricks to complete the arch. Allow the arches to dry overnight and you may wish to fill in the cracks the next day.

Post Workshop Discussion

You may wish to have a discussion about how successful the students were in their construction. Finish the workshop by relating the arches (or tunnels) that they have constructed to the Islington Tunnel. The Islington Tunnel was completed in 1820 and was built using bricks. Mention that the tunnel (unlike the ones the students made) used four layers of bricks. It is approximately ½ mile long (880 yards). Possible questions:

- When was the tunnel constructed?
- How long is the tunnel?
- How was the tunnel constructed?

Appendix U

Information on the PIC Logicator Program

Before you build a flow sheet you must configure the program to which PIC microcontroller you will be using. For this workshop we will be using the model 16F84A. To configure the program to this model, go to Option in the task bar, then go to PIC Type and choose 16F84A.

Commands

You can create a control system or the PIC by making a flow sheet. A flow sheet is composed of different commands. The commands will be on the right of the screen. Drag the required command from that commands list and place it in an unoccupied space. Many of the commands have a Cell Details box where you can specify the details of the command (we will learn more about this later).

START and STOP commands

These two commands do not have Cell Details boxes. The START command marks the point where the flow sheet starts running. When the PIC microcontroller gets reset or powered up, the flow sheet starts running at the START command. The flow sheet will stop whenever it reaches a STOP command.

Labelling a Command

To label a command (such as "switches on light") double click on the command, which opens the Cell Details box. Type your label in the yellow highlighted area and then click OK. This label has no affect on the way the command runs.

Deleting a Command

Click on the command to select it. When the command is coloured red, press the delete key.

Moving a Command

To move a command, select it and drag it to a new position.

Routes

Routes can be drawn through the middle of a cell, or in either one of the two rails between cells. Routes must be drawn in the direction that you want flow to take when the flow sheet runs.

Drawing Routes

Click with the right mouse button on the command at the start of the route. Hold down the button and draw the route and then release the button when you have completed the route.

Deleting Routes

Click on the square with the line that you would like to delete in it. Once the square is highlighted, simply press the delete button, and the line should disappear.

Outputs

In order to make your system perform a task, you have to understand what it is you want it to do, or the output that you want to receive. Once you know what your outputs need to be (on or off), you can set up your flow chart to make different outputs at each of the output pins of the chip.

Creating Outputs

By clicking on the "Outputs" block on the right hand side of your screen, you can drag it on to the workspace. This command lets you make each of the pins on our chip any combination of high or low (1 or 0 respectively). Click on each number in the Output screen, and you will see that they are either a 0, 1, or *. The 1 will represent an 'on' command, a 0 will represent an 'off' command, and the '*' will ignore the pin, or stay at what it was at before.

Testing Outputs

To see what your outputs are, you may click on the Digital Panel icon in the task bar, represented by a set of 6 lights with 2, 1, 0 underneath it. When your flow sheets are run, it will show whether the outputs are on or off in the Output display.

Running your flow chart

You must make sure that all the lines are connected between the blocks in your program and that there is a start and a stop block. Then simply click the Run! Menu or the green task bar icon. To stop the flow sheet, click the Stop! Menu or the red task bar icon.

Appendix V

Leader's Guide for the PIC Module Lesson 1

This workshop is intended for year eight students. The lesson will last for approximately 100 minutes and children need access to the PIC Logicator Program on a computer.

Science National Curriculum Content

The children should be taught:

To recognise outputs in their own and existing products
The importance of feedback in control systems

Possible Workshop Sequence

1. Introduce systems (input/output). Give an example of input/output (action/reaction).
2. Introduce electronic control systems like a thermostat. Go over inputs/outputs of a thermostat.
3. Discuss how outputs can be logic high (1) or logic low (0)
4. Allow the children to gather around one computer so that you can show the PIC Logicator program and discuss why it is used and how it is used (for example, how to construct a flow sheet, commands and their tasks, high and low output command).
5. Then show the students an example of a simple flow sheet/program and its respective outputs. Also, write the flow sheet on the blackboard.
6. Send the students back to their computers and construct and then run the same flow sheet/program that was on the board.
7. After completing that task, bring them back to the leader's computer to show an example of a feedback loop and the concept of a repeating loop, again writing the flow sheet on the blackboard).
8. Send them back to their computers to try this example.
9. Give the students the lesson one worksheet/checklist to accomplish the first two tasks.
10. After the students finish the first two tasks, teach them the concepts needed for tasks three and four.
11. Then let the students finish the worksheet by themselves. Tick the boxes when they have shown you that they have completed the task.
12. Ensure that all students have completed tasks one and two at the minimum.
13. Allow ten minutes at the end of the lesson to review the concepts that have been covered (logic states, what things have control systems, etc).

Leader's Guide of the PIC Module Lesson 2

This workshop is intended for year eight students. The lesson will last for approximately 100 minutes and children need access to the PIC Logicator Program on a computer. This lesson will cover the fundamentals of downloading the program to the PIC and using that chip as a central control device. This lesson will also go over the basics of using inputs on the program as well as on the chip.

Science National Curriculum Content

By the end of the lesson, the children should:

Understand how to recognise inputs, processes and outputs in their own and existing products.

Recognise the importance of feedback in control systems.

Comprehend how to use electronics, microprocessors and computers to control systems, including the use of feedback in these systems.

Possible Workshop Sequence

1. Review systems and outputs from previous lesson.
2. Discuss with the students having only the chip as the control device, and how the programme that they are designing will control the inputs and outputs of the chip.
3. Show demonstrations to the children around a computer of a flow chart and how to download it to the chip. Make sure to show them that they need to configure the program for the chip that is being used. Go to options, then go to PIC type and choose the chip 16F84A (8 output, 5 input pins).
4. Show students the downloading process of a simple programme that they, as a group may want the board/chip to do (outputs only, perhaps SOUND command).
5. Get the children to develop the same programme on their computer using more advanced concepts if they wish (feedback loops), then have them download it to chip (over network, one at a time)
6. Let the children develop their own programme on the computer that they wish to download to the chip and "try out".
7. Introduce the concept of inputs once again, and how they may be used in the software, focusing once again on the digital logic states of "on" and "off".
8. Demonstrate the use of the Digital Decision input command on the computer. Use feedback at the end of the flow chart to re-emphasise this concept with the students.

9. Give the students the worksheet for week two. Have them follow and complete the first 2 tasks on their own, tick the boxes when the students have completed the tasks.
10. Have the students complete the third task on their own and tick the box when it is completed.
11. Have the students come up with their own flow chart that uses the Digital Decision command. The use of feedback is encouraged.
12. Wrap up with a question session on systems, feedback, outputs, sound and inputs.

Leader's Guide of the PIC Module Lesson 3

This workshop is intended for year eight students. The lesson will last for approximately 100 minutes and children need access to the PIC Logicator Program on a computer. This lesson introduces the concepts of controlled looping and controlled repetition. Because variables are used for this concept, it is important to explain variables on a basic level if they have not already been introduced in the mathematics curriculum.

Science National Curriculum Content

By the end of the lesson, the children should:

Understand the importance of feedback in control systems

Know how to use electronics, microprocessors and computers to control systems, including the use of feedback

Recognise inputs, processes, and outputs in their own and existing products

Possible Workshop Sequence

1. Begin the lesson by reviewing the previous lesson's main aspect of inputs, as well as the lesson before that of looping, feedback and outputs.
2. Introduce the concept of repeating a loop for a certain amount of time.
3. Ask the students how they think it would be possible to obtain this goal, see if their ideas resemble the idea of a loop control variable
4. Introduce the concept of a variable, VERY simply. Tell them about the use of a variable that you can set to any number and have it count up every time the loop is run, therefore including the use of the INC command. Along with the INC command, the use of the COMPARE command needs to be gone over. The concept of comparing the current variable value to a predetermined value will be a key concept in looping for a certain amount of time.
5. Run a simple, but thorough demonstration of this concept for the students.

6. Go over the worksheet with the students. Tick the boxes on the worksheet when the students have demonstrated that they can perform the tasks. Demonstrate several different examples if necessary.
7. Let the children create their own loops using variables and explain how they want them to run. Then go over what they want versus what they got from their program. If they can build their loop without much trouble, have them include the use of inputs into their system.

Leader's Guide of the PIC Module Lesson 4

This workshop is intended for year eight students. The lesson will last for approximately 100 minutes and children need access to the PIC Logicator Program on a computer. This final lesson will first test the children as to the concepts that they have learned throughout the course. Also, the use of subsystems will be gone over by using the MACRO command, giving the students a deeper understanding as to how systems can be broken down into simpler tasks through sub-systems.

Science National Curriculum Content

By the end of the lesson, the children should:

Understand how to recognise inputs, processes and outputs in their own and existing products.

Recognise the importance of feedback in control systems.

Comprehend how to use electronics, microprocessors and computers to control systems, including the use of feedback in these systems.

Understand that complex systems can be broken down into sub-systems to make it easier to analyse them, and that each sub-system also has inputs, processes and outputs.

Recognise how different types of systems and sub-systems can be interconnected to achieve a particular function.

Possible Workshop Sequence

1. Start the lesson by collecting the homework from the previous week.
2. Begin reviewing some of the major concepts from the past 4 weeks. These include what outputs are, what inputs are, how each of these are used, along with feedback and loops.
3. Distribute the test to each student and have them work at the computer for approximately 30-40 minutes to complete their task.
4. After they have finished their task, have each of the students download their program to the PIC and see if it completes the designated task in the right order.
5. Introduce the concept that complex tasks can be broken down into sub-sections, and how they can be useful for doing very complex flow charts.

6. Show an example around the computer using the MACRO and DO MACRO commands. Make a simple task on the computer under the MACRO heading then put the DO MACRO command in the main flow chart that will use the smaller command that was just built.
7. Have the students go to their computer and make the same flow chart and check to see that they have completed it.
8. The students should then try and make their own complex flow chart using the MACRO command
9. Wrap up with a review of what the students have learned throughout the workshop, and what kinds of things they now think use the PIC's and similar chips.

Appendix W

National Curriculum Guidelines
Systems and Control
Key Stage 3

Knowledge and understanding of systems and control

5 Pupils should be taught:

a to recognise inputs, processes and outputs in their own and existing products

b that complex systems can be broken down into sub-systems to make it easier to analyse them, and that each sub-system also has inputs, processes and outputs

c the importance of feedback in control systems

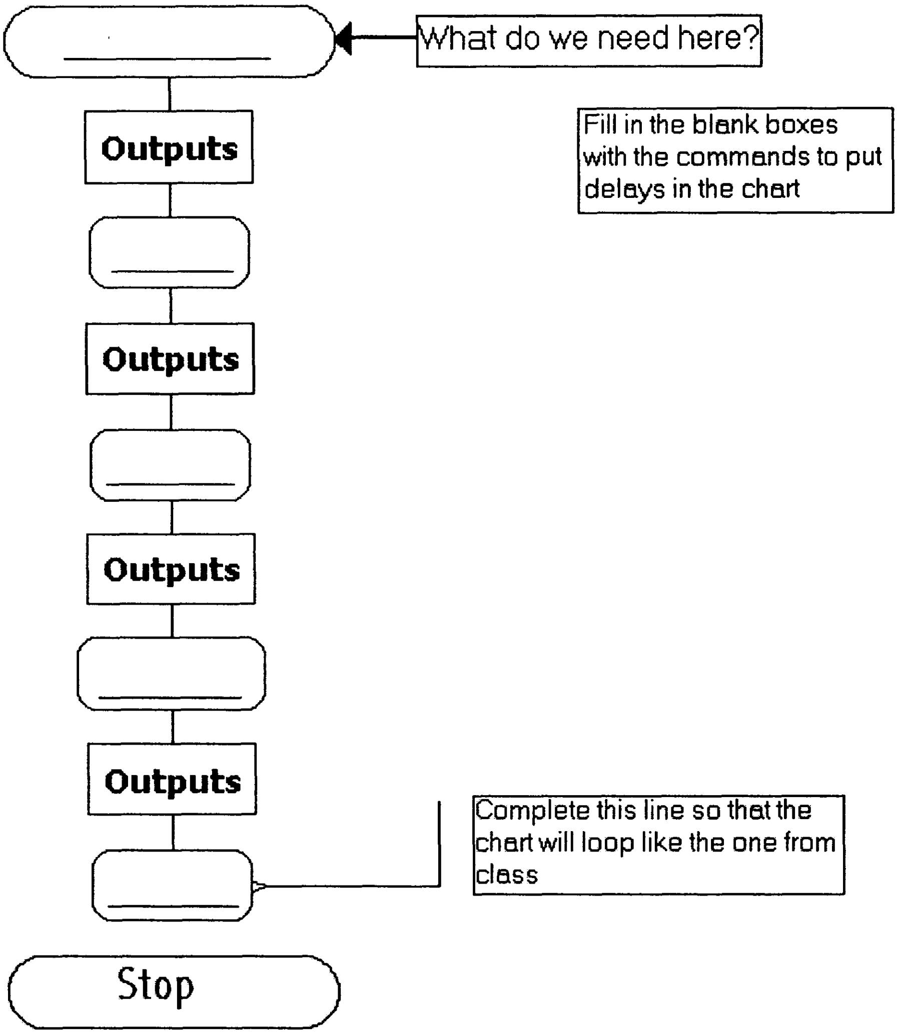
d about mechanical, electrical, electronic and pneumatic control systems, including the use of switches in electrical systems, sensors in electronic switching circuits, and how mechanical systems can be joined together to create different kinds of movement

e how different types of systems and sub-systems can be interconnected to achieve a particular function

f how to use electronics, microprocessors and computers to control systems, including the use of feedback

Appendix X

Year 8 PIC Workshop Homework 1



If the output pin is set to 1, is it on or off? ________________________

What happens when an output pin is set to a '*'?____________________

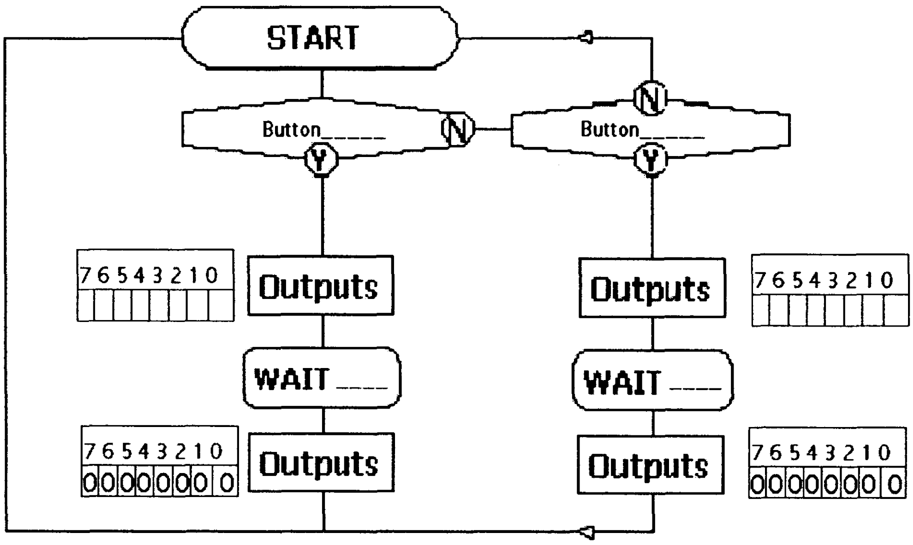
____

How many output pins does the PIC that we are using have?__________

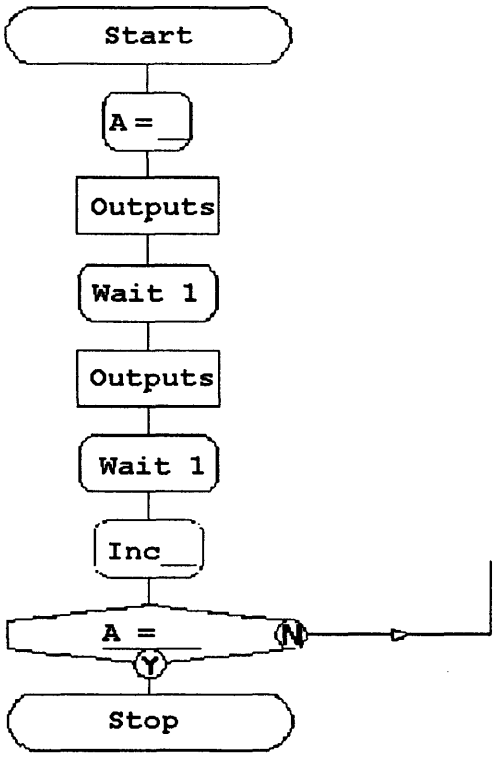
Which block should you place after an output command so that there is a delay so we can see the pins light up? ____________________________

Year 8 PIC Workshop Homework #2

1. In the first example, try and fill in the blanks that will make a system that will blink the numbers 0,2,4,6 for 3 seconds if you press button 2, and blink the numbers 1,3,5,7 for 6 seconds when you press number 1.



2. For the second example, you must fill in the blank spaces to make a flow chart that will repeat the same sequence for 7 times using the looping that we learned in class last week.



Appendix Y

PIC Workshop Final Test

This test will go over all of the things that you have learned in this workshop over the past 4 weeks. In this exam, you will be given a design, and from this description, you must create a control device (a flowchart) that will perform the task. This is the main idea behind what engineers do. They are given a set of inputs to a system and the outputs that are needed, and they must design a system that will do that task.

The system that you must design must do the following:

It must be like your own little electronic lock. When the right combination of keys (the INPUT commands) are pushed (you can choose whichever keys you want, and however many you want), then an output sequence that you can design will start. If the right combination is not pressed, then that sequence will not start, and will have to go back to the beginning and check for the right set of keys again.

You can test out your system using the input from the keyboard. When you run your program on the computer, you can use F4 through F9 to simulate the buttons being pressed on the actual board. F9 is for button 0, F8 is for button 1, F7 for 2, etc.

Make sure you run your program on the computer first to make sure it works. Once you download it into the chip and test it on the board, you will be graded on how well it works. The program that works the best and has the best output will be put on display in the hall, and be the Programmer of the Week.

Appendix Z

PIC Module Self Evaluation

PIC Module Pre-test of Lesson 1
Warren Comprehensive School
18 Students – Year 8
Time for Workshop: 1:40

Structure: The students needed to work in pairs because of the number of available computers. The teacher started the workshop with a review of the students' prior lesson on inputs and outputs while they were sitting at tables. Then we gave an overview of how to create a flow sheet using the PIC Logicator program while the students were gathered around one computer. We demonstrated one specific flow sheet and then asked the students to create the same one as practice on their computers. After completing that task we asked them to gather around the computer again so we could describe the concept of a continuous loop. Then the students went back to their computers again and we handed out a worksheet for them to complete. There were four different tasks that they had to complete. The first two showed what the flow sheets were supposed to look like so they could practice the building of a flow sheet. The last two forced them to create the flow sheet on their own. Each pair had to raise their hand when finished with a task so that one of the teachers could tick the box, therefore saying that they completed that task (the teacher had to make sure that it was a correct flow sheet first). All of the pairs completed the first three tasks and all, but one, finished the entire worksheet. Two of the groups asked for more tasks to complete because they finished the initial four tasks with time to spare. We reserved ten minutes at the end of the workshop for a review discussion on the concepts learned during the lesson. There was ample time at the end of the workshop for an adequate discussion.

Comments/Ideas: We had plenty of time to run the workshop. The students seemed interested and they were pleased when they got an immediate result from their flow sheets. We wish that we could have given each student the opportunity to complete the tasks by themselves because it was difficult to monitor whether only one member of each pair was doing the work or if both were collaborating to finish the worksheet. The two Warren Comprehensive School teachers that were present during the pre-test both expressed positive reactions toward the first lesson of the workshop.

Appendix AA

Non-Curriculum based science and technology programs

The Exploratorium is a non-profit, educational museum that was founded in 1969. It is located in the Palace of Fine Arts in San Francisco, California. Encyclopaedia Britannica commented that the Exploratorium is the "archetype of the hands-on science museum". The Exploratorium has a nationally recognized program that educates teachers on reforming and improving science education. The Exploratorium also has a Summer Science Day camp geared towards children seven to ten years old. It offers "content-based activities" that highlight the camp's chosen theme for the summer and also provide the children with free time that allows them to explore their own curiosities. There are three summer sessions of 21 campers each, and over 250 campers have participated in the program thus far. Annually, the museum hosts 600,000 guests, including representatives from 36 museums in 18 different countries. The success of the Exploratorium's camp suggests that allowing children to explore on their own is key to getting them interested in science. (Retrieved November 12, 2001 from www.exploratorium.com).

The Exploratorium also offers a community outreach program called Children's Educational Outreach, which brings science to inner-city children and teens in their own neighbourhoods. The program, which started in 1984, provides many resources for these students, including "free educational materials, professional in-service workshops for staff, and training on Internet research and Web site creation" (Retrieved December 7, 2001 from www.exploratorium.com/programs/outreach/index.hmtl, December 2001). In this program, as well as other activities, the Exploratorium provides a variety of resources including, the "Exploratorium Snackbook" exhibits. This "snackbook" was created by the staff of the Exploratorium in conjunction with over one hundred teachers for over three years. These "snackbook" exhibits are actually small-scale models of the real exhibits that teachers and students can create in the classroom using inexpensive materials. The creation of these miniature exhibits stemmed from the museum's desire to bring the exhibits to the children instead of the teachers bringing the children to the museum (Retrieved December 7, 2001 from www.exploratorium.com/snacks/index/hmtl).

The Exploratorium published the instructions for the mini-exhibits in four separate volumes of the "Science Snackbook Series" which has been very popular. According to the Exploratorium, one week after print, they received contact from a teacher in Australia that needed help finding materials. Even though the books were established for high schools, they are used by elementary school teachers and university professors. Teachers of all subjects, including math and art, use the books as well. At one school a teacher of English as a Second Language (ESL) students reported that all of her students were communicating better and helping one another with the lesson. One sixth grade class started building its own science museum at school using these books. The "snackbooks" were also helping Boy Scouts get merit badges, creating fun activities at birthday parties, and giving students ideas for science fair projects (Retrieved December 7, 2001 from www.exploratorium.com/snacks/index.html).

Allowing children to construct these mini-exhibits gives students a better understanding of how they work and how they pertain to science lessons. Evidently, when the children can create the projects on their own, they have not only pride in their creation, but also a better comprehension.

The Science Place in Dallas, Texas is a museum focused on hands-on learning techniques. They perform school assembly and classroom programs that incorporate different concepts in science like electricity, states of matter, simple machines, magnetism, and engineering. "Science-to-go Discovery Trunks" are also available through the Science Place. Each trunk has materials for a three-week lesson on a specific science subject. In addition to the large amounts of deliverables that the Science Place provides, they entertain over 150,000 students that visit during field trips every year. Students can come to Science Place School five days per week instead of going to a regular public school (even preschool is offered). Although science is the centre of the curriculum, it is presented through reading, writing, math and other subjects. (Retrieved December 7, 2001 from www.scienceplace.org/EP/EPPreschool.html) By incorporating science and technology into other areas of curricula, the information on science and/or technology can reach those interested in the other subjects.

Lawrence Hall of Science (LHS), located at the University of California at Berkeley, is a resource centre that specializes in the development of new materials and programs for students and teachers. LHS has been working since 1968 to create modern programs that spread to all members of the community. They have many types of programs that publicize science and technology. Some of these include on-line activities, workshops and assemblies brought right to schools, programs that enhance the knowledge and development of teachers, as well as hands-on workshops that get the entire family involved in the learning process (Retrieved November 12, 2001 from www.lhs.berkeley.edu).

One of the family workshops at the Lawrence Hall of Science is called Dinosaurs. This program allows for children and adults to act as palaeontologists. Under this role, they search and dig for artificial fossils of a dinosaur. After finding all pieces, these palaeontologists construct a replica of a dinosaur's skeleton. According to LHS, these workshops are usually fully subscribed within a few days of registration (Retrieved December 9, 2001 from www.lhs.berkeley.edu/classes/familyworkshops.html)

The family workshops at LHS offer valuable information about teaching science to children and a very affordable way to get children and their parents involved in learning science. Involving the entire family in this learning process allows the lesson to be carried to the home as well, instead of being left at the museum or classroom. The rest of the family can play a very active role in reinforcing the lesson to the student if they learned (or re-learned) the lesson too.

Appendix BB

History of Tunnelling and the Three Types of Tunnels

As far back as 2000 B.C., people throughout the world and all through history have used tunnelling to accomplish various tasks. Tunnels can provide travel space for cars, trains and boats, a place for water or sewage to run, and also space for power lines. The Romans made tunnels to carry water into the city from the mountains. These tunnels (called aqueducts) also took sewage out of the city. In the seventeenth century, tunnels for boats created a new way to carry goods far distances in a shorter time. During the nineteenth and twentieth centuries, tunnels became more important for transportation, as the use of trains and cars increased. (Retrieved December 13, 2001 from www.pbs.org)

Over the past 4000 years, tunnels (as well as the tools for digging them) have become more sophisticated. Tunnels have been made using fire, hand tools, explosives (such as dynamite, gunpowder, and nitro-glycerine), compressed air drills, tunnel boring machines, tunnel shields, and combinations thereof. (Retrieved December 13, 2001 from www.pbs.org/wgbh/buildingbig/tunnel/index.html)

Tunnel builders in 2000 B.C. sometimes used fire. The workers would light the soil on fire and then drench it with water. When the circumstances were right, the sudden change in temperature of the soil would cause the area (such as a section of the side of a mountain) to break off in large pieces. The Egyptians used fire for the first time to mine gold and copper from the mountains. The Romans also used fire as a tunnelling technique. Slaves in Rome built the Cloaca Maxima, one of the earliest "sewer pipes" in Rome. Even though this technique proved to be very dangerous (toxic fumes and extreme heat caused thousands of deaths), this was the technique used for over 2,000 years after it was invented. (Retrieved December 13, 2001 from www.pbs.org/wgbh/buildingbig/tunnel/basics.html)

In 2000 B.C. workers also utilized hand tools for digging tunnels. The Belgians, the French, and the Portuguese all uses shovels and picks to mine gold, copper, and salt in their respective countries. In the middle ages, armies used hand tools to dig tunnels under the castles of enemies. They supported the tunnels with wooden structures as they built the tunnel. The intent of these constructions was to take away support from underneath the castle, so when they burned the wooded timbers that supported the tunnel and the castle, the whole castle would cave in. (Retrieved December 13, 2001 from www.pbs.org/wgbh/buildingbig/tunnel/challenge/tools/hand.html)

Explosives proved their effectiveness when it came to building tunnels through mountains. Dynamite, nitro-glycerine, and gunpowder helped workers to remove large quantities of rock or soil much faster than with fire or hand tools. In 1679, gunpowder helped in the construction of the Canal du Midi, which linked the Atlantic Ocean and the Mediterranean Sea. In North Adams, Massachusetts in 1867, workers on the Hoosac Tunnel used nitro-glycerine for the first time in history, replacing gunpowder as their primary tool. Also during 1867, dynamite was invented. Nitro-glycerine and gunpowder were both very dangerous to work with, so dynamite offered a alternative to those methods. (Retrieved December 13, 2001 from www.pbs.org/wgbh/buildingbig/tunnel/challenge/tools/explosive.html)

The builders of the Hoosac Tunnel first used gunpowder to start the construction, which was dangerous because the gunpowder often exploded at the wrong time. To their relief, the compressed air drill was soon invented and used thereafter on the Hoosac Tunnel. This drill was safer than gunpowder, three times more effective than gunpowder, and also created a cooling wind inside of the unventilated tunnel. However, a drawback was the big clouds of dust resulting from chipping away at the rock with these drills. (Retrieved December 13, 2001 from www.pbs.org/wgbh/buildingbig/tunnel/challenge/tools/explosive.html)

The year 1957 introduced the Tunnel Boring Machine. A Tunnel Boring Machine weighs approximately 200 tons; it was created to cut through rock. Its first job was to cut through shale and limestone in Toronto, Canada, to produce a sewer tunnel. When working at its best, these machines can cut through 76.2 meters (250 feet) of rock in one day. Geologists have to be very aware of the types of rock that the boring machine will encounter while tunnelling, as problems may arise if it reaches a rock that is too hard. (Retrieved December 13, 2001 from www.pbs.org/wgbh/buildingbig/tunnel/challenge/tools/boring.html)

Another tool used to construct tunnels is the Tunnel Shield. Workers built this shield to support loose dirt around them from caving in. An iron frame is built inside the tunnel as the workers progress until masons can line the tunnel with bricks to give the needed support. The Tunnel Shield was first used for the Thames Tunnel in 1825. (Retrieved December 13, 2001 from www.pbs.org/wgbh/buildingbig/tunnel/challenge/tools/shield.html)

The Three Types of Tunnels

There are three major types of tunnels -- namely, soft-ground tunnels, rock tunnels, and underwater tunnels. Engineers need to evaluate the setting so that they may construct the tunnel correctly. After assessing the setting, there are three major steps to creating this tunnel. The first step is digging through the soil with the proper tools and techniques, which is determined according to the setting (soft-ground, rock, or underwater). Next, the workers have to provide support for the earth above and around them. The third and final step is to add needed items, such as lights and pavement. (Retrieved December 13, 2001 from www.pbs.org)

Each type of tunnel needs different things for success. Soft-ground tunnels usually house things like subways, sewers, and water-supply systems. A specific example is the Thames Tunnel. To build a soft-ground tunnel, a tunnel shield is the tool used most often. This shield is needed as a support because the heavy ground pushes on all sides of the tunnel. Without the shield, the walls of the tunnel would collapse from the pressure

Rock tunnels often permit railways to go through mountains. As mentioned, explosives would have been used in earlier years, but today engineers use Tunnel Boring Machines. The dense rock walls in these tunnels require very little additional support, because the stress created from the weight of the solid rock is evenly distributed throughout it.

The third and most difficult type of tunnel to construct is the underwater tunnel. In early years, tunnel chambers had to be pressurized to keep water from leaking in. Today, professionals sink pre-made sections of tunnels into the water and fasten them together underwater. These pre-made tunnels need to be able to withstand the pressure of the water to be effective. (Retrieved December 13, 2001 from www.pbs.org)

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