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PARTNERSHIPS IMPLEMENTING ENGINEERING EDUCATION IN THE WORCESTER PUBLIC SCHOOLS

Implementing Engineering in Second Grade Classrooms

An Interactive Qualifying Project Report

Submitted to the Faculty of the

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

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Abstract

This project studied the influence of an engineering based curriculum on second grade students over the course of one year. During this time, we implemented lessons that met the requirements set forth by the Massachusetts Educational Frameworks for public schools and the requirements of the Worcester Public Schools Benchmarks. Although we found that students involved with the project did come out of it with a better understanding of engineering, our influence did not necessarily increase their interest in the field.

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I - Introduction

I.1 - Science and Technology/Engineering Frameworks

The Partnerships Implementing Engineering Education (PIEE) was introduced as a result of the Commonwealth of Massachusetts introducing a technology and engineering aspect to the K-12 curriculum frameworks in 2001. Its development stemmed from two reform initiatives in Massachusetts, the Education Reform Act of 1993 and Partnerships Advancing the Learning of Mathematics and Science (PALMS). Since 1992, the PALMS Statewide Initiative has been funded by the National Science Foundation, the state, and the Noyce Foundation. The first science and technology framework was approved in 1995 and implemented in classrooms.

Since the Education Reform Act called for periodic revisions and reviews, the Commissioner and Board of Education appointed a revision panel in 1998 that studied the standards in the original frameworks, took comments from the classroom into account, and assessed the appropriateness of the frameworks in order to obtain a more unified organization of concepts and skills through the grade levels. The panel also reviewed data collected from the Third International Mathematics and Science Study, the *National Research Council's National Science Education Standards,* the Technology for All Americans Project, the results of the 1998 MCAS tests, *Benchmarks for Science Literacy-Project 2061,* and advances in science, technology, and engineering.

In August 1999, the draft the panel had created was released for public comment from science and technology/engineering educators, as well as other educators. From these comments, further revisions were made, mainly at the high school level.

The purpose of a science and technology/engineering curriculum stems from the desire for Massachusetts students to draw on skills, habits of mind, and specific knowledge of subject matter that are associated with science and technology/engineering. Armed with these, it is hoped that students that go through the public school system in Massachusetts will be better prepared to participate in the civil and intellectual life of America and to seek further education in these areas if they so desire. (*Massachusetts Curriculum Frameworks,* http://www.doe.mass.edu/frameworks/)

In response to the frameworks introduced by the state, Worcester Public Schools introduced their own curriculum benchmarks that would address the state frameworks through specific lesson interactions. The benchmarks integrate the material required by the frameworks into preexisting grade level curriculum maps for the schools in the Worcester region. The benchmarks allow the Massachusetts frameworks to be implemented alongside science lessons generated in previous school years. (*Worcester Public Schools*, http://www.wpsweb.com/benchmark/default.htm)

I.2 - High Stakes Testing

In 1998, the state of Massachusetts began its implementation of the Massachusetts Comprehensive Assessment System (MCAS) in response to the Education Reform Law of 1993. This series of tests was initially administered to students in grades 4, 8, and 10 in the areas of mathematics, English language arts, and science and technology. In subsequent years the tests grew to include grades 3-10 and expanded to also include the fields of engineering and reading.

The fundamental goal of the Education Reform Act of 1993 was to improve students' academic performance. The Massachusetts curriculum frameworks combined with MCAS endeavor to create uniform academic standards for all public school students in Massachusetts. (*Massachusetts Comprehensive Assessment System,* http://www.doe.mass.edu/mcas/)

According to the Education Reform Act all Massachusetts high school students must meet both local requirements as well as achieve a level of "Needs Improvement" on their MCAS test to receive their diploma. The students must demonstrate "a partial understanding of subject matter and [solve] some simple problems." This particular testing system is unique to Massachusetts, but many other states have implemented their own standardized testing to monitor students' performance and determine where improvement is necessary. In parallel with showing general areas that need improvement across the state, it can help determine which schools and districts in particular are falling behind.

I.3 WPI and WPS Partnership

In response to both the new frameworks and MCAS, Worcester Polytechnic Institute and the Worcester Public Schools endeavored to expand upon their preexisting relationship to benefit the students of both schools. The students at Worcester Polytechnic Institute (WPI) could use their knowledge of engineering concepts to help create specific curriculum materials for the new science and technology/engineering frameworks while simultaneously fulfilling their Interactive Qualifying Project requirement for graduation.

WPI and Worcester Public Schools (WPS) determined that a partnership to help Worcester Public Schools develop engineering and technology based curriculum and prepare teachers in the Worcester Public Schools to teach it was a worthwhile venture. The project would develop relationships between WPI and the Worcester Public Schools while introducing the new curriculum to kindergarten through sixth grade classrooms throughout Worcester.

I.4 National Science Foundation Grant

WPI and WPS applied for and received a grant from the National Science Foundation. The grant application outlined a plan to develop teaching strategies specific to the needs of implementing the new Massachusetts frameworks while developing partnerships between graduate and undergraduate fellows, public school teachers and students, and the WPI community. The grant, which lasts from June 1, 2003 through May 31, 2006, was granted to develop curricular materials in the areas of science and technology/engineering and prepare the teachers to present the curriculum themselves once the PIEE project ends.

I.5 - The PIEE Project

The PIEE project would involve three of the ten schools from Worcester's Doherty Quadrant, due in part to their proximity to the WPI campus. In the first year, six classrooms were involved. A fourth, fifth and sixth grade classroom each from both the Elm Park and Midland Street schools were the first to have the PIEE project try to implement a new engineering and technology curriculum. The second year expanded the number of classrooms to seventeen, absorbing the rest of the fourth, fifth and sixth grade classrooms at Elm Park as well as another fourth and fifth grade classroom at Midland Street. Also added were a third grade class at Midland Street and second and third grade classes at the Flagg Street School. Plans eventually call for the program to be extended to the remaining second through sixth grade classrooms at all three schools and to add kindergarten and first grade classrooms.

The hierarchical structure of the project was as follows; WPI faculty, partnerships teachers, Fellows, IQP students from WPI, and finally the elementary school students. Additionally, the partnership teachers involved directly with Fellows and IQP students would also act as resources to other teachers in their respective grade levels.

Although the curriculum materials were to be devised by the IQP students with input from the Fellows, it was important that the teachers actually teach the lessons themselves during the project. This was a result of the necessity that the program be self-sustained after the WPI students' involvement ends. After the grant expires, the teachers are still expected to be able to present the curricular material to their students with a minimum of lesson plan development and materials investment on the behalf of the teachers personally or the schools involved with the Partnerships Implementing Engineering Education (PIEE) project. Materials we received that described the project can be found in **Appendix A**.

I.6 - The Challenges of Teaching an Engineering Oriented Curriculum

I.6a - Engineering

Engineering has been a very strong and growing field of study in the United States since 1945 when the Department of Education began recording information related to degrees in engineering. (*Degrees Since 1945,* 2003) With all of the products and new technologies that are developed annually in the United States, engineers have been an integral prerequisite. And, with all of the people willing to work hard and become educated, there have typically been plenty of engineers to supply this demand.

I.6b - Bachelor Degrees

Today engineering as a field of study continues to thrive in many aspects, though this statement is dependent upon the level of education being discussed. The number of bachelor's degrees in engineering awarded fell dramatically in the eighties, but is now on the rise (Gibbons, 2003). The number of master's degrees given has been steadily increasing for the last decade, followed by only a minor dip (Hill, 2004). Finally, the number of doctoral degrees given in engineering has been unstable for the last ten years and interest in achieving this level of education has decreased in recent years (Hoffer, 2003). While the growth of engineering as a whole may seem merely a function of the economy, many professional organizations have proposed ways to improve the stability of this growth, which has always been a problem in the field.

As the lowest tier of engineering education, bachelor's degrees are by far the most numerous degrees given out. Though people who earn these degrees have spent the least amount of time possible to become professional engineers, they are far from the least important demographic. In the mid-eighties the number of bachelor's degrees awarded to students in American colleges reached its peak at nearly eighty thousand. This marked an almost two hundred percent increase in the number of degrees awarded in ten years (*Degrees Since 1945,* 2003). With that dramatic of an increase in a ten year period, a drop had to be expected. After the peak in 1985 there was a twenty-five percent decrease over the next five years, which then leveled out over the course of the next few years.

Early in the new millennium the number of bachelor's degrees began to increase and this growth has continued up to 2003.

Data collected over the past fifty-plus years indicates that growth will continue for some time. In 1945 there was a dramatic increase in the degrees awarded, which was followed by a dramatic fall. After that the number of degrees steadily increased over the next twenty years until a veritable explosion through the late seventies into the eighties. While the number of bachelor's degrees has waned slightly in the nineties, a strong recovery is predicted by the past and indicated by the growth currently happening (*Degrees Since 1945,* 2003).

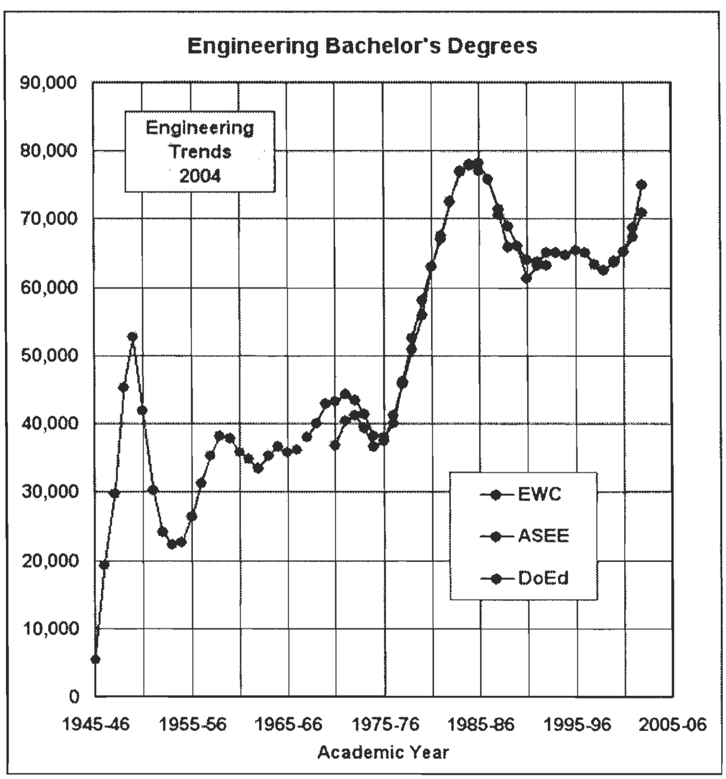

Figure 1 – Trends of Engineering Bachelor's Degrees in the U.S.

[Combines information from the Engineering Workforce Commission (EWC), the American Society for Engineering Education (ASEE), and the Department of Education (DoEd).]

I.6c - Master's Degrees

As mentioned previously, the number of master's degrees awarded has been invariably the most stable. Since 1945 the number has only had three major decreases, each of which lasted five years or less. This would seem to indicate that once people enter the field of engineering, many maintain an interest in studying it and wish to learn more, at least for a short time. Master's degree programs are typically two year investments, with many colleges offering five year BS/MS programs or something similar.

Completing one of these programs may seem to take a short time when compared to what the students have already invested in post-secondary school and the amount of time needed to earn either a bachelor's or a doctoral degree. Having a master's degree also considerably bolsters a person's value in the job market. (Hill, 2004).

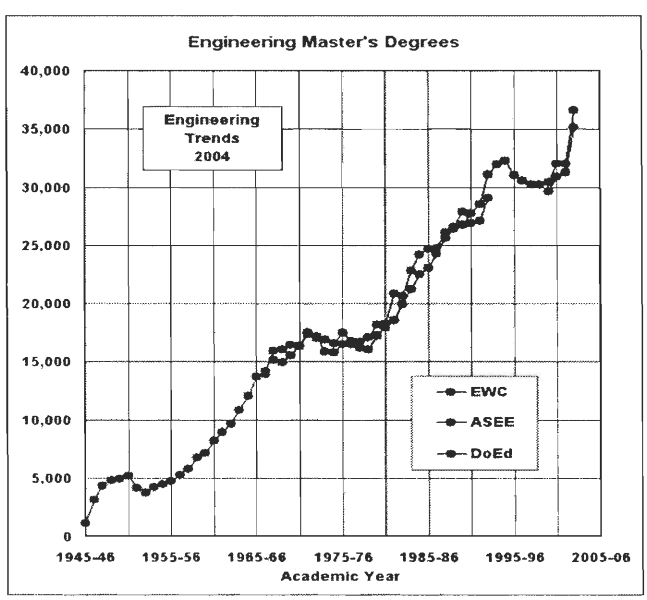

Figure 2 – Trends of Engineering Master's Degrees in the U.S.

I.6d - Doctoral Degrees

Up to this point, trends have indicated healthy, if somewhat erratic, growth in the engineering field, but the number of doctoral degrees earned over the last ten years paints a different picture. After the last peak of about seven thousand doctoral degrees awarded in 1996, there was a sudden drop in their numbers that has not yet shown any sign of reversal. The continued lack of representation from women and minorities is partly reflected in this, but the drop mostly results from the sudden drop of bachelor's degrees earned in the late eighties. Though this does not guarantee that numbers in this area will go back up, it does provide a reasonable explanation as to what has happened so far (*Degrees Since 1945,* 2003).

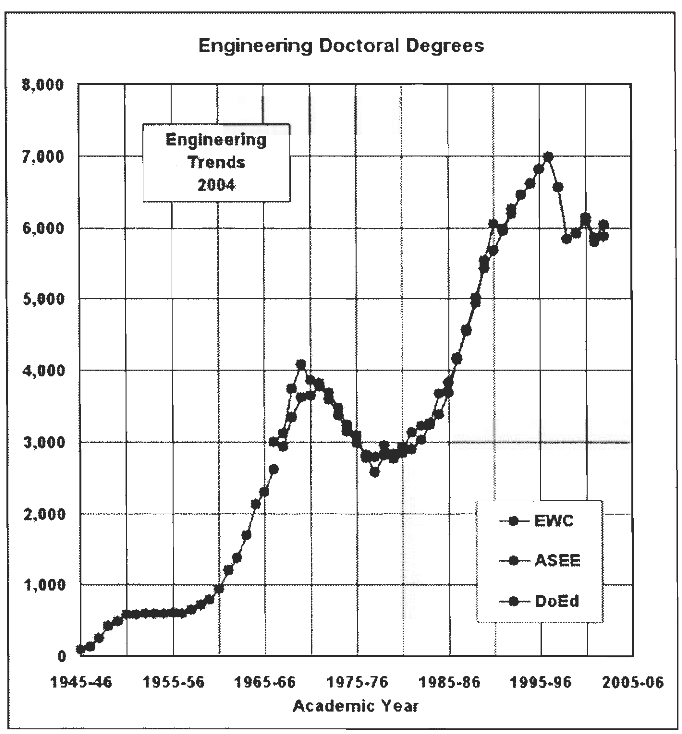

Figure 3 – Trends of Engineering Doctoral Degrees in the U.S.

I.6e - Rationalization

Engineering Trends, an e-commerce consulting firm specializing in engineering education explains the erratic behavior of the numbers of degrees given as part of a supply and demand cycle. Employers have a large demand for engineers at some times and nearly no demand for them at others. When there is a large demand, and not enough engineers, engineers are typically compensated well for their services. As a result, more people decide to enter the engineering field, but by the time they graduate the demand has diminished and they are forced to take jobs for less money. This in turn discourages people from entering the engineering field. Unfortunately, when there is a higher demand for engineers amongst employers, the number of people graduating has decreased and cycle starts over. (Heckel, 2003)

I.6 f - Changing Current Trends

Many professional organizations recognize the need to draw people to the engineering field on a more consistent basis. A common solution has been to introduce engineering concepts to children early on in their school careers. There are many reasons that people who have the ability never make it to the engineering field, but introducing engineering early would be able to solve some. Many children know nothing about engineering and, because of this, never consider it a possibility for their lives. Other children might find out about it too late and not feel that they are prepared to tackle the obstacles that lie in the way of becoming an engineer. Introducing engineering concepts early could solve both of those problems.

Early exposure is ideal, but exposure in general can make a difference too. Ask an average American to think about an engineer, what they're doing, and what they look like. Chances are one would think of a Caucasian male, perhaps working alone. To them, he'd probably look unattractive, clumsy, and awkward. This is a popular stereotype, but as it is with many stereotypes, is far from the truth. The population of engineers is as diverse as the population of in any field. So how does such a negative view of engineering come to be? Why is engineering seen as an undesirable occupation?

Many people do not know what an engineer is. Because of this lack of knowledge, they may fill in the blanks with what they *think* an engineer is. They can pull together the concepts of engineering and intelligence, but sadly this may be the extent of the logical thought process. Many times, the intelligence that is associated with good engineers is also equated with a certain level of social ineptness. This can mostly be attributed to how intelligent people are portrayed in the media.

This stereotype, like all stereotypes, was caused by fear and a lack of understanding. Someone looking in from the outside sees something they don't understand and instead of finding out more, they judge, or more accurately, prejudge. What that individual considers true about engineers and intelligence then spreads to more people who do not understand what engineering involves.

I.6g - Female Engineering Students

Historically there have been few women in the field of engineering. There are many factors that contribute to this trend. During the first half of the twentieth century, most professional fields were almost completely male dominated. The few exceptions to this rule were fields like nursing and teaching that were seen as a woman's work. It was believed that since engineering consisted primarily of math and science, and that only a man could do these things well, only men were equipped to succeed in engineering. A change started to occur during the United States' involvement in World War II. At the time, many women did the jobs that the men had vacated in order to go overseas and fight in the war. When the war ended however, the women went back into their homes. (Isaacs, 2001)

Over the following decades women made many strides, but there were still only a handful of female engineers. In the 1960's, less than 1% of all engineers were female. This number increased to 5.8% in 1983, and then to 9.5% in 1994, but fell back down to 8% in 1995. Despite this trend, the percentage of women in engineering remains low. (Isaacs, 2001)

To address this problem, many post-secondary schools have started programs to increase female enrollment in engineering. But even with these programs, the percentage of women enrolled in engineering programs remains low. In 1999 the percentage of first year female engineering undergraduates was only 19.2%. (*Women, Minorities, and Persons with Disabilities in Science and Engineering*, 2002)

Many colleges employ a cost effective recruiting method. They attempt to maximize the gains in student population with the least monetary cost to them. With this strategy in place, many schools have implemented outreach programs that target selected student populations. The students that have shown amplitude for math and science are most likely to be targeted. This approach, although profitable for universities, is flawed because it allows many students to fall between the cracks. Upon entering high school, many women are falling behind their male counterparts in math and science. Therefore, universities with a focus on engineering do not target female high school students. (Isaacs, 2001)

Engineering remains a mystery to both sexes, but when students think of engineering, males tend to think that they can do it while females are hesitant. Children generally are not exposed to engineering, keeping many potential students away. By exposing students to engineering, the mystery surrounding its definition may be eliminated. If young women were to understand this, then they may become more interested in the field. (Isaacs, 2001)

Eliminating the mystery surrounding engineering might bring with it another benefit, showing the social relevance of engineering. Some colleges, specifically Tufts and Smith, have made recent drives toward switching to a "learning by doing" approach in introductory engineering courses. Students are exposed to the social benefits of engineering while seeing the passion that their professors have for the field. Tufts University has allowed their professors to use their hobbies to illustrate the basic principles involved in engineering since 1994. Students are less likely to dropout of the programs when they can see how the principles they are learning are useful. Tufts officials believe that this approach has helped to bolster their enrollment; the engineering department at Tufts is currently 40% female, twice the national average, and the faculty is 18% female, four times the national average. (Farrell, 2002)

Though women are falling behind their male counterparts early in high school, this can likely be attributed to social pressure more than females' abilities to do the work. Historically women have remained in liberal areas of study while men have pursued math and science related fields. (Isaacs, 2001) Perhaps with exposure to women from the engineering field, as well as exposure in general to engineering, female students may develop more of an interest in engineering that carries on into their college and professional lives.

I.6h - Minorities in Engineering

Considering the prevailing stereotypes and this general lack of understanding regarding engineering, a minority student may not know what an engineer really is and might feel as though they do not fit the "archetype" of an engineer. That "archetype" is nothing more than an inaccurate stereotype, but may be convincing enough to discourage a minority student from studying engineering.

Considering more than half of the children enrolled in the Worcester Public Schools are of an ethnic minority in Massachusetts, targeting these students with engineering curricula could prove to generate an enormous increase in the number of minority students that go on to study engineering.

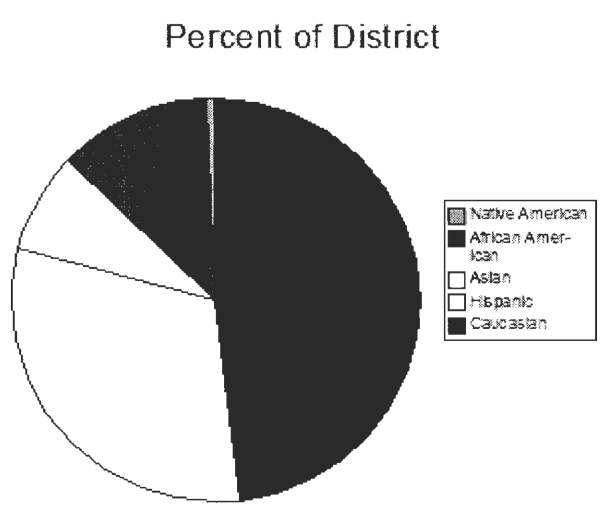

Figure 4 – Ethnic Breakdown of Worcester School District

From (http://www.wpsweb.com/flaggstreet/Profile.htm)

It would take a concerted effort to spread knowledge as to what engineering truly is. This mission becomes increasingly important as interest in engineering decreases. This project will hopefully allow young students to compare what they think an engineer is to what an engineer really is. With that newfound knowledge, they may realize that they take on the roles of engineers themselves. Children ask questions and solve problems on a daily basis, probably more so than most adults do. With a newfound feeling of empowerment they may grow up to become engineers or just go to college. Either way, exposure to students from the engineering field and our engineering lesson plans may help them make positive connections that will hopefully be a positive influence for the rest of their lives.

In addition to using engineering based curricula to create an interest in engineering among elementary students, topics and ideas stemming from engineering lesson plans could benefit all students, regardless of their interests. Basic skills derived from engineering could prove beneficial regardless of what career path they may choose to follow as adults. Part of the engineering process is creative and critical thinking as well as applying problem solving skills. Though teaching engineering to young children may seems as though it would only draw out interests in continuing to pursue engineering as a childhood interest or eventually a career, the skills that develop as a result of thinking in terms of engineering may prove beneficial to students as they continue through school. Teaching engineering lessons may also provide developmental advantages to young children that will eventually help them in their professional lives, regardless of whether they choose to become an electrical engineer or the manager of a restaurant.

The basic concepts and principles of engineering may aid in creative problem solving as well as show the most effective learning techniques for individual students in a classroom. These techniques make it possible for children to achieve a level of higher thinking which can be applied to any aspect of life.

I.6i - Engineering curriculum and learning/thinking

The introduction of engineering curriculum at an elementary school level is not an entirely new idea. Integrating this type of curriculum statewide into the landmarks of education for public schools, however, is.

There are already a number of schools across the nation that focus solely on an engineering based curriculum for elementary school students. These schools, known as engineering magnet or engineering attractor schools, obviously have a certain goal in mind. The inclusion of terms such as magnet and attractor in the names of the schools display a strong emphasis on drawing children into the engineering field.

Although these schools have their own goals in teaching an engineering based curriculum, the lessons and projects that the schools present to their students may contribute some learning skills that benefit the children attending in a manner not exclusively relevant to engineering. Austin Children's Engineering Magnet, a school that focuses on engineering from kindergarten through sixth grade, requires students to build structures that withstand forces from wind, gravity, and magnetism as early as the first grade (Austin, http://austin.wfisd.net). In fifth grade, students at the Douglas L. Jamerson, Jr. Elementary school use paperclips, string, a toy vehicle, and a pulley to discover the relationships between the amount of force required to move a vehicle and its variable elements such as weight and construction elements (Douglas, http://www.jamerson-es.pinellas.k12.fl.us/engineering.htm).

The Montgomery County, Maryland public schools issue engineering challenges to a number of elementary grades. This year's fourth grade challenge was to design and build an electric circuit board with science and technology based questions that lights up when a correct answer is pressed (Montgomery, 2004). The critical thought processes that go into completing these projects could carry over into every aspect of the students' lives, making them better problem solvers and better at teaching themselves about the world surrounding them.

At least one of these schools, The Douglas L Jamerson Jr. Mathematics and Engineering Elementary Attractor School, does believe in teaching engineering at an elementary level as more than solely a cursory introduction for a future career path. They assert that engineering curricula enrich other classroom subjects with higher order thinking and problem solving skills already in place. The focus of engineering forces students to ask the questions who, what, where, when, why, and how as they approach every problem put before them in any field from mathematics to history. With these questions and an engineering mindset constantly reinforced by classroom activities, a student's perspective of the world and every item in it changes as they strive for a better understanding of its existence and function (Douglas, http://www.jamerson-es.pinellas.k12.fl.us/engineering.htm).

By introducing an introductory engineering curriculum to all public elementary schools, the same critical thinking and problem solving skills could be imparted to every student and applied to different situations should a student decide that they are, in fact, not interested in becoming an engineer.

II - Methodology

II.1 - Lessons

II.1a - Massachusetts Curriculum Frameworks

As stated above, Massachusetts created the set of frameworks for the teachers to follow. We looked at the Science and Technology/Engineering Frameworks when creating our lessons, as our duty was to introduce ideas that they would need to be very familiar with for the MCAS. These frameworks can be found in **Appendix A**. Another concept we used was the simplified engineering design process from the PIEE project last year. . The engineering design process is the backbone of solving problems as an engineer; this is a point we tried to stress when brainstorming. Since we designed the lessons for second graders, we used the simplified design process shown in the figure below.

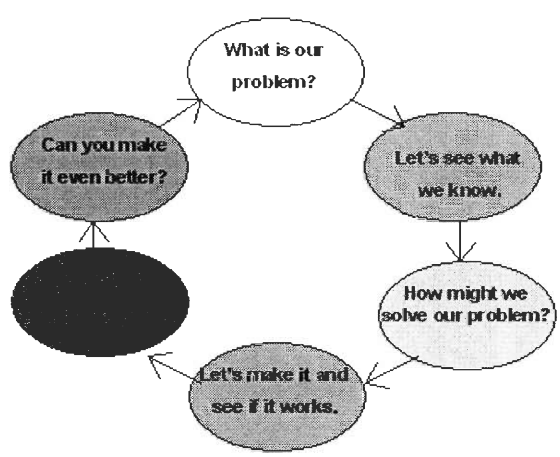

Figure 5 – Simplified Design Process

This is a derivative of the engineering design process found in the Curriculum Frameworks. As mentioned, the Worcester Public School Benchmarks were also derived from these frameworks.

II.1b - Worcester Public School Benchmarks

We found that the benchmarks were not more beneficial than the frameworks, but rather used the ideas from the frameworks and were also custom fitted to the city's existing curriculum. The benchmarks were subdivided into five different categories; Skills of Inquiry, Earth/Space Science, Life Science, Physical Science and Technology/Engineering. These Benchmarks can be found in **Appendix A**. With these benchmarks, the Flagg St. School made their curriculum map to fit the standards set by the state. This can also be found in **Appendix A**. After receiving the map, we looked at all of the existing subjects and chose lessons we thought related most closely to engineering. For example, we made lessons for the entire solids, liquids, and gases unit because it was something they planned to teach, but could be given an engineering foundation. To reiterate, we found the benchmarks were better suited to match the requirements of the state without completely deconstructing the existing syllabus.

II.2 - PIEE: Year One

A major influence as to how we wrote lessons was the progress made in the first year. For instance, the basic outline all of our lessons followed was derived from a template that was created in the first year. This template can be found in **Appendix A**. Although some groups took existing lessons from the 6th grade classes from the previous year and helped implement them at a new school, we were charged with creating lessons for the classrooms introduced this year. These lessons would subsequently be taught and then implemented at the new schools introduced in the year following our project.

II.3 - Creating Lessons

The first step in our creative process was brainstorming. When thinking of ideas for lessons we not only incorporated the Benchmarks, but also tried to stress ideas that would be the most interesting for our target group. As our target group was a class of second graders, we drew largely on experiences from our own childhoods. One lesson idea that initially seemed ridiculous when it was first brought up was the "Three Little Pigs" lesson, which required that the subjects create houses out of three different materials to see which one works best. We were able to take this idea and create a comprehensive lesson that the students could relate to and enjoy.

Also, after spending some time in the classrooms we were able to draw conclusion from our individual experiences. There were several ideas as to how to keep students interested in our lessons that we used repeatedly. The first idea was to add some hands on activity to each lesson. We wanted to make sure that the students would each be able to do something on their own. Keeping the students involved in the project was essential to keeping their interest and helping them enjoy difficult material. Also, we consistently made use of visual demonstrations. Actually seeing something happen is much more interesting than simply reading about it. This is as true for college students as it is for second graders.

We noticed that the students would work harder when there was competition or a prize involved. By making the lessons fun and interesting we increased the possibility that students would not only remember what they were taught, but also perhaps see that engineering is not entirely cold and dull.

II.4 - Writing Lessons

When actually writing the lessons we tried to be as explicit as possible. The first reason we did this was because the children in the second grade classrooms needed detailed instructions. This is not because they do not have the ability to get the work done, but rather when they are given vague instructions, they cannot get beyond those instructions. The students literally need to be led to conclusions. The second reason is that the teachers need to be completely comfortable with the lesson in order to teach it, including understanding the science behind the lessons. A major tool in terms of getting our points across was to offer potential questions that children may ask along with answers to these questions.

When we created our bulletin boards, we followed the lesson plans and templates from last year as to how to structure them. We made about two bulletin boards a month, one was about tools and the other was about inventors. These bulletin boards can be found in **Appendix C**. Although we referenced last year's work, we also made our own contributions. For instance, we found that the teachers struggled to get through the lesson plans ahead of time, so we created summary sheets for them to use as reference guides while teaching. These sheets included important information such as key concepts and materials.

II.5 - Revising and Finalizing Lessons

After writing the lessons, we put them to the test; we ran the lessons, or at least the experimental parts. The first thing we did was make sure that the lessons were not only possible to complete in class, but also still hands-on and interactive as we found those lessons to be the most effective to helping second graders retain knowledge. Next we made sure that the lessons did not run too long or stray too far from the core concepts of the lessons, as the students' attention spans were much shorter than ours. We also ran lesson ideas by teachers to get their input. They usually thought they were good ideas and normally had good ideas for things to add to the lessons or gave suggestions for things to keep in mind when finalizing. Next, we presented the finalized lessons to the teachers and assisted them in teaching. Finally we received feedback from the teachers on how the lessons could be made better and made the changes that they suggested.

II.6 - Teacher Feedback

From the start, the teachers had many suggestions about what they wanted to do for lessons. We feel that the program is set up well so that the lines of communication between the IQP students, fellows, and the schools were very open. For instance, we had large meetings every term with everyone involved with the program. When the teachers were asked for suggestions, they immediately responded that they wanted an historic toys unit. It was something they not only suggested at one of the program-wide meetings, but also when we made our classroom visits. So needless to say, it was rather easy to get feedback from them.

The teachers did not negatively criticize our lessons, but there were instances where some lessons were not used. We did not understand why this was, so we decided to make a feedback form at the end of our lessons for them to fill out for us. This form can be found in **Appendix D**. Even though this was provided, it seems that both teachers and IQP representatives felt it was best to discuss issues face to face; we found that private meetings were the best way to get constructive feedback from the teachers.

III - Implementation

III.1 - Responsibilities

Implementation of the lessons was not set in stone; however, there was a general trend it followed. After finishing the lesson plans, we would give them to the teachers to look over before teaching. The group had scheduled times to go into the classrooms and on certain days the teachers planned to teach the lessons we had provided. The teachers were in charge of teaching the lessons to the students, but we were there to help out if needed.

During the times in which we did co-teach, we made sure that the teacher was still in charge of the lesson. The trend was that for those lessons, the teacher would ask us to answer questions about important concepts or questions which they were not confident in answering themselves. More commonly, we led the exercises while the teacher explained the concepts. We were there not only to assist in teaching, but also to field any technical questions that might arise. Interestingly, many students did bring up some difficult questions from time to time. For example, one student asked whether electricity was living or non-living

III.2 - Teacher Responsibilities

In terms of the teachers' duties, they ideally would prepare for the lessons on their own time and would not be completely dependant on us to help teach their lessons. In a few rare instances, we co-taught with the teacher, but we were told by our fellows and advisor to make sure that the teachers did most of the work as they were going to teach the lessons to other teachers the following year. The teachers were charged with arranging for students to bring materials from home if necessary, but for the most part, we were in charge of getting materials.

IV - Results

IV.1 - PIEE Showcase

On April 5th, 2005, the PIEE team held a showcase to display all the work that the project was involved in. We invited the students and their parents to come in and see what their children had done. Each participating grade at every school had a section with which they could show what they had worked on. This was a very important event for a few reasons. First of all, it was a positive way for the parents to stay involved and informed about what their children had done throughout the year. Secondly, it helped the project gain support from the parents and the community. They could see opportunities provided to students as a result of the PIEE partnership. Another reason that the showcase was important was that it allowed the people who worked on the lessons to see their work and students get recognition.

IV.2 - Completed Unit Plans

IV.2a Simple Machines

Simple Machines and the Lever

The first lesson presented to the students was entitled "Simple Machines and the Lever" It was intended to be an introduction to simple machines with an emphasis on the lever. The lever was chosen to discuss first as it is probably the most basic to understand of all the simple machines. To keep the attention of the students in this lesson, we had physical demonstrations and experiments that would be fun for them to take part in. First, we used a ruler, a pencil, and some change to demonstrate how a lever works. The students changed the position of the fulcrum, in this case a pencil, and stacks of coins on the ruler to see how the different situations affect how the lever is balanced. This demonstration is particularly effective, because most of the students have the materials needed to try it again at home if interested or challenged by the demonstration. Another demonstration we used that proved to be amusing for the students was a large scale lever which used a bottle for a fulcrum, a long piece of wood for the lever arm, and a large box of paper as the load to be lifted. The amount of weight used would be difficult for a second grader to lift without any help, but this helped to illustrate that they could use levers to make work easier. Some students seemed more impressed that they could make the box of paper rise in the air a few inches and fall off of the lever if they tried hard enough. Although they might have been interested for the wrong reasons, the demonstration definitely got them to focus on the usefulness of the lever.

The concepts in the lesson relate to engineering in that we used a simple machine to accomplish something we would not have otherwise been able to do. In other words, we were finding ways to solve problems. In this case, there was a large object that needed to be lifted. We were unable to simply lift it without aid, so we found another solution. From the engineering design process we found the specific problem, which was that we needed to lift the box. We knew that simple machines make it easier to do work and that they would probably make it easier to lift the box. We set the lever up on the box, which we can do by pushing and some light lifting. We then share our ideas with the class and discuss possible ways to make a more efficient system.

This lesson stresses concepts outlined in the Massachusetts Curriculum Frameworks and the Worcester Public School Benchmarks.

Skills of Inquiry – Students will…

02.SC.IS.01 - Ask questions about events in the environment.

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Physical Science – Students will…

02.SC.PS.01 – Recognize that under some conditions, objects can be balanced.

Technology/Engineering

02.SC.TE.04 – Identify tools and simple machines used for a specific purpose.

These Benchmarks are addressed in the demonstrations mentioned above, by having the teachers discuss where else we see levers, and by asking the students what would happen before actually performing the demonstration.

Inclined Plane

This lesson follows the introduction to simple machines and provides a more in depth look at the inclined plane, which is only mentioned in the previous lesson. We first got the students involved and thinking by using a work sheet and asking them how they could get a large box onto a high ledge in which a picture indicated that it would be difficult to simply pick it up. After that, we did a demonstration in which we created inclined planes with varied heights and rolled cars down them. We had the students make predictions about what would happen and record how far each car traveled in each trial. This demonstration was effective because it inspired a bit of competition between the students to figure out the right answers and, since it used toys that the students had brought into class from home, inspired some students to root for their favorite cars.

The concepts in the lesson relate to engineering in that we used a simple machine to observe changes in the amount of work returned from the same force acting on the cars under different conditions. Again, we were finding ways to solve problems. In this case, there was a large object that needed to be raised. We were unable to simply lift it, so we found another solution. By following the engineering design process we found the specific problem, which was that we needed to raise the box. We knew that simple machines make it easier to do the same amount of work, so they would probably make it easier to raise the box. Using the work sheet we showed that it would be easier to raise the box using an inclined plane. We then shared our ideas with the class and discussed possible ways to make a more efficient system. After that we expanded upon the idea of the inclined plane with the car demonstration.

This lesson addresses concepts outlined in the Massachusetts Curriculum Frameworks and the Worcester Public School Benchmarks. Specifically,

Technology/Engineering

02.SC.TE.04 – Identify tools and simple machines used for a specific purpose.

In this lesson we met this Benchmark by having the teachers discuss where else we see inclined planes and by asking the students what they thought would happen before actually performing the demonstration.

Wheels, Axles and Pulleys

This lesson continued to stress the idea that simple machines make work easier. We demonstrated this by having the students try to push a heavy object across a rough surface such as a sidewalk or a strip of sandpaper on the floor. After doing this, they put dowels underneath the object and pushed it again. Having the dowels there made it much easier to do. We encouraged the students to make predictions before using the dowels and to compare what actually happened to their predictions. This demonstration engaged the students well, because they often times wanted to prove that they could do something equally well without the machine.

The concepts in this lesson again related to engineering in that we figured out how to solve a problem. We found out about wheels and axles, and we moved a large object across a surface. Along with the students we came up with the idea of placing dowels underneath the object. Then we thought of possible ways to make the system better. For instance, making a wheel and axle that would actually attach to the object.

From the Benchmarks we stressed

Technology/Engineering

02.SC.TE.04 – Identify tools and simple machines used for a specific purpose. This was done by having the teachers discuss where else we see wheels and axles and what kinds of variations the students could think of.

Screws and Gears

In this lesson students were introduced to screws and gears through two demonstrations. The first was a demonstration of an Archimedes screw. This demonstration tried to show that a screw is simply an inclined plane wrapped around a cylinder. This part of the lesson really got the students interested because it showed them how the screw could be used in a way they had probably never thought of or heard of before. It definitely impressed the students, and even some of the teachers. After that we wrote an activity involving Spirographs, a toy many of us used to play with as children. This toy uses a series of gears with holes for colored pens to make intricate designs on paper. It is interesting to children because they use these seemingly scientific objects to create art like they never have before.

This lesson relates to engineering because we used the tools we had in new and interesting ways to do things that would have been difficult without the use of machines. This lesson stressed the Benchmark concepts

Technology/Engineering

02.SC.TE.04 Identify tools and simple machines used for a specific purpose.

Skills of Inquiry – Students will…

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

We touched upon these concepts by asking the students what would happen with the Spirograph after they had seen a simple demonstration and what would happen before actually performing the Archimedes screw demonstration.

Pulleys

In this lesson the students built small elevators with a pulley and tested it out. In the activity, the students made two boxes out of paper and then tied each of them to the ends of a piece of string. They then put an empty spool on a coat hanger for the pulley and draped the string over it. The students then raised and lowered the 'elevators' by using pennies or other weights. This activity engaged the students because they had to do a lot of hands on work, such as putting together the boxes and setting up the pulley. Then, after they had put it together, they got to actually see what they had done in action and relate it to a real life situation. The idea that they were actually making a simple kind of elevator kept the students interested.

This lesson helped reinforce one of the Worcester Public Schools Benchmarks,

Technology/Engineering

02.SC.TE.04 Identify tools and simple machines used for a specific purpose.

Simple Machines in the Playground

This lesson was the final lesson in the unit and was intended to tie together all of the ideas that were found in the previous lessons. In this lesson we engaged the students by asking them to design what they thought a perfect playground would be. They were encouraged to use anything at all like roller coasters or Ferris wheels. The students enjoyed this because it was something they really cared about. It got them to think about times they had fun, and therefore made them associate the assignment with fun.

This lesson involved engineering concepts as the students designed the best playground they could think of. They had to look at what they know, like what different rides/objects could go in a playground. They then tried it out by drawing on a piece of paper. Then students were given the opportunity to share and discuss their results with others in order to see what might have been done better.

This lesson stresses the concepts

Technology/Engineering

02.SC.TE.04 Identify tools and simple machines used for a specific purpose.

Skills of Inquiry – Students will…

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

IV.2b - Solids, Liquids, and Gasses

Evaporation and Condensation and Steam and Gas Energy

This lesson included two demonstrations which the students could participate in. These demonstrations were particularly interesting to students because they involved actually applying heat to water in order to observe changes. In the evaporation and condensation lesson, the teacher boils water and puts a pyramid of plastic wrap above the boiling pot. Students particularly enjoyed this because it almost seemed as though we were creating water out of thin air. In addition to this, we intended to use steam to blow a pinwheel around. This is similar to the previous demonstration in that it seems that we are getting something from nothing, in this we were getting motion from steam. Unfortunately though, the pinwheel used actually melted rather than spinning.

The lesson used engineering concepts to find solutions to a problem. In this case we figured out how to trap evaporated water and use steam to generate kinetic energy.

This lesson again stressed the concepts

Skills of Inquiry – Students will…

02.SC.IS.01 Ask questions about objects, organisms, and events in the environment.

02.SC.IS.02 Tell about why and what would happen if...

02.SC.IS.06 Discuss observations with others.

which were touched upon by asking the students if what they have seen could happen again under the same conditions and if they could use what they had seen in other situations, by asking the students what they thought would happen before actually doing the experiment, and by discussing what other uses the experiments could have with the students.

Melting and Freezing Part 1

In this lesson students performed an experiment in which they filled used soda or water bottles with different amounts of water and froze them. When some of the bottles broke, the students needed to figure out why. This experiment drew the attention of students because they are often impressed by the powers inherent in the forces of nature. Also, students may have been impressed by the fact that water expands when it freezes, which is a somewhat counterintuitive concept and a property unique to water.

This lesson relates to engineering because we had to solve a problem. We isolated the problem of some of the bottles breaking when the water froze. We then looked at what we knew; the bottles with smaller amounts of water inside did not break. With that, we found that we could solve our problem by putting less water in the bottle.

This lesson stresses concepts involving

Skills of Inquiry – Students will…

02.SC.IS.01 Ask questions about objects, organisms, and events in the environment.

02.SC.IS.02 Tell about why and what would happen if...

02.SC.IS.06 Discuss observations with others.

These were addressed by discussing the experiment and freezing process with the students and by discussing with the students what happened in the experiment.

Melting and Freezing Part 2

In this lesson students made ice cream in a very simple way. This grabbed the students' attention because they were interested in finding out about something they like, and if they performed the experiment correctly they got to eat ice cream at the end of it. This lesson's relation to engineering arose from having to analyze the problem of ice cream melting and determining what they could do about it. It also related the concepts of liquids and solids to changes in temperature in a concrete way.

The Benchmarks addressed by this lesson again included Skills of Inquiry – Students will…

02.SC.IS.01 Ask questions about objects, organisms, and events in the environment.

02.SC.IS.02 Tell about why and what would happen if...

02.SC.IS.06 Discuss observations with others.

This time the Benchmarks were met by discussing the experiment and freezing process with the students and by discussing with the students what happened in the experiment.

IV.2c - Inventor of the month Bulletin Boards

These bulletin boards were meant to help the students understand the engineering design process by showing how real inventors might have done it. In order to grab the attention of the students we used inventors that the students might find interesting, such as the inventor of the Super Soaker and the child inventor who created Wristies.

The inventor of the Super Soaker invented what is very likely among the students' favorite summer toys, so they probably had a good deal of interest in how he did it. The inventor of Wristies was very young when she came up with her idea, so the students might be interested and inspired by her. Each bulletin board had a copy of the engineering design process diagram, and pictures of the inventors and their inventions. These helped make the bulletin boards more colorful, and showed specific examples of what we were talking about in their classes. Teachers were supposed to go over the bulletin boards with their students and discuss how the design process applied to it. The bulletin boards went through each step of the design process and how the inventor may have used that step in order to solve the problems that they had.

A cumulative quiz about the bulletin boards was included in our lesson plans, but the students probably never saw it.

IV.2d - Historic Toys

Paper Airplane Competition

The paper airplane competition was designed to motivate the students to ask questions and think of new things to try. Like real planes, there are many different basic designs that people use. There are also many modifications to these designs that will alter the way the plane flies. Some of them will make them fly farther, while others will make them fly erratically. The students all made planes and then tested them. Based on these tests they then made changes to the planes to see how each change affected the airplanes flight characteristics. This kind of observation and experimentation prompted the students to think about the plane and the forces acting on it, the first step in building a better one. This lesson required students to call upon the engineering design process. The students first had to identify the problem: the plane needed to fly farther. They then had to determine what we already knew? We knew about the different environmental factors at play and the design of the plane. The students then hypothesized about how they could change the plane to make it go farther. They then tried the new design to see how well it worked.

This lesson met three subsections of the Inquiry section of the Worcester Public Schools Benchmarks. These were as follows:

Skills of Inquiry – Students will…

02.SC.IS.01 - Ask questions about events in the environment.

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Cup and Ball Activity

The Cup and Ball Activity was designed to be a fun activity for the students. It is a game that helps to improve hand eye coordination. The Cup and Ball game is very old and developed independently in many different parts of the world.

The students tried many different variations on the original design to find one that worked well. They tried changing the type and size of the ball used as well as the length of the string. This kind of testing and modification process is the same one that was used in the Paper Airplane Competition lesson. The students attempted to make the toy better by trying different lengths of string, as well as different types and weights of balls. The students generated hypotheses and then tested their modifications. Through this testing process they were able to make a more enjoyable toy by employing the design process.

This activity was designed to be a fun way for the students to learn about historic toys. There were no problems when it was implemented in the classroom. The students enjoyed playing with the toys as well as experimenting to make better designs. This kind of motivation is typically not seen when the students have to do worksheets.

IV.2e - Structures

Design Your Own Structure

The Design Your Own Structure lesson was designed to introduce the students to the area of designing structures such as bridges. In this lesson the students were introduced to different types of bridges and asked what they had in common and what was different. They were then asked to design their own bridge between two desks that would hold a book. The students observed and discussed the different features of their bridge designs. They then hypothesized about what would be needed to support the book. Finally they drew their bridges and discussed them with the class. This lesson was made to introduce the students to the basic concepts of structural engineering.

This lesson touched upon two areas of the Massachusetts Benchmarks. These included Skills of Inquiry and Technology/Engineering.

Skills of Inquiry – Students will…

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Technology/Engineering – Students will...

02.SC.TE.02 – Identify and explain some possible uses for natural materials and human-made materials.

02.SC.TE.03 – Identify and describe the safe and proper use of materials and tools to construct a simple structure.

These Skills of Inquiry Benchmarks were implemented when the students made predictions about what their structures needed. The Technology/Engineering Benchmarks were met when the students determined what their structures would be made of and how they would be made.

Three Little Structures

The Three Little Structures lesson was designed to introduce the students to the different types of materials used in construction with a fairy tale theme. Based on The Three Little Pigs, the students had to create three different structures; one each from straws, popsicle sticks, and Lego blocks. These structures were then subjected to structural tests to show the students that the Legos or "bricks" were the best structural material to build with for this application.

This lesson touched upon two sections of the state Benchmarks. These sections included both Skills of Inquiry and Technology/Engineering.

Skills of Inquiry – Students will…
02.SC.IS.02 - Tell about why and what would happen if..?
02.SC.IS.03 - Make predictions based on observed patterns.
Technology/Engineering – Students will...
02.SC.TE.02 – Identify and explain some possible uses for natural materials and human-made materials.
02.SC.TE.03 – Identify and describe the safe and proper use of materials and tools to construct a simple structure.

The Skills of Inquiry Benchmarks were implemented when the students hypothesized about what would happen when their structures were tested. The Technology/Engineering Benchmarks were addressed when the students made their structures. They had to find a way to make a house out of the materials given to them and accomplished this by using different materials and tools.

The students did not understand all of the directions. Some of the students that were working with straws built a two dimensional house front instead of a three dimensional structure. Still others using the blocks built stacks then placed them side by side.

Designing Straw Structures

The Designing Straw Structures lesson was based along the same lines as the Three Little Structures lesson. Students built straw structures intended to support a given weight. Once they successfully built their first structure, they were then expected to go home and think about redesigning their structure to support even more weight. Ideally, they would approach this redesign problem using the design process we had been trying to reinforce all year.

This lesson touched upon the Skills of Inquiry and Technology/Engineering Benchmarks, in much the same manner as the Three Little Structures lesson. The students hypothesized as to what would happen when they tried different designs for the first structure. They met the Technology/Engineering Benchmarks by using tools and different materials to make their structures.

Skills of Inquiry – Students will…

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Technology/Engineering – Students will...

02.SC.TE.02 – Identify and explain some possible uses for natural materials and human-made materials.

02.SC.TE.03 – Identify and describe the safe and proper use of materials and tools to construct a simple structure.

Some of the students had trouble making the structure. They needed prompting to get a working structure. With the proper guidance the students were able to complete the assignment.

IV.3 - Assessment

In order to determine the impact of the PIEE project on the students in our second grade classrooms, we administered a survey to the students at the end of our involvement with them. This survey, combined with one conducted by Paula Quinn at the beginning of their school year, allowed us to analyze the changes in students' perceptions and interests after being exposed to an engineering curriculum, as well as some people involved in the engineering field.

Based on the survey we administered near the end of the project, only 27% of the students surveyed said they had known anything about what engineers did at the beginning of the school year. This provides some serious support for the implementation of the PIEE project since one of the initial purposes of this project was to introduce engineering to public school students. Keeping this in mind, fully 72% of students surveyed said that they had enjoyed learning about the engineering process. This may be due to the nature of the lessons we created for the students, however, as the main theme throughout our lessons was to keep them interesting to the students. This theory is somewhat supported by finding that only 62% of students said that they enjoyed learning how science ideas are used in engineering. Additionally, 80% of the students surveyed claimed that they felt they now have a better understanding of what engineers do than when the school year started. This definitely lends support to the idea that the PIEE program has helped introduce some concepts of engineering to the students in classrooms currently involved with the project.

Despite these facts, some conflicting data comes from a comparison of the initial survey to the survey conducted at the end of the program. The last twelve questions from the survey conducted near the end of the project were reflections of the questions asked on the initial survey. This was done in order to get an idea of what kind of trends in student interests PIEE IQP students caused by their involvement with the classes. Since the number of students as well as the individual students involved changed slightly during the course of the project, comparing the percentage of the class that responded in each manner provides the most accurate representation of the trends observed from the project.

In the areas that relate particularly to engineering studies, there was an overall increase in student interest, as is illustrated in Figure 6. Students' responses indicated that their interest as a whole increased in the categories of rockets and space travel; how things work; the Earth; the Sun, moon, stars and planets; living things; machines; electricity; motion and forces; and doing science projects. Inexplicably though, the interest in engineering expressed by the students decreased on a whole over the course of the project. In a result that seems as though it may be related to the decreased interest in engineering was a decrease in students' interest in using tools and building things.

So, keeping in mind that only forty percent of students surveyed at the end of the program said they were interested in engineering, nearly thirty-three percent of students surveyed said they may want to study engineering in college. Only sixteen percent of the students went on to express interest in the possibility of one day working in the field of engineering.

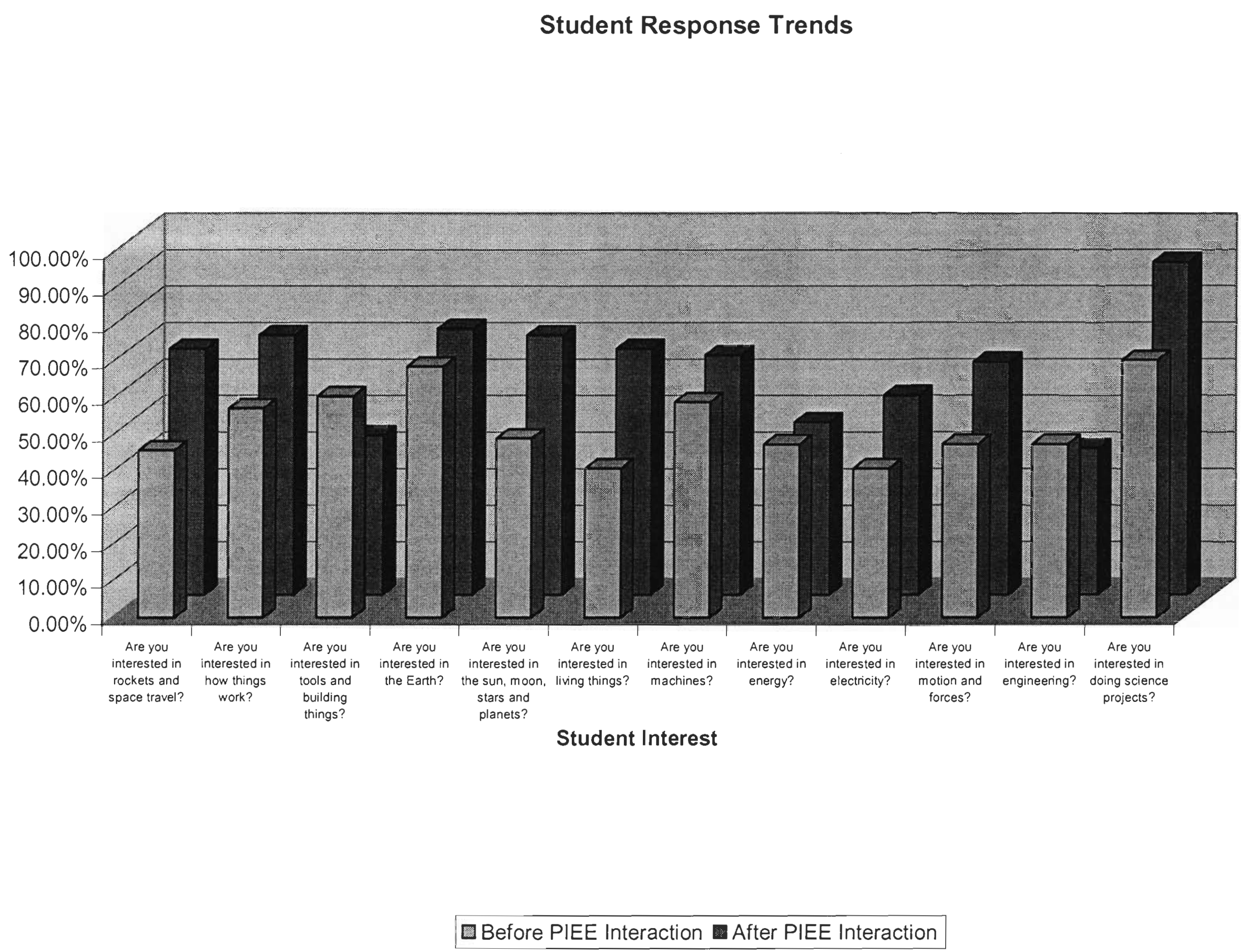

Figure 6 – Student Survey Responses over the Course of the Project

IV.4 - Trends by Gender

Among the students that claimed they were interested in engineering, the distribution between male and female students was actually rather narrow. Where forty-five percent of the male students surveyed expressed interest in engineering at the end of the project, thirty-three percent of the females in the survey expressed the same interest. From there, thirty-five percent of male students surveyed said they may one day like to go on to study engineering in college while twenty-nine percent of females responded the same way. Of the sixteen percent of students that claimed they may one day like to work in engineering, females and males were essentially tied as seventeen percent of the female students and sixteen percent of the male students surveyed responded they might like to work in engineering. Figure 7 shows the distribution of positive responses between male and female responses to the questions discussed here.

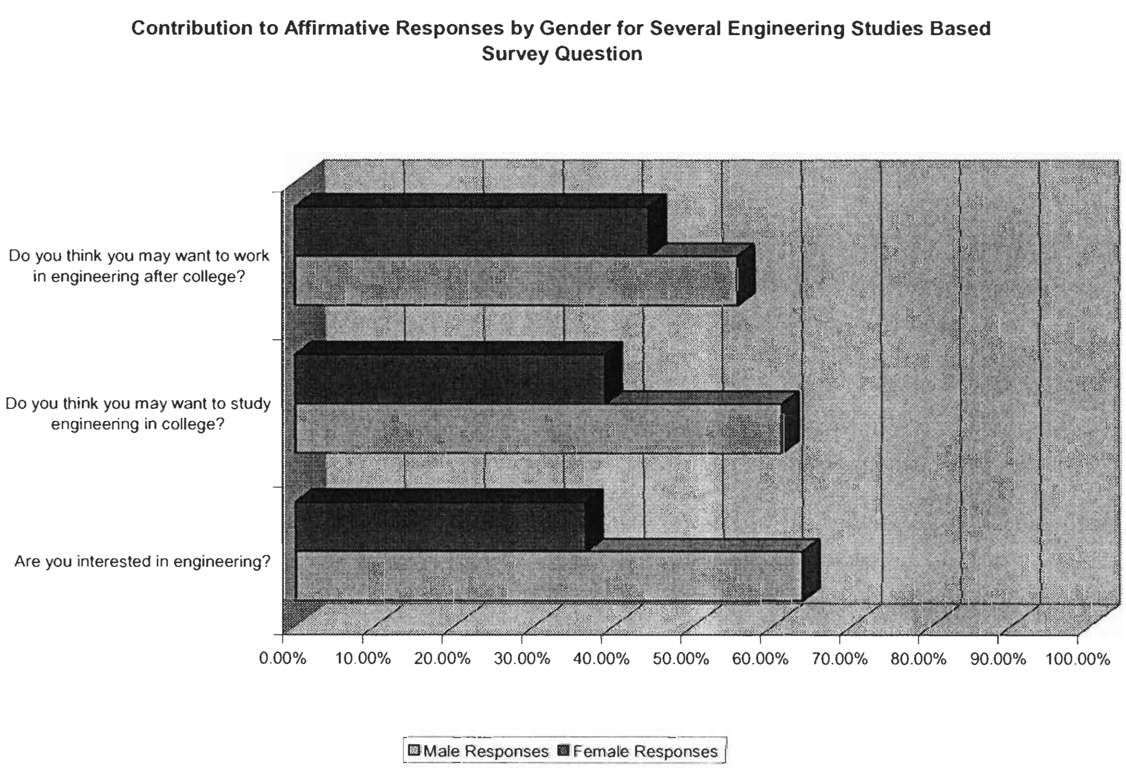

Figure 7 – Affirmative Response Distribution by Gender

IV.5 - Trends by Ethnicity

Among the students in the classroom who were registered by their parents as belonging to an ethnic minority, forty-three percent responded that they were at least interested in engineering, thirty-one percent responded they may want to study engineering in college, and twenty-five percent responded that they may want to work in engineering one day. In fact, of all the responses from students regarding interest in engineering, the possible desire to study engineering, and the possible desire to work in engineering, minority students accounted for thirty-one percent, twenty-two percent, and eighteen percent of the affirmative responses, respectively. This trend is illustrated in Figure 8. The figure shows that, although only thirteen percent of minority students responded that they were interested in engineering, those students accounted for thirty-two percent of the students that were interested in engineering. This would seem to indicate, at least in this small cross section, that students belonging to a minority are equally as likely to develop an interest in engineering.

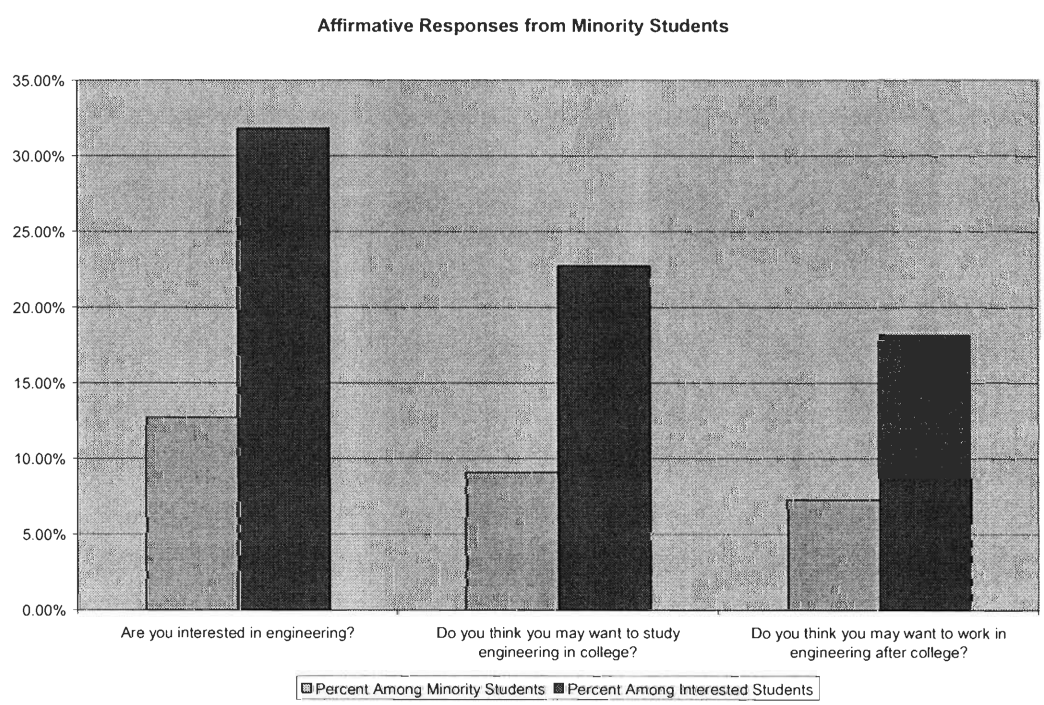

Figure 8 – Interest among Minority Students versus Their Contribution to the Total Responses

V - Conclusion

V.1 - Assessment Conclusions

Seeing as one of the goals of the PIEE project was to increase awareness of engineering concepts among public school students, the fact that 80% of the students involved in the survey felt that they had a better understanding of what engineers do after being exposed to the program after only 27% had an idea of what engineering was before this academic year seems to indicate success. The fact that 73% of the students in the survey responded that they enjoyed the study of engineering this year, while fewer students, 62%, enjoyed learning about the parallels between engineering and their concurrent science lessons seems to suggest that, although students enjoyed the lesson plans we created for their classrooms, they did not necessarily care for the scientific principles that formed the basis for the engineering in the lessons presented to them.

This increased awareness of engineering however, did not necessarily have a positive effect on students' feelings toward engineering as a field of study or as an occupation. Even after being exposed to engineering lessons and several young people in the engineering field, the interest among the students in studying or working in engineering in the future was still rather low. Surprisingly, the percentage of students who expressed an interest in engineering decreased over the course of the project as well. It is possible that students either still do not have a very clear idea of what engineers do or that students do now understand and simply do not find engineering to be an appealing field of study. For example, since the students' primary exposure to the work of engineers was our presentation of lesson plans to them, they may think that that is what engineers spend the bulk of their time doing and do not have an interest in essentially becoming teachers. Or, the students may know what engineers do and find it far less appealing than becoming president, an astronaut or a professional baseball star, or all three. Since we were working with second grade students, they have at least another ten years to decide what kind of occupation they will seek out after their career in public schools is over.

In light of the decrease in the students' interest in engineering, there did appear to be an overall increase of interest regarding general science topics. This may be due to how our engineering based lessons were conceived and presented. Since all of our lessons focused on being somewhat fun and definitely interesting to eight year olds while applying their current science lesson topics to problems that engineers work with, the students might have found the science to be more interesting when applied to tangible problems rather than being just an abstract idea.

After interacting with the second grade students involved with the PIEE project, it was rather surprising to see that the interest in engineering actually decreased as students' awareness and understanding of it increased. This seems somewhat counterintuitive to us, being members of the engineering community, but reflects the way students still, or perhaps now, perceive engineers and engineering. However, we still trust that the skills learned through this curriculum will translate to other areas in the students' further endeavors.

V.1a - Teacher Conclusions

Throughout the year, we spoke with the teachers privately and found that the teachers were very enthusiastic about the program and saw the potential value of it, but we wanted to know if our efforts were making an impact on the way they perceived engineering. So, we gave the teachers a survey to fill out at the end of the year concerning their opinions about engineering. This survey can be found in **Appendix D**.

From the surveys, we found that all three teachers saw engineering as a male-dominated field and two out of three thought of it as specifically a white male field. But, all thought this was a trend that definitely needed to be changed. Two saw this trend to be the result of a lack of understanding, while the last saw lack of exposure to be the issue. All the teachers surveyed saw this field as one that is desirable to study and all felt that children being exposed to college students was a positive experience.

While the survey may not be perfect, we feel that their responses show an interest in changing the way people see engineering, especially their students. With a devoted interest in the PIEE program, they will be more interested in and devoted to teaching other teachers about engineering so that they feel they can help increase understanding and exposure to what engineering truly is.

V.1b - Classroom Observations

One of our initial concerns actually turned out to be one of the first things we found to be false. That was that the students would not be capable of understanding the material we were presenting to them. This was in fact not the case as they were typically able to grasp the concepts we were presenting them with. Although the students were not always able to apply the concepts, it seemed as though they could retain the purpose of the information we were giving them.

On the other hand, we had overestimated the teachers' level of understanding. Unfortunately, we thought they would be able to understand the concepts behind the lessons we gave them. Since they could not, it made it difficult to relate the lessons to the students. Thus the teachers relied on us to explain how the lessons worked to them before they could present the lesson. This typically occurred on the day of the lesson.

This also relates to the level of preparation the teachers exhibited during our dealings with them. Oftentimes, we would enter the classroom to find that the teacher had not read over the lesson they intended to present that day. Commonly, this led to a lack of the materials or background required to properly present the lesson or complete planned activities. For instance, one group member was present when a teacher tried to present a lesson without having looked at anything beforehand but the title. In fact, she read from the lesson plan while teaching. This obviously did not work well as there were missing materials and the pace of the lesson was too slow to keep the attention of the students. Needless to say, the three teachers were all quite different.

Another trend we found common was that when we visited the classrooms, there were times when our duties involved helping out with activities unrelated to our project. During these times, we found that some students struggled with their work. This seemed prevalent among students who were behind in reading and writing. The work was difficult for them not because they lacked the ability to complete the assignments, but rather they lacked motivation. What we found in some cases is that competing for rewards or recognition generated much more interest in finishing the assignment. Prizes did not even have to be very big or special. At times it could just be things we had in our pockets.

Although all of the students are in the same grade and seemed to have been in similar classes the previous year, their abilities varied greatly. While some students were quite proficient, most needed time to understand the basic concepts of engineering. When making lessons we took this into consideration; we made sure the concepts were broken down to a level that was simple enough for the students to understand. Also, we wanted to make sure that our lessons were simple enough for the students who spoke English as their second language to participate in. We needed to make sure that the lessons were not a test of English skills, but a test of the concepts presented. Using quizzes that were picture based was a very effective way to break the language barriers.

V.2 - Personal Conclusions

V.2a - Calvin Chu

I found this project to be fairly successful considering how difficult it is to teach second graders the concepts of engineering. There were many things that could have been implemented better, but I think that all parties could've done more to reach that goal. Despite that, I found this experience to be very satisfying. To think that work that I have done will be used to help teachers in the future makes me feel like I have really accomplished something more, something that most college students can't say they've experienced, unless they're an education major. I've always enjoyed working with children but this time was different from all the other times I've worked with children. I feel that this project is a very important one, but it is flawed. It requires cooperation from all parties and there needs to be a better way to tabulate results of the project. There also needs to be a better follow-up. This is obviously a difficult task as the project will end before the first class graduates from high school. If there was a way to be able to follow these students through high school, that would be ideal. Another suggestion for the project would be to have the IQP students meet with the teachers to discuss the lessons before they reach their "final" stage. This allows the teacher to understand the lessons before they have to teach them and the students to understand what is needed of them and how the lessons may fail. This could also be difficult as having meetings based on so many different schedules may not be possible to arrange. On a professional level, I found the staff at Flagg Street School to be very kind and easy to work with. The teachers were interested in our work and that is very helpful in keeping us inspired to do our work. Another benefit was the fact that the kids were interested in learning the material we were teaching.

V.2b - Chris Donoghue

Through the course of this project, I feel as though the concept of engineering has become more accessible to the second grade students at Flagg Street Elementary School, but only marginally so. Even though we tried to implement lesson plans that would emphasize the engineering aspects of material the students were concurrently covering in their basic science lessons, the students seemed typically to look at these lessons as an exploration of specific applications of the science concepts rather than as generalized examples of the possible applications of the concepts they were discussing.

Although the engineering design process had been posted in the classrooms for nearly half a year, if any of the students were approached and asked to repeat the process, or even paraphrase what it states, I am fairly certain that they would not be able to do so. This can be attributed to two major factors at work.

First, the approach to the lessons, both by the teachers and students, seemed to be that of a break from regular science lessons to see or do something entertaining. The presence of several guests introducing their own lessons, especially several semi-adults in a classroom full of eight-year-olds, already sends the students into a state of excitement about what they may do today. As the project progressed, this sentiment from the students became harder and harder to break as they did experiments and watched demonstrations.

Second, creating lesson plans that entailed using the engineering design process was difficult because of our lack of information on just how deep the second grade students' level of understanding was. Although I believe the students could have worked through several simple iterations of a design or had the presence of mind to draw some sort of machine that would perform a prescribed task, we discussed the fact that the students would first become frustrated with a non-working design or have absolutely no idea where to start when told to draw "a machine." Had we felt that the students would be able to accomplish these tasks, even with some guidance or explanation, it would have been a much simpler matter to reinforce the engineering design process as a tool the students could use to approach and solve problems.

Although the second grade students at Flagg Street Elementary School were exposed to the general concepts of engineering for an entire school year, they did not develop an understanding of the processes and purposes behind engineering. The overall impression of engineering the students have is nothing more than a few examples of engineering being used to apply some concepts from their science lessons to create interesting, fun demonstrations.

V.2c - Mike Raimondi

With America's strong work ethic and willingness to learn, it has been a leader in developing technologies for many years. America has been home to many of the world's greatest inventions such as the light bulb, the telephone, the cell phone, and much development of the modern personal computer occurred here. The people who did much of this work are engineers. A simple definition of an engineer would be a person who uses the engineering design process in order to efficiently solve problems. Most people who decide to enter this field enter a school for it and eventually earn degrees. Unfortunately, the number of people who do this is unstable. This can cause problems in the engineering field, because when people are needed to do engineering work there may be not enough engineers available, which would slow down the advancement of technology.

In order to provide more stability to the number of people going in to the engineering field we have decided introduce engineering to children at an early age. Though this subject is included in the Massachusetts Curriculum Framework, many of the teachers have trouble with the subject themselves and, therefore, do not teach it well or sometimes at all. In order to remedy this we first designed lessons that involved engineering concepts and the use of the engineering design process. Then, we provided detailed instructions for the teachers on" how it works and how it should be taught. These lessons were designed with a "hands on approach that children enjoy so that they will remember engineering and science as being fun and will hopefully continue it in the future.

A survey was provided for the students in order to gauge the effectiveness of our efforts. The survey is provided in **Appendix D**. The results of the survey were largely in our favor and indicate a stronger interest in engineering in our students. The only problem is that the percentage of students who answered the question of "Are you interested in engineering" decreased over the year. This, however, does not indicate that these students will not turn to engineering in the future. Although, they seem uninterested in engineering directly, interest in subjects that involve engineering greatly increased or retained a large percentage of the surveyed students. For instance, the number of students interested in doing science projects increased about thirty percent. Also, many more students were interested in how things work than in the beginning of the year.

I believe that the flaw in our system was that we did not stress enough that the projects we were doing with them actually involved engineering. Although the lessons were a great success, they were not really associated with engineering. The good news is that we believe the core concepts of engineering and the engineering design process did get through. When the students come to the technology/engineering part of the MCAS tests, the students will find that they are good at it. If students see this as their strong suit, they will be more likely to enter more technically inclined fields in college. For this reason, our project was a success.

V.2d - Amanda Hines

We spent the 2004-2005 school year working in the classroom implementing the lessons we developed. In this time the students were introduced to many new concepts and ideas surrounding engineering. While in the classroom I did not notice any difference in the abilities or understanding between the male and female students. The students enjoyed and seemed to learn more from hands on experiments than written work. I believe that the students became more aware about who engineers are and what they do. They did not seem to understand the design process, though in the end, I believe that this project was a benefit to the students involved, and will continue to be for future students.

There does not seem to be a marked difference between female and male students in their capabilities or understanding. Both sexes appeared to enjoy the experiments. The boys tended to be more vocal, and the girls shy. There also existed a tendency in group work for the boys to ask for help while the girls solved the problem on their own. The boys also tended to group with other girls and the girls grouped with other girls. There is a difference in attitude between the boys and the girls, but I do not believe that this difference causes the trend with the sexes in engineering.

Much of our time was spent helping the teachers with unrelated work. In many instances when I went in, science was not being taught. In these instances I found myself helping with math, social sciences or English. This led to a lot of wasted time. In the beginning of the term, any time in the classroom helped us understand the students and the requirements that our lessons would have to meet. Later in the term, the time was wasted. Our time would have been better spent with the teachers and students implementing the lessons that we designed. This would have led to less confusion with the lessons when they were implemented.

The students enjoyed the experiments and hands-on activities more than the worksheets. These activities kept the students attention longer. This led the students to do more of the activities on their own, and learn more of the lessons taught. I believe that the hands-on approach is a good method for teaching second graders the concepts of engineering.

The second graders at Flagg Street Elementary School were exposed to many different concepts and ideas. They were continuously exposed to the engineering design process, but could not seem to follow it on their own. In the coming years, with more exposure to engineering, these students will be able to develop a better understanding of the process. There did not seem to be any difference between the males or females in their understanding of the concepts and ideas. This project was a benefit for the students and teachers involved. The students may still have a limited view of engineering, but with more exposure over the coming years they will develop a better understanding of who engineers are and what they do.

V.3 - Future Implementation

The plans are that these lessons we created would not only be implemented at just one school; the plans are that they will be used all over the country once the project is over. It will begin its spread next year when the teachers we wrote these lessons for will help other 2nd grade teachers in another school in the Worcester area to teach them.

In an ideal world, these teachers would be able to keep spreading these lessons without the aid of a WPI student. As the teachers are inexperienced with this subject matter, they will not be able to teach these lessons effectively yet. That's why next year another team of IQP students will be assisting the teachers who will be taught to make sure they understand the material themselves, and to make sure they have back up when they teach the lessons to their students.

VI – Recommendations

Although we believe that the project in general was a success, we had recommendations to improve upon it in the future. One aspect that we could have concentrated more on would have been to emphasize the fact that by doing the lessons, the children were participating in engineering and that they were using the engineering process. Although we believe we got the core concepts through, we are not sure how well the students connected those concepts with engineering. This was reinforced by the student survey in which the number of students who were interested in engineering had gone down even though the number of students interested in doing science experiments had gone up.

Even though we were scheduled to go to classrooms at certain times every week, teachers did not always take full advantage of that fact. Frankly, the project would have benefited from scheduled times to implement lessons. Perhaps, instead of having assigned times to go in to the classroom, we should have had the teachers find a time when they would do an engineering lesson ahead of time. That way we would not run into the problem of never implementing our lessons, as this was a rather common occurrence.

Having scheduled dates would help counteract another problem we ran into. Repeatedly, the teachers were ill prepared to teach the lessons. Many times they had not even looked at the lesson plan until the day they intended to teach it. Another suggestion to counteract this would be to schedule a time when we go over the lessons with the teachers and actually have them try them out. This would make sure that the teachers understood them, and their opinions would definitely give us tremendous insight into writing lessons.

In terms of preparation, having time to go over lessons would allow IQP students to fully test their experiments out before teaching them. We tested some of the lessons, but not all. A few that we did not test turned out to be faulty. For instance, while implementing the lesson on steam power, we did not test the pinwheels that the teachers had. As a result, the pinwheel melted. If we tested the experiment using their pinwheels, we would have been able to solve the problem prior to implementation.

We should have IQP students focus on one classroom. They are not exclusive to just one, but having them focus on one allows the students to be able to develop better relationships with one classroom and one teacher, rather than strain to have useful relationships with more. In our case, Chris and Calvin went to the same classroom every Wednesday, while Amanda and Mike switched classrooms every time they went. As a result, Chris and Calvin developed closer relationships with the students and teacher they worked with.

Taking more input from IQP students about group performance and project recommendations in the form of surveys would be a good idea. This would prevent any group members from falling behind on their work, because any slacking would almost immediately be brought to light. Also, it would help the IQP students improve the project as it was going on. Weekly or Bi-Weekly Surveys would be ideal.

I believe that the flaw in our system was that although the lessons were a great success, they were not entirely associated with engineering. Fortunately, we believe the core concepts of engineering and the engineering design process did get through. When the students come to the technology/engineering part of the MCAS tests, the students should find that they are well prepared for it. If students see this as their strong suit, they will be more likely to enter more technically inclined fields in college. For this reason, our project was a success.

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Appendices

Appendix A – Pre-Lesson Materials

Curriculum Map

2nd grade

WPI PIEE Project / Second Grade Matrix
Flagg Street School 2004 -2005

Curriculum Frameworks	Sept./Oct.	Nov./Dec.	Jan./Feb.	Mar./Apr.	May/June
Earth and Space Science				**Earth's Changes and Patterns** • Weather • Patterns • Light/color • Sun as heat/light	• Earth's surface • Water, rocks, soil
Life Science	**Living and Non-Living** • Characteristics of organisms • Life cycles • Mammals - bats • Heredity • Habitats • Trees-seasons • Five senses				**Dinosaurs/Fossils** • Earth through time
Physical Science		**Balance, Motion, Forces** • Movement • Pulleys/levers • Simple machine • Push/pull	**Solids, Liquids, Gases** • States of matter • Properties • Reactions **Germs** • Types of germs • Healthy habits		
Technology/ Engineering	• Classroom tools • EDM/Foss Kits • Tool of the month • Terrariums	• Historical toys • Transportation • Ramps • Foss Kits • Tool of the month	• Experiments • Natural vs. human made materials • Structures • Tool of the month	• Weather gauge • Kites • Tool of the month	• How humans use thei body as tools • Inventions • Tool of the month
Resources	• Guest speaker • Nature Trail • Grade level trip	• Parents	• Fallon Partnership		• Guest speaker • Fossil samples

Worcester Public Schools Benchmarks

GRADE TWO

SKILLS OF INQUIRY

(Tools for learning and life-long learning.)

Students will...

02.SC.IS.01 Ask questions about objects, organisms, and events in the environment.

02.SC.IS.02 Tell about why and what would happen if?

02.SC.IS.03 Make predictions based on observed patterns.

02.SC.IS.04 Name and use simple equipment and tools (e.g., rulers, meter sticks, thermometers, hand lenses, and balances) to gather data and extend the senses.

02.SC.IS.05 Record observations and data with pictures, numbers or written statements.

02.SC.IS.06 Discuss observations with others.

EARTH/SPACE SCIENCE

Students will...

02.SC.ES.01 Describe the weather changes from day to day and over the seasons.

02.SC.ES.02 Recognize that the sun supplies heat and light to the earth and is necessary for life.

02.SC.ES.03 Identify some events around us that have repeating patterns, including the seasons of the year, day and night.

02.SC.ES.04 Graph various kinds of weather (over a period of time) and begin to predict possible weather (seasonal) patterns. Recognize and communicate simple patterns in data.

02.SC.ES.05 Make a list of what you see outdoors and in the sky during the day. Make another list of things you see outdoors and in the sky at night. Discuss the differences between the day and night lists.

LIFE SCIENCE

Students will...

02.SC.LS.01 Recognize changes in appearance that animals and plants go through as the seasons change.

02.SC.LS.02 Observe and record changes in plants (e.g., trees, flowers, grass) on the playground and around the school during fall, winter, and spring.

02.SC.LS.03 Identify the ways in which an organism's habitat provides for its basic needs (plants require air, water, nutrients, and light; animals require food, water, air and shelter).

02.SC.LS.04 Create a garden habitat for birds and butterflies. Research and plant appropriate flowers.

02.SC.LS.05 Recognize that fossils provide us with information about living things that inhabited the earth years ago.

02.SC.LS.06 Look at a variety of fossils or pictures of fossils, including plants, fish, and extinct species. Guess what living organisms they might be related to.

02.SC.LS.07 Recognize the people and other animals interact with the environment through their senses of sight, hearing, touch, smell and taste.

02.SC.LS.08 Observe small animals in the classroom while they find food, water, shelter, etc.

02.SC.LS.09 Talk about how people use their senses every day.

PHYSICAL SCIENCE

Students will...

02.SC.PS.01 Recognize that under some conditions, objects can be balanced.

02.SC.PS.02 Try to make a long, thin, rectangular block of wood stand upright on each face. Note that it stands (balances) very easily on some faces, but not on all.

02.SC.PS.03 Describe the various ways that objects can move, such as in a straight line, zigzag, back-and-forth, round-and-round, fast and slow.

02.SC.PS.04 Observe objects as they push and pull them on a hard, smooth surface. Make predictions as to what direction they will move and how far they will go. Repeat using various surfaces, e.g., rough, soft.

02.SC.PS.05 Demonstrate that the way to change the motion of an object is to apply a force (give it a push or a pull). The greater the force, the greater the change in the motion of the object.

02.SC.PS.06 Use a spinning toy (e.g., top) and a rocking toy (e.g., rocking horse) to explore round-and-round motion and back-and-forth motion.

ECHNOLOGY/ENGINEERING

Students will...

02.SC.TE.01 Identify and describe the characteristics of natural materials (e.g., wood, cotton, fur, wool) and human-made materials (e.g., plastic, Styrofoam).

02.SC.TE.02 Identify and explain some possible uses for natural materials (e.g., wood, cotton, fur, wool) and human-made materials (e.g., plastic, Styrofoam).

02.SC.TE.03 Identify and describe the safe and proper use of tools and materials (e.g., glue, scissors, tape, ruler, paper, toothpicks, straws, spools) to construct simple structure.

02.SC.TE.04 Identify tools and simple machines used for a specific purpose, e.g., ramp, wheel, pulley, lever.

02.SC.TE.05 Describe how human beings use parts of the body as tools (e.g., teeth for cutting, hands for grasping and catching), and compare their use with the ways in which animals use those parts of their bodies.

Classroom Assignments

grade level teams d8.doc
9/14/2004

PIEE CLASSROOM ASSIGNMENTS

Teachers	Fellows	IQP Students
Second Grade Team (Faculty Advisor Rulfs)		
Jyoti Datta, Robin Ring, Monica Wolf (Flagg)	Sarah Linderme (G) Josh Pesch (UG-A,C,D terms)	Calvin Chu Christopher Donoghue Amanda Hines Michael Raimondi
Third Grade Team (Faculty Advisor Goulet)		
Jen Lahue (Flagg)	Heather Blackwell (G) Jon Scobo (UG-B,C,D terms)	Jeanne Shaffer Lindsay Strum
Nancy Mattus (Midland) Mary Navin	Becky Stanley (G)	Daniel Vitale
Fourth Grade Team (Faculty Advisor Pins)		
Lori Degnan, Mike Dunphy, Jodi Watson (Elm Park)	Kerry Malone (G) Meagan Ward (UG-A,B,C,D terms)	Andrea Flynn Johnny Parretti Paul Ragaglia
Sue Bercume, Philip Carlson (Midland)	Jennifer Gray (G)	Daniel Bartl Rick McCleary
Fifth Grade Team (Faculty Advisor Orr)		
Lisa Ansara, Fran Mahoney (Elm)	Leena Razzaq (G)	Robert Doughty Paul Ingemi
Donna Griffin, Michele Sullivan (Midland)	Crystal Bishop (UG-summer, A,B,C,D)	Thomas Gramzow Shamballa Kawamoto
Sixth Grade Team (Faculty Advisor Miller)		
Deborha Dennison, Lisa Quinn (Elm)	Edwin Mercado (G) Eli Mojica (UG-B,C,D)	William Wong Melissa Costello
Cecelia Gray (Midland)	Jennifer Gray (G)	Ben Johnson James Rocci

Timeline

IQP timeline 04-05 d5.doc
6/21/2004

IQP Timeline for PIEE Project

Approx. Schedule[1]	Task
Summer (IQP students not required to be present)	
June (during workshop)	Teacher and fellow brainstorm and decide on a list of possible topics based on specific learning standards from which the IQP students can choose lessons to write. Lessons should be scheduled to be implemented between November and February
A term[2] (IQP students present in classroom on a regular schedule)	
Beginning of A term	IQP team chooses topics for their lessons, and locates related lesson plans with assistance of teacher and fellow.
Mid A term	Literature review for project proposal underway.
End of A term	Project proposal[3] completed, one per grade level team. Proposal contains an outline of at least two lesson plans per IQP student[4]. In collaboration with the classroom teacher and fellow, each IQP team decides which lessons (at least one per IQP student) they will implement. If any lessons will be implemented early in B term, completed lesson plans must be reviewed by teacher and fellow, and gathering of supplies must be underway. Decision is made as to the role of the teacher, Fellow, and IQP student(s) in implementing each lesson plan.
B term[5] (IQP students present in classroom on a regular schedule)	
Nov. 1	First lesson plan per IQP student is ready for implementation; i.e. lesson plans revised, supplies purchased sufficient for a dry run, and prototypes and demonstration setups prepared as needed. IQP team presents a dry run of lessons to be implemented to other IQP students, fellows and advisor. Approval from the fellow and the advisor is needed before the lessons are taught in the actual classroom.[6]
Nov. 15-Dec. 15	Lesson is implemented. Advisor observes if possible. Shortly after implementation (same day preferred), teacher and fellow provide the IQP team with written feedback on the implemented lesson. IQP team revises the lesson plans.
Nov. 15-Dec. 15	Prepare poster for spring conference(s) as needed.

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[1] These dates are approximate; acceleration of the schedule is encouraged, and serious slippage will jeopardize the satisfactory completion of the project.
[2] Aug. 26-Oct. 14
[3] Proposal consists of Introduction, Literature Review of selected relevant topics, Objectives, and draft Methodology section consisting of lesson plans and lesson plan outlines.
[4] Lesson plans are indicated "per student" as a counting device to equalize work across teams of different sizes, but IQP teams are expected to collaborate on lesson development and implementation, rather than working as individual students.
[5] Oct. 26-Dec. 16
[6] If the lesson is not satisfactory, comments are given by the advisor and fellow with specific items that need to be addressed for a second dry run. If the second dry run is not successful, the attempted lesson(s) is/are not implemented.

IQP timeline 04-05 d5.doc
6/21/2004

C term[7] (IQP students present in classroom on a regular schedule)	
Jan. 15	Second lesson plan per IQP student ready for implementation; i.e. lesson plans revised, supplies purchased sufficient for a dry run, and prototypes and demonstration setups prepared as needed. IQP team presents a dry run of lessons to be implemented to other IQP students, fellows and advisor. Approval from the fellow and the advisor is needed before the lessons are taught in the actual classroom.[8]
Jan. 30-Feb. 28	Lesson is implemented. Advisor observes if possible. Shortly after implementation (same day preferred), teacher and fellow provide the IQP team with written feedback on the implemented lesson. IQP team revises the lesson plans.
D term[9] (IQP students present in classroom on a regular schedule)	
March 15-April 15	IQP team finishes writeup of additional lesson plans (those not planned to be implemented).
April 30	All final lesson plans (and unit plan(s), if applicable) are submitted as part of final report and to online repository. Final report is due in hard copy and on CD, to advisor, to project PI, and to teacher (one copy each).

[7] Jan. 13-March 3
[8] If the lesson is not satisfactory, comments are given by the advisor and fellow with specific items that need to be addressed for a second dry run by Feb. 1. If the second dry run is not successful, the attempted lesson(s) is/are not implemented.
[9] March 15-May 3

PIEE Project Summary

project summary for iqp students d7.doc
8/25/04

WPI-NSF K-6 PIEE PROJECT
K-6 Gets a Piece of the PIEE:
Partnerships Implementing Engineering Education

PROJECT SUMMARY

Background:

- Massachusetts introduced technology/engineering into its K-12 curriculum framework (MSTECF) in 2001.
- WPI and WPS applied for and received a National Science Foundation (NSF) grant to help WPS develop curriculum and prepare teachers to deliver it.

Objectives:

- To develop partnerships between WPS and WPI.
- To implement the technology/engineering portion of the MSTECF in grades K-6.
- To develop curricular materials and prepare teachers so that the project is self-sustaining after the grant expires.

Project Overview:

- Project lasts three years (June 1, 2003-May 31, 2006). In the three years of the project, we will work in grades K-6 in several Doherty quadrant primary schools.
- In the first year, we worked in one class each in grades 4, 5, and 6 in Elm Park and Midland St. Schools. Teams at each grade level (4, 5, 6) developed and delivered technology/engineering curriculum.
- In the second year (this year), we will continue to work in those six classrooms, and will add (for a total of 17 classrooms)
  - the remaining 4th, 5th, and 6th grade classrooms at Elm Park;
  - a 3rd grade and second 4th and 5th grade classrooms at Midland St.
  - 2nd and 3rd grade classrooms at Flagg St.
- In succeeding year(s), we plan to add
  - remaining 2nd and 3rd grades at Elm Park and Midland St.
  - remaining 2nd and 3rd grades, and 4th, 5th, and 6th grades at Flagg St.
  - K and 1st grade (schools TBD)
- Curriculum is intended to both address the MSTECF and to integrate with existing curriculum (mainly science).
- Teachers provide grade level pedagogy and curriculum expertise; fellows and IQP students provide engineering expertise, ideas, and resources. Implementation is done by WPS teachers with the assistance of WPI fellows and IQP students.
- Most 4th, 5th, and 6th grade teams consist of a mixture of experienced and new teachers; 2nd and 3rd grade teachers are all new to the project.

IQP Commitment:

- You need not be an engineering major to participate in this project!
- You must register for all four terms: A term 1/6 unit, B term 1/3, C term 1/3, D term 1/6 is ideal.

project summary for iqp students d7.doc
8/25/04

- Each classroom (i.e. each teacher) will be assigned 1-2 IQP students. You will spend time in the classroom (1-2 hours at a time, once to twice per week) but your primary purpose is not to teach the class.
- All the IQP students working in the same grade level will be one grade level team, and also one IQP team. Each grade level team will have one faculty advisor and between one and three fellows (undergraduate and graduate). Each grade level team meets once a week.
- Fellows are responsible for supervising the day to day activities of the IQP students; the faculty advisor provides overall supervision and grades the IQP. See handbook of role descriptions (linked from http://www.wpi.edu/Academics/PIEE/Resources/staff.html) for more details.
- IQP timeline handout (also linked from http://www.wpi.edu/Academics/PIEE/Resources/staff.html) contains more details about IQP expectations and activities.

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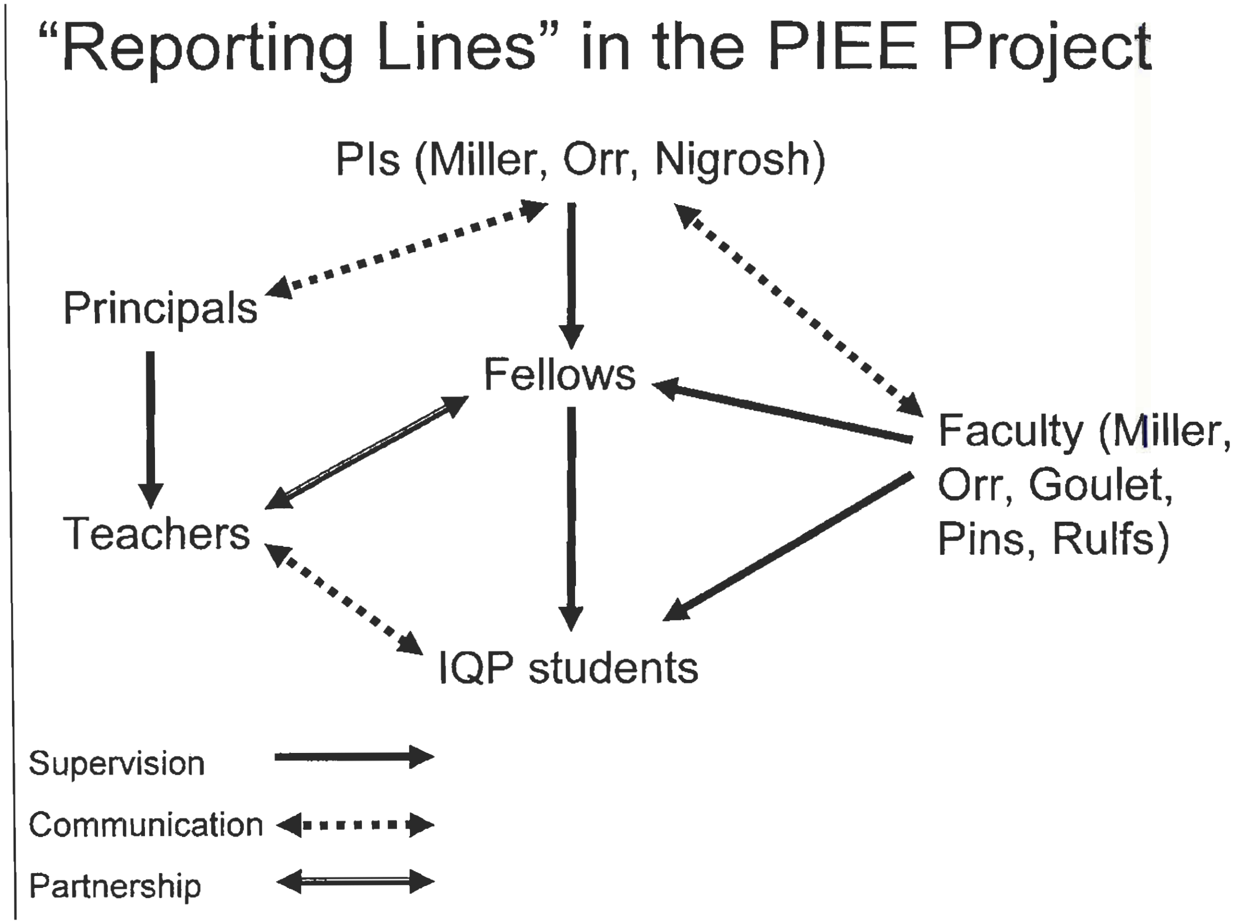
Please visit the project web site at http://www.wpi.edu/Academics/PIEE . It contains most project documents.

Reporting Lines in the PIEE Project



Appendix B - Lessons

Unit Plan Template

Unit Title --

Grade Level --

Unit Time –

Summary –

Subject Area(s) –

Educational Standards –

> **Massachusetts Science and Technology/Engineering Curriculum Framework (MSTECF) Standards –**
>
> Engineering Design
>
> **Worcester Public School (WPS) Benchmarks –**
>
> Skills of Inquiry – Students will…
>
> Physical Science – Students will…
>
> Technology/Engineering

Additional Learning Objectives – none

Essential Questions –

Lessons --

Pre-Requisite Knowledge – Push/Pull, Balance

Vocabulary List –

Summative Assessment/Evaluation –

Unit Background and Concepts for Teacher –

Unit Extension Activities –

Attachments –

Unit References –

Comments –

Redirect URL –

Owner ID – WPI

Contributors – Calvin Chu, Chris Donoghue, Amanda Hines, Michael Raimondi
Key Words – Science, Technology, Engineering

Lesson Plan

Lesson Title –

Grade Level –

Lesson Time –

Instructional Mode –

Team/Group Size –

Summary –

Learning Objectives – Worcester Public Schools Benchmarks (WPS) for 2nd Grade:

Skills of Inquiry – Students will…

Physical Science – Students will…

Technology/Engineering

Essential Questions –

Introduction / Motivation –

Procedure –

Materials List –

Vocabulary with Definition –

Assessment/Evaluation of Students –

Lesson Extensions –

Attachments –

Troubleshooting Tips –

Safety Issues --

Redirect URL –

Key Words – Science, Technology, Engineering

Unit Plan – Simple Machines

Unit Title -- Simple Machines

Grade Level -- Second Grade

Unit Time -- Seven hours

Summary – The students will be introduced to the ideas of simple machines as a means to make work easier. They will be guided through a series of activities involving simple machines and have hands on experience using simple machines to make work easier.
Subject Area(s) – Simple Machines, Push/Pull

Educational Standards –

Massachusetts Science and Technology/Engineering Curriculum Framework (MSTECF) Standards –

Engineering Design

2.1 Identify tools and simple machines used for a specific purpose, eg., ramp, wheel, pulley, lever.

Worcester Public School (WPS) Benchmarks –

Skills of Inquiry – Students will…

02.SC.IS.01 - Ask questions about events in the environment.

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Physical Science – Students will…

02.SC.PS.01 – Recognize that under some conditions, objects can be balanced.

Technology/Engineering

02.SC.TE.04 – Identify tools and simple machines used for a specific purpose.

Additional Learning Objectives – none

Essential Questions – What is a machine? How do simple machines help us? Where do we see simple machines in use?

Lessons --

1. Simple Machines and the Lever
2. Inclined Plane
3. Wheels and Axles and Pulleys
4. Screws and Gears

5. Pulleys
6. Playground

Pre-Requisite Knowledge – Push/Pull, Balance

Vocabulary List – machine, simple machine, force, lever, fulcrum, inclined plane, wedge, screw, wheel and axle, pulley, gear, friction, gravity

Summative Assessment/Evaluation – Introductory worksheets, Cumulative test of key terms and ideas.

Unit Background and Concepts for Teacher – The types of simple machines and their function in making work easier.

Unit Extension Activities – Simple machine activities at Edheads.com

Attachments –Inclined Plane Worksheet, Beginning Wheel, Axles and Pulleys Worksheet, Playground Worksheet, Cumulative Assessment Worksheet

Unit References – edheads.com

Comments -- none

Redirect URL – none

Owner ID – WPI

Contributors – Calvin Chu, Chris Donoghue, Amanda Hines, Michael Raimondi
Key Words – Science, Technology, Engineering, Simple Machines

Lesson Title – Simple Machines and The Lever

Summary – Students will come up with a general definition for a machine. They will then experiment with using a lever to balance uneven loads.

Materials List –

Machine Drawing – This is a class learning activity.

- One sheet of paper per student.
- One pencil per student.
- One bin of markers, crayons, or colored pencils per five students.

Balancing Demonstration – This is a group activity.

- Ten pennies for each group.
- A small lever devised of a ruler and pencil or a prefabricated lever.

Large Scale Experiment –

- One case of office paper.
- One six foot beam.
- A fulcrum made from a soda bottle full of water.

Introduction / Motivation – Discussion of what machines are and how simple they can be. Demonstration of balancing different weights with a lever and fixed fulcrum.

Procedure –

1. Ask students to name examples of machines. Ask questions to coach students into creating a very general definition of a machine as something that **makes work easier**.
2. Explain that a group of machines called simple machines are the most basic forms of mechanical machines.
3. Ask students to recall balance lessons and introduce small levers on desks. Ask them if they think this could be a machine. Discuss the parts of the lever.
4. Students will place one penny on each end to balance the beam. They should add another penny to the same side and move the stack until it is again balanced.
5. Discuss examples of levers with students.
6. Large Scale Lever Experiment
   a. Place the box on one end of the lever. Have the students again try to raise the box using the lever. When one of the students cannot move the box, ask whether the fulcrum (pivot) should be moved closer to the box or farther away.
   b. Move the fulcrum in the direction suggested by students and have them try again. Moving the fulcrum closer to the box will make it easier, so if the initial answer is farther away, have the students try again with the fulcrum closer.

Troubleshooting Tips – none

Safety Issues – Do not allow students to stand on the lever to move the box. Make sure fingers and toes are not caught under the box side of the lever.

Lesson Plan

Lesson Title – Simple Machines and the Lever

Grade Level – Second Grade

Lesson Time – One hour

Instructional Mode – Whole Class, Group Exploration

Team/Group Size – Whole Class, Groups of 4-5 students

Summary – Students will come up with a general definition for a machine. They will then experiment with using a lever to balance uneven loads.

Learning Objectives – Worcester Public Schools Benchmarks (WPS) for 2nd Grade:

Skills of Inquiry – Students will…

02.SC.IS.01 - Ask questions about events in the environment.

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Physical Science – Students will…

02.SC.PS.01 – Recognize that under some conditions, objects can be balanced.

Technology/Engineering

02.SC.TE.04 – Identify tools and simple machines used for a specific purpose.

Essential Questions – What is a machine? How do machines help us? What is a lever? How does a lever help us? Where do we see levers in our lives?

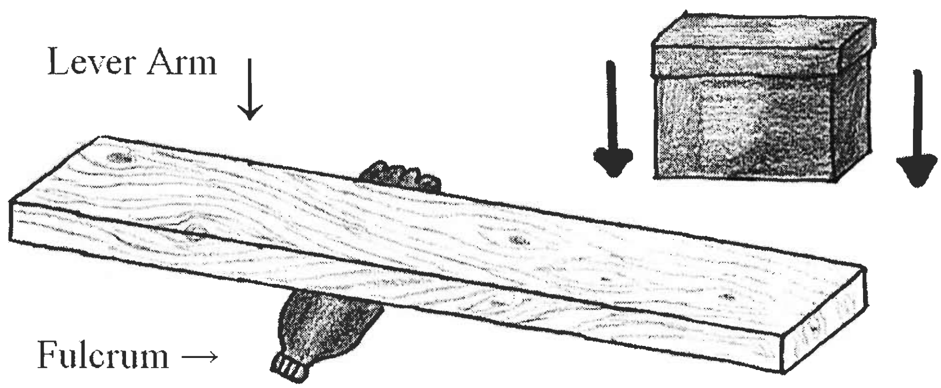
Introduction / Motivation – Discussion of what machines are and how simple they can be. Demonstration of balancing different weights with a lever and fixed fulcrum.

Procedure –

1. Ask students to name examples of machines. Ask students to explain what each machine is, what it does, why they picked it, and their definition of a machine. Ask questions about what all the machines named have in common to coach students into creating a very general definition of a machine as something that **makes work easier**.
2. Explain that a group of machines called simple machines are the most basic forms of mechanical machines that make it easier to do work. Introduce the

definition of each simple machine in the defined vocabulary section. This may be accompanied by a picture book illustrating each machine.

3. Ask students to recall balance lessons and introduce small levers on desks with equal length arms and a fixed fulcrum if possible, a pencil under a ruler would suffice. Ask them if they think this could be a machine, and have them recall that a machine simply **makes work easier**. Discuss the parts of the lever, naming the lever arm and the fulcrum, or pivot.
4. Students will place one penny on each end to balance the beam. They should add another penny to the same side and move the stack until it is again balanced. Repeat with another penny and another for six trials. Explain that this is a demonstration of how a machine makes work easier. The weight on one side keeps increasing, but the distance from the fulcrum makes it balance.
5. Discuss examples of levers with students, such as see-saws, baseball bats, hammers, etc.
6. Large Scale Lever Experiment
   a. Have each student try to lift the box.
   b. Create the lever from a six foot long board and a fulcrum made from a used 2 liter soda bottle filled with water.



   c. Place the box on one end of the lever. Have the students again try to raise the box using the lever. When one of the students cannot move the box, ask whether the fulcrum (pivot) should be moved closer to the box or farther away.
   d. Move the fulcrum in the direction suggested by students and have them try again. Moving the fulcrum closer to the box will make it easier, so if the

initial answer is farther away, have the students try again with the fulcrum closer.

e. Ask students to discuss how the lever helped lift the box.

Materials List –

Machine Drawing – This is a class learning activity.

- One sheet of paper per student.
- One pencil per student.
- One bin of markers, crayons, or colored pencils per five students.

Balancing Demonstration – This is a group activity.

- Ten pennies for each group.
- A small lever devised of a ruler and pencil or a prefabricated lever.

Large Scale Experiment –

- One case of office paper.
- One six foot beam.
- A fulcrum made from a soda bottle full of water.

Vocabulary with Definition –

Machine – Any device that makes doing work easier for people

Simple machine – A machine that only uses the force of a human to do work. The seven types are

- **Lever**
- **Wheel and axle**
- **Pulley**
- **Inclined plane**
- **Wedge**
- **Screw**
- **Gear.**

Force – A push or a pull.

Fulcrum – The pivot of a lever.

Assessment/Evaluation of Students – End of Unit Cumulative Worksheet

Lesson Extensions – none

Attachments – none

Troubleshooting Tips – none

Safety Issues – Do not allow students to stand on the lever to move the box. Make sure fingers and toes are not caught under the box side of the lever.

Redirect URL – none

Key Words – Science, Technology, Engineering, Simple Machines, Lever

Lesson Title – Inclined Plane

Summary – Students will be introduced to the concept of the inclined plane. Students will observe how an inclined plane can help reduce the amount of work used to complete tasks. Students will share real-life examples to show how an inclined plane works as a simple machine.

Materials List –

- Inclined plane made from books leaned against a stack of books
- Toy cars (ask students to bring them in)
- One yard stick per group

Introduction / Motivation – Worksheet where the children will draw a machine that will make it easier to get a box onto a ledge.

Procedure –

1. Have the students participate in a discussion involving the Beginning Inclined Plane worksheet.
2. Explain an inclined plane as an angled flat surface and how it can help in this situation.
3. Ask about where they've seen inclined planes before, such as wheelchair ramps, slides, ski jumps.
4. <u>Inclined Plane Car Demonstration</u>
   a. Create a short stack of books for each group of students. Lean another book or strip of cardboard against the stack to act as the inclined plane. Place the yard stick at the base of the inclined plane.
   b. Have students place their cars at the top of the inclined plane, resting the rear wheels over the edge of the book.
   c. The students should gently push the car with just enough force to get the wheels over the edge.
   d. After the car rolls down the inclined plane, the students should record how far the car travels.
   e. Make the stack taller and repeat the experiment with the same cars.
   f. Make the stacks of books taller again and have students predict how far the cars will travel.
   g. Ask the students what made the cars roll down the inclined plane (gravity). Using their observations, ask if the ramp made the pull of gravity do more work on the car or less when the stack was short (less).

Troubleshooting Tips – none

Safety Issues – none

Lesson Plan

Lesson Title – Inclined Plane

Grade Level – Second Grade

Lesson Time – One hour

Instructional Mode – Whole Class Discussion, Group Experiment

Team/Group Size – Whole Class, Groups of Five Students

Summary – Students will be introduced to the concept of the inclined plane. Students will observe how an inclined plane can help reduce the amount of work used to complete tasks. Students will share real-life examples to show how an inclined plane works as a simple machine.

Learning Objectives –

Technology/Engineering

02.SC.TE.04 – Identify tools and simple machines used for a specific purpose.

Essential Questions – What is an inclined plane? Where would an inclined plane help reduce work? Where do we see inclined planes used in our lives?

Introduction / Motivation – Worksheet where the children will draw a machine that will make it easier to get a box onto a ledge.

Procedure –

1. Have the students participate in a discussion involving the Beginning Inclined Plane worksheet. The teacher should lead the discussion prompting students for ways to use an inclined plane to move the box up to the top of the cliff.

   Possible Questions:

   -How can we move the box?

   -Can we slide it on the ground?

   -Can we build something to move the box?

   -What would make it easier to move the box up while sliding it?

2. Have them recall the definition of a machine that they arrived at as something that makes doing work easier.
3. Explain to them that an inclined plane is an angled flat surface and how it can help in this situation by making it easier to push the box up to the top of the ledge instead of having to lift it up. The usefulness of an inclined plane might

be described in relation to moving something vertically in very small amounts instead of all at once, such as lifting something to a height of six feet by moving it a half of a foot at a time twelve times.

4. Ask about where they've seen inclined planes before, such as wheelchair ramps, slides, ski jumps.
5. <u>Inclined Plane Car Demonstration</u>
    h. Create a short stack of books for each group of students. Lean another book or strip of cardboard against the stack to act as the inclined plane. Place the yard stick at the base of the inclined plane.
    i. Review how to measure inches with a yardstick.
    j. Have students place their cars at the top of the inclined plane, resting the rear wheels over the edge of the book.
    k. The students should gently push the car with just enough force to get the wheels over the edge.
    l. After the car rolls down the inclined plane, the students should record how far the car travels.
    m. Make the stack taller and repeat the experiment with the same cars, again recording how far they travel after the inclined plane. Ask students to make observations and discuss why they think the cars traveled different distances. They should be coached to answer that the inclined plane made them do different amounts of work to get to the bottom. More for cars that went far, less for cars that did not go far.
    n. Make the stacks of books taller again and have students predict how far the cars will travel.
    o. Ask the students what made the cars roll down the inclined plane (gravity). Using their observations, ask if the ramp made the pull of gravity do more work on the car or less when the stack was short (less). Ask whether the pull of gravity did more or less work on the car when the ramp was tall.

Materials List –

- Inclined plane made from books leaned against a stack of books

- Toy cars (ask students to bring them in)
- One yard stick per group

Vocabulary with Definition –

Machine – Any device that makes doing work easier for people

Inclined Plane – An angled flat surface

Gravity – Downward pull

Assessment/Evaluation of Students – End of Unit cumulative worksheet.

Lesson Extensions – None

Attachments – Inclined Plane Worksheet

Troubleshooting Tips – None

Safety Issues – None

Redirect URL – None

Key Words – Simple Machine, Inclined Plane, Science, Technology, Engineering

Lesson Title – Wheels, Axles, and Pulleys

Summary – Wheels, axles and pulleys will be demonstrated to the class through physical models, discussions and worksheets. Students will learn how these simple machines help to reduce the work required to move objects.

Materials List –

Wheel and Axle Demonstration

Rough surface, such as sandpaper or the pavement of a sidewalk

Flat bottomed object, such as a block of wood or a cardboard box filled with some items for weight

Rounded dowels to act as the wheels and axles

Introduction / Motivation – Demonstration of how wheels, axles and pulleys make work easier.

Procedure –

1) Wheel and Axle Demonstration
   a. Lay down some rough surface like sandpaper or use a concrete sidewalk.
   b. Have students try to push a flat bottomed object across the rough surface. Make observations about the difficulty.
   c. Lay rounded dowels over the rough surface and again push the object across it.
2) Have students discuss their observations
3) Explain how wheels and axles help to move objects across the ground by overcoming friction from surfaces, giving a brief description of friction as a force that keeps things from sliding.
4) Explain how pulleys can help move objects by changing the direction of the force and the distance the force travels to move an object in the same way a lever can.

Troubleshooting Tips – none

Safety Issues – none

Lesson Plan

Lesson Title – Wheels, Axles, and Pulleys

Grade Level – Second Grade

Lesson Time – One hour

Instructional Mode – Demonstration, Whole Class

Team/Group Size – Whole Class

Summary – Wheels, axles and pulleys will be demonstrated to the class through physical models, discussions and worksheets. Students will learn how these simple machines help to reduce the work required to move objects.

Learning Objectives –

Technology/Engineering

02.SC.TE.04 – Identify tools and simple machines used for a specific purpose.

Essential Questions – What is a wheel and axle? What is a pulley? How do wheels, axles and pulleys help us do work? Where do we see wheels, axles and pulleys used in our lives?

Introduction / Motivation – Demonstration of how wheels, axles and pulleys make work easier.

Procedure –

1) Wheel and Axle Demonstration
   a. Lay down some rough surface like sandpaper or use a concrete sidewalk.
   b. Have students try to push a flat bottomed object across the rough surface. Make observations about the difficulty.
   c. Lay rounded dowels over the rough surface and again push the object across it.
2) Have students discuss their observations
3) Explain how wheels and axles help to move objects across the ground by overcoming friction from surfaces, giving a brief description of friction as a force that keeps things from sliding.
4) Explain how pulleys can help move objects by changing the direction of the force and the distance the force travels to move an object in the same way a lever can.

Materials List (per class, per group and / or per student) –

Wheel and Axle Demonstration

Rough surface, such as sandpaper or the pavement of a sidewalk

Flat bottomed object, such as a block of wood or a cardboard box

filled with some items for weight

Rounded dowels to act as the wheels and axles

Vocabulary with Definition –

Wheel- A circular object made of a hard material that turns around a cylinder

Axle – A cylinder which a wheel turns on or with

Pulley- A wheel with grooves used with a string or rope to lift objects off the ground

Friction – A force that keeps objects from sliding.

Gravity - A downward pull, keeps you on the ground

Assessment/Evaluation of Students – End of Unit cumulative worksheet.

Lesson Extensions – None

Attachments – Beginning Wheel, Axles and Pulleys Worksheet

Troubleshooting Tips – None

Safety Issues – None

Redirect URL – None

Key Words – Wheel, Axel, Pulley, Gravity, Science, Technology, Engineering

Lesson Title – Screws and Gears

Summary – Introduce students to screws and gears as simple machines. Have students make observation and predictions of how variations in machines will change performance.

Materials List –

Archimedes Screw Demonstration -

- Empty 2 liter soda bottle
- Scissors
- Seven feet of vinyl tubing (5/8 to 7/8 inch outside diameter)
- Two tubs to hold water

Spirograph Activity –

- Spirograph kit
- Paper for each student
- Pens or pencils to trace the path

Introduction / Motivation – Demonstration of an Archimedes screw, Spirograph gear activity.

Procedure –

1. Archimedes Screw
   a. Assemble an Archimedes screw from simple materials.
   b. Fill one tub with enough water to submerge one end of the screw. Set up an empty tub at a level slightly above the first.
   c. Hold the screw at about a forty-five degree angle. Turn the screw continuously to show how water is forced up the hose.
   d. Discuss the usefulness of this machine with students.
2. Spirograph Gear Activity.
   a. While students are at their desks, pass out paper and parts of the kit to each table.
   b. Ask students to place the largest gear they have on the paper. Then ask them to place the smallest gear along the outside and trace its path with their pen/pencil.
   c. Ask them to replace the smallest gear with the next largest and again trace its path.
   d. Start discussion about the changes they observed when the size of the moving gear changed.
   e. Have students pick their own combination of two gears and trace the outside one's path. Then have them replace one gear and make predictions about the speed of the gear and how easily it will move this time in comparison to the previous try.

Troubleshooting Tips – none

Safety Issues – none

Lesson Plan

Lesson Title – Screws and Gears

Grade Level – Second Grade

Lesson Time – One Hour

Instructional Mode – Whole Class

Team/Group Size – Whole Class

Summary – Introduce students to screws and gears as simple machines. Have students make observation and predictions of how variations in machines will change performance.

Learning Objectives – Worcester Public Schools Benchmarks (WPS) for 2nd Grade:

Technology/Engineering

02.SC.TE.04 Identify tools and simple machines used for a specific purpose.

Skills of Inquiry – Students will…

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Essential Questions

- What can screws and gears be used for?
- Where do you see screws and gears in every day life?

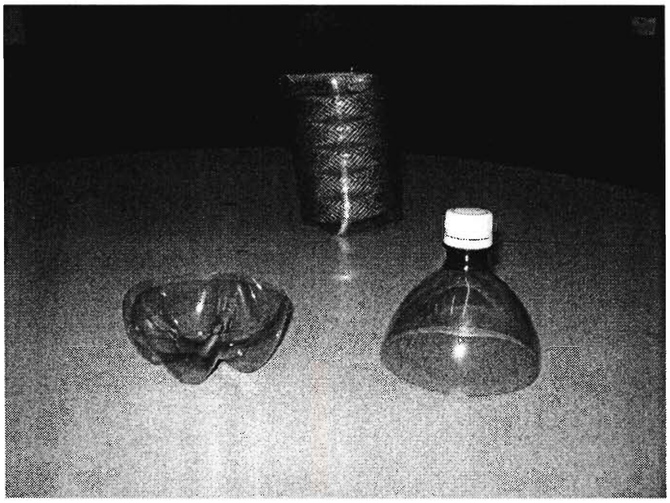
Introduction / Motivation – Demonstration of an Archimedes screw, Spirograph gear activity

Procedure –

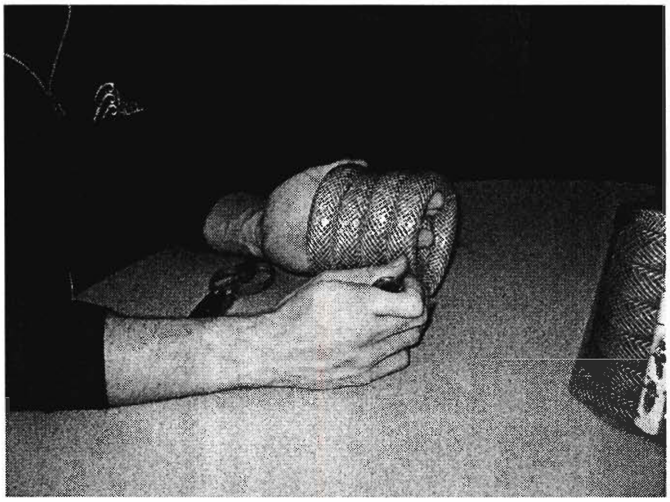
3. Archimedes Screw

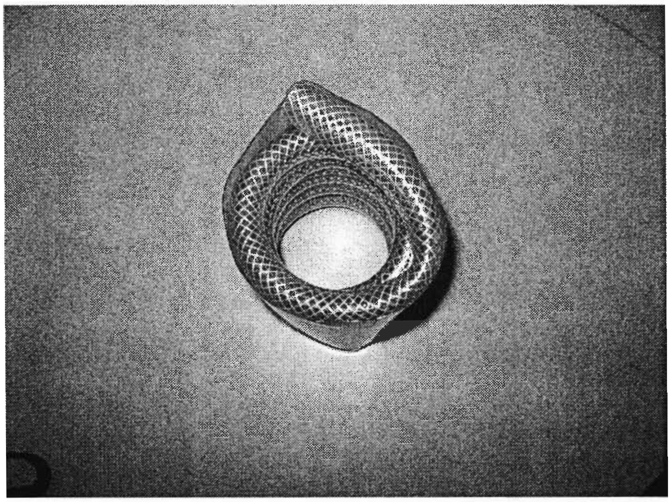
   a. Assemble an Archimedes screw from simple materials including a clear soda bottle and approximately six feet of vinyl tubing.

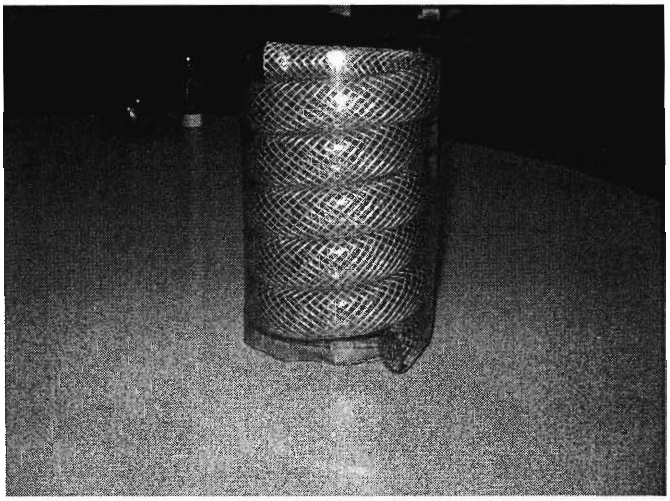
      I. Cut the top and bottom off of the soda bottle.



      II. Coil the length of vinyl tubing tightly against itself. It can be done by hand with a good amount of nudging after the hose is inside, but it may be useful to rent a spring compressor from an auto parts store (typically costing nothing, only a deposit that is returned when the part is).







II. Fill one tub with enough water to submerge one end of the screw. Set up an empty tub at a level slightly above the first.

III. Hold the screw at about a forty-five degree angle. Turn the screw continuously to show how water is forced up the hose.

d. Discuss the usefulness of this machine with students. Try to elicit the uses for this machine before revealing the use of the screw on ships to bail out water before mechanical or electrical pumps were made.

4. <u>Spirograph Gear Activity</u>.

f. While students are at their desks, pass out paper and parts of the kit to each table.

g. Ask students to place the largest gear they have on the paper. Then ask them to place the smallest gear along the outside and trace its path with their pen/pencil.

h. Ask them to replace the smallest gear with the next largest and again trace its path.
i. Start discussion about the changes they observed when the size of the moving gear changed. Did it seem to change the speed of the pen? Did it become easier to move the pen around the large gear?
j. Have students pick their own combination of two gears and trace the outside one's path. Then have them replace one gear and make predictions about the speed of the gear and how easily it will move this time in comparison to the previous try.
k. Repeat until the concept that gears can make work easier by changing the forces applied to them is adequately reinforced, or until the students have lovely pictures.

Materials List -

Archimedes Screw Demonstration -

Empty 2 liter soda bottle

Scissors

Seven feet of vinyl tubing (5/8 to 7/8 inch outside diameter)

Two tubs to hold water

Spirograph Activity –

Spirograph kit

Paper for each student

Pens or pencils to trace the path

Vocabulary with Definition –

Screw - An inclined plane that winds around a cylinder.

Gear - A simple machine used to shift motion to another object.

Assessment/Evaluation of Students – End of Unit cumulative worksheet

Lesson Extensions – none

Attachments – none

Troubleshooting Tips – none

Safety Issues – none

Redirect URL – none

Key Words – Science, Technology, Engineering, Simple Machines, Gear, Screw, Wedge

Lesson Title – Pulleys

Summary – The class will talk about pulleys and how they are applied. They will then work on building small elevators. The class will learn how pulleys work, and how they are applied in the world around them.

Materials List –

1 Metal Coat hanger (supplied by students from home)

1 Small spool (thread spool will work) (supplied by students from home)

2 feet of string (approximately)

2 Box designs (made from Oak tag paper)

2 Metal Paperclips

Scissors

Tape/glue/glue sticks

Crayons/markers/colored pencils (for coloring the boxes if desired)

Pennies (of equal weight to what you want to lift)

Something to lift (like matchbox cars; anything that will fit in the boxes)

Introduction / Motivation – Demonstration of how pulleys operate through constructing one.

Procedure –

1. Have the students participate in a discussion involving the Beginning Wheel Axle and Pulleys Worksheet.
2. <u>Pulley Activity</u>
   a. Students will make two oak tag paper boxes from the template attached to this unit.
   b. Once the students have constructed their pulleys, hang the pulleys up so that the children can easily reach them, but so that the pulley is about 1.5 feet from the floor/desk. Have the students place objects of different weights into one side of the box. Have them then place pennies into the other box until the boxes are balanced.

Troubleshooting Tips – none

Safety Issues – Remind class of scissor safety rules.

Lesson Plan

Lesson Title – Pulleys

Grade Level – Second Grade

Lesson Time – One Hour

Instructional Mode – Independent Activity, Whole Class

Team/Group Size – Individual students and whole class

Summary – The class will talk about pulleys and how they are applied. They will then work on building small elevators. The class will learn how pulleys work, and how they are applied in the world around them.

Learning Objectives –

Technology/Engineering

02.SC.TE.04 Identify tools and simple machines used for a specific purpose.

Essential Questions – What are pulleys and how are they used in everyday life?

Introduction / Motivation – Demonstration of how pulleys operate through constructing one.

Procedure –

1. Have the students participate in a discussion involving the Beginning Wheel Axle and Pulleys Worksheet. The teacher should lead the discussion prompting students for ways to use an inclined plane to move the box up to the top of the cliff.

    Possible Questions:

    -How can we move the box?

    -Can we lift it up off the ground? (Students may suggest picking it up and hoisting it over their heads; they should be told that the cliff is too high)

    -Can we build something to move the box?

    -What would make it easier to pick the box up?

2. Pulley Activity

    c. Students will make two oak tag paper boxes by folding along the dotted lines and cutting along the solid lines of the template attached to this unit.

They should then use glue to hold the boxes together. Punch a hole on each side of the boxes on the circular marks.

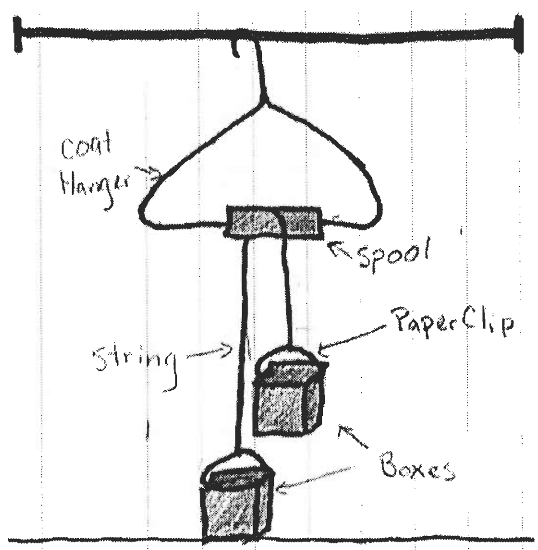
d. The two paperclips should be unfolded from the center. Put one paper clip through the two holes of each box.

e. The string should be tied around the center of each paper clip so that the two boxes are connected by the string.

f. Open the coat hanger at the top (children will need help with this).

g. The spool should be slid over the open coat hanger. The coat hanger must then be closed at the top again. The spool will rest at the bottom of the coat hanger.

h. Students will then place the string with the boxes over the spool. The pulley is now complete.



i. Once the students have constructed their pulleys, hang the pulleys up so that the children can easily reach them, but so that the pulley is about 1.5 feet from the floor/desk. Have the students place objects of different weights into one side of the box. Have them then place pennies into the other box until the boxes are balanced, meaning that neither moves rather than they are at equal heights.

Materials List (per class, per group and / or per student) –

1 Metal Coat hanger (supplied by students from home)

1 Small spool (thread spool will work) (supplied by students from home)

2 feet of string (approximately)

2 Box designs (made from Oak tag paper)

2 Metal Paperclips

Scissors

Tape/glue/glue sticks

Crayons/markers/colored pencils (for coloring the boxes if desired)

Pennies (of equal weight to what you want to lift)

Something to lift (like matchbox cars; anything that will fit in the boxes)

Vocabulary with Definition –

Pulley - a small wheel with a grooved rim used with a rope to help life heavy objects.

Assessment/Evaluation of Students – End of Unit cumulative worksheet.

Lesson Extensions – None

Attachments – Pulley Worksheet, Box Template

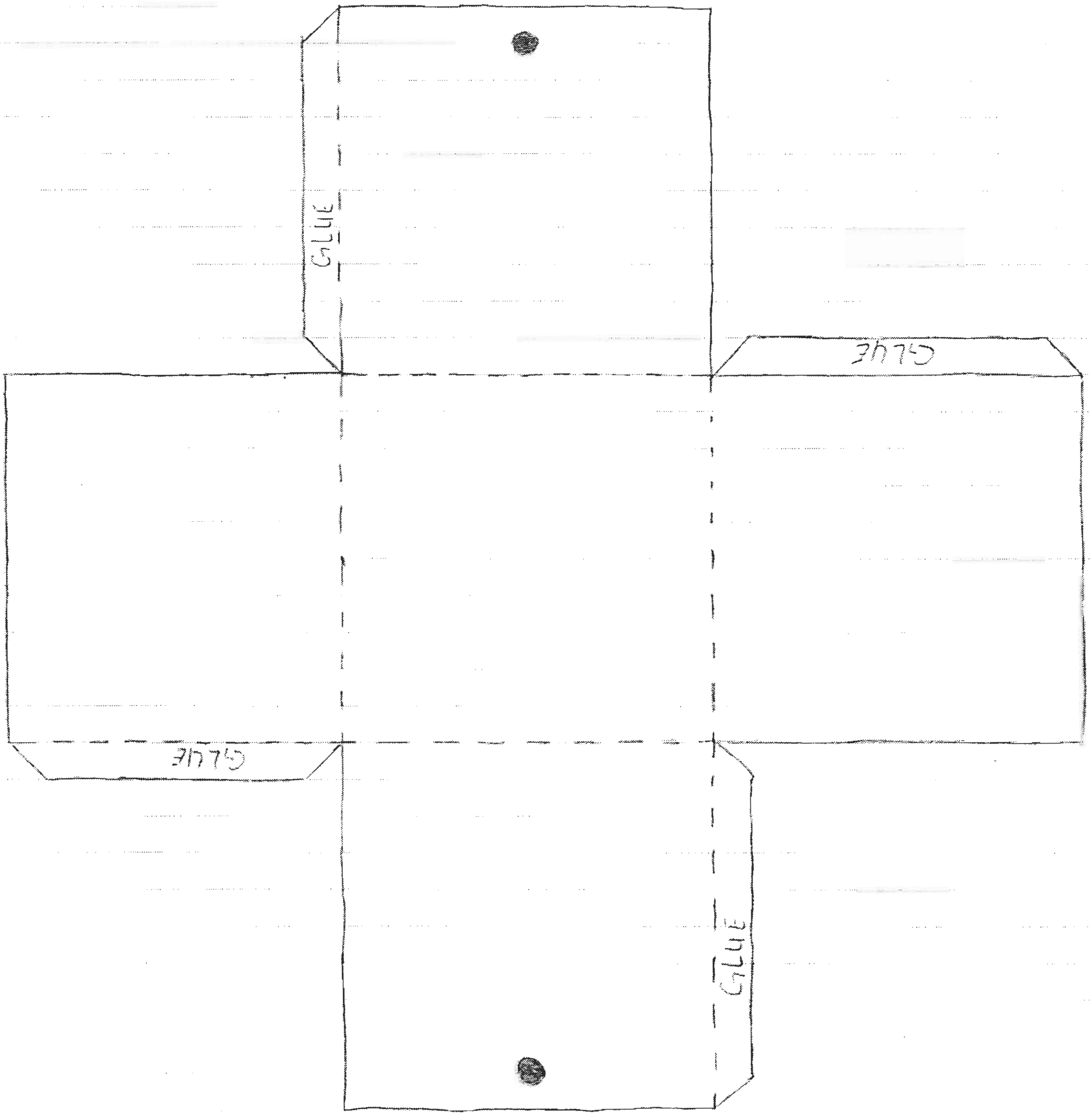
Troubleshooting Tips – None

Safety Issues – Remind class of scissor safety rules.

Redirect URL – None

Key Words – Pulley, Simple Machines

Pulley Box Template



Name: ______________________________________

Pulley Activity

Use your pulleys to weigh each object. Place the object in one box and the pennies in the other box. When the two boxes are at the same height, count the number of pennies in the box.

Object Name	Number of Pennies

Lesson Title – Simple Machines in the Playground

Summary –Everyday uses of simple machines will be discussed. The playground design activity will be completed. Discussion on simple machines in the playground will be done. Students will be evaluated on what was learned in the lesson.

Materials List –

- 1 piece of paper
- 1 writing utensil

Introduction / Motivation – Simple machines are used everyday by most people. The wheels as well as the gears in cars or bicycles get many people to school. When you cut a piece of paper you use scissors as a wedge. There are probably people enjoying the use of skateboards or roller skates right now. Even students use simple machines on a regular basis.

Procedure –

1. Introduce lesson as described above.
    - Ask students if there are any other simple machines they use everyday.
2. Separate students into groups and give them the handout.
3. Ask each student to draw what they think is the perfect playground.
4. Collect playgrounds sheets and display some of the students' playgrounds asking the whole class where the simple machines are.
5. Hand out evaluation worksheet.
6. Collect worksheet.

Troubleshooting Tips – none

Safety Issues – If lesson extension is used, make sure students do not use any part of the playground inappropriately.

Lesson Plan

Lesson Title – Simple Machines in the Playground

Grade Level – 2

Lesson Time – 60 minutes

Instructional Mode – Whole Class

Team/Group Size – 4 to 5

Summary – As one of the final lessons of the unit on simple machines, this lesson should help tie together what they have learned about simple machines so far and give the students some experience in looking for simple machines in the world around them. Everyday uses of simple machines will be discussed. The playground design activity will be completed. Discussion on simple machines in the playground will be done. Students will be evaluated on what was learned in the lesson.

Learning Objectives – Worcester Public Schools Benchmarks (WPS) for 2nd Grade:

Technology/Engineering

02.SC.TE.04 Identify tools and simple machines used for a specific purpose.

Skills of Inquiry – Students will…

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Essential Questions

- Why do simple machines make good toys?
- What toys in your playground use simple machines?
- How do the toys use simple machines?

Introduction / Motivation – Simple machines are used everyday by most people. The wheels as well as the gears in cars or bicycles get many people to school. When you cut a piece of paper you use scissors as a wedge. There are probably people enjoying the use of skateboards or roller skates right now. Even students use simple machines on a regular basis.

Procedure –

7. Introduce lesson as described above.
8. Ask students if there are any other simple machines they use everyday. Here is a list of things the students may come up with.

- Toothbrush – In addition to allowing you to reach inside your mouth in order to brush your teeth. The toothbrush acts as a lever by allowing you to push down on your teeth harder than you could if the brush had no handle.
- Handicap ramp into the school (if there is one) - This is an inclined plane that makes it easier for people in wheel chairs to get into schools.
- Lunch Box – Some lunchboxes have hinges on them that act as a wheel and axle. The pin is the axle that holds the wheels on and allows both sides of the box to swing freely.
- Car/Bicycle – Uses the wheel and axle as well as gears to make it easy to move.
- Scissors – Scissors act as a wedge in order to slice paper cleanly.
- Many toys use the wheel and axle. Many arms of toys can be considered levers. Some toys like matchbox car tracks have loops in them which can be seen as an inclined plane.

9. Separate students into groups and give them the handout.
10. Ask each student to draw what they think is the perfect playground. Moderate interaction is okay for this. Allow them to spend somewhere from 10 to 15 minutes on the activity.
11. Collect playgrounds sheets.
12. Display some of the students' playgrounds and ask whole class where the simple machines are. Refer to attachment to help with discussion. Continue this as long as time warrants. Students will undoubtedly put objects in their playground that are not simple machines, such as monkey bars. This is not bad. Commend the students on any creative playground innovation they have. Explain that some parts of the playground are not simple machines because they do not fit the definition of the any of the simple machines.
13. Hand out evaluation worksheet.
14. Collect worksheet.

Materials List (per class, per group and / or per student) –

- 1 piece of paper

- 1 writing utensil

Vocabulary with Definition –

Wedge: A wedge is a simple machine used to push two objects apart. A wedge is made up of two inclined planes. These planes meet and form a sharp edge. This edge can split things apart.

Screw: An inclined plane that winds around itself.

Gear: A simple machine used to shift motion to another object.

Assessment/Evaluation of Students – worksheet

Lesson Extensions – If desired and possible have demonstration in real playground and describe what simple machines are being used and how.

Attachments –

- Common perfect playground reference material
- Evaluation worksheet

Troubleshooting Tips – None

Safety Issues – If lesson extension is used, make sure students do not use any part of the playground inappropriately.

Redirect URL – None

Key Words – Gear, Incline, Plane, Lever, Pulley, Screw, Wheel, Axle, Simple Machine, Wedge

Common playground simple machines and ways they are used:

- **Slide** – An *inclined plane* connects ladder to the ground. It changes the motion of the user who, would otherwise fall, so that they glide smoothly to the ground. This is similar to the application in which an inclined is used to make it easier to move an object higher up. Pushing an object up an inclined plane can be much easier than simply lifting the object up.
- **See Saw** – A *lever* balances on an object. Because the lever is so large, it allows the users to easily push themselves up and down. Note that it could also be used if an object that weighed slightly less than the user was placed on one end of the see saw.
- **Shovel** – This would probably come with a sandbox. The end of the shovel is a *wedge* that pushes sand or dirt either down into the ground or up into the shovel. It is similar to the way an axe cuts wood, but the shovel does not need to be as sharp because it cuts through soft things like dirt. This could also be seen as an *inclined plane,* which allows the user to hold a larger amount of sand then they would be able to with their hands.
- **Zip Lines –** Use a *wheel and axle* attached to a line to allow the user to easily cover a large distance.
- **Roller coaster –** A rollercoaster can be seen as a bunch of *inclined planes* that are rounded off where they are connected. The inclined planes make it easy for the rollercoaster to move up and down. Roller coasters also have wheels that allow them to move easily along the inclined planes.
- **Ferris wheel –** A really large *wheel and axle*. The axle is supported by large structures that are strongly fixed to the ground.
- **Monkey bars** – Monkey bars are not simple machines. They can be more accurately as structures. Many modern playgrounds contain multiple structures, because children enjoy climbing and being high off the ground. Other structural playground parts are large steps, large tubes, sliding poles (like fire stations have), and small rock climbing walls.
- **Cars –** Some playgrounds have immobile cars or trains. Some have mobile wheels or steering wheels, which are examples of *wheel and axel*

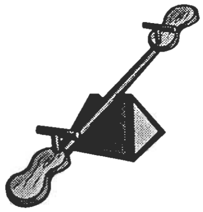
simple machines. Children may draw real cars which use *wheel and axels* in addition to *gears.*

- **Go-carts –** See Cars.
- **Ladder** – A ladder is like an *inclined plane* with steps in it. If it didn't have steps it would be more like a slide, which is very hard for a human to climb at steep angles.

Name ____________________________

Date ______________________________

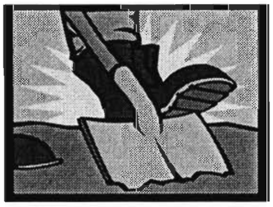
Directions: Match the part of the playground with the simple machine that it is similar to. Some answers can be used twice and some may not be used at all.

1. 

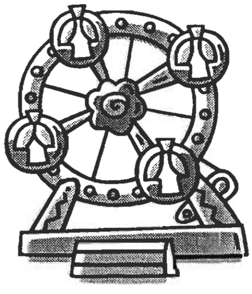
a.) Pulley

2. 

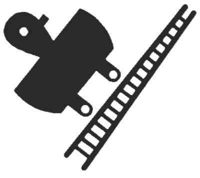
b.) Wedge

3. 

c) Inclined Plane

4. 

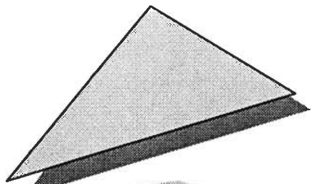
d.) Wheel and Axle

5. 

e.) Lever

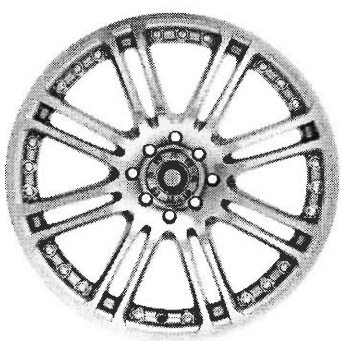
Answer Key: 1-e, 2-c, 3-b, 4-d, 5-c

Cumulative Worksheet



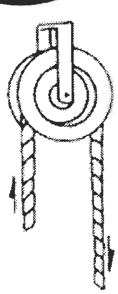
Screw

Wedge

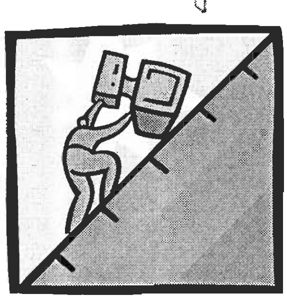


Lever

Pulley



Wheel and Axle



Inclined Plane

Cumulative Worksheet

This simple machine can be used to hold doors open by sliding one under the bottom of the door.______________

This simple machine is an inclined plane wrapped around a cylinder. ______________________________

This simple machine can be found on your bike and rollerblades and help you roll around. ____________________

This simple machine can be used to make elevators move or lift things off the ground. ______________

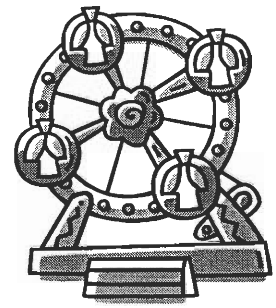
This simple machine is a flat surface that is tilted on an angle.

____

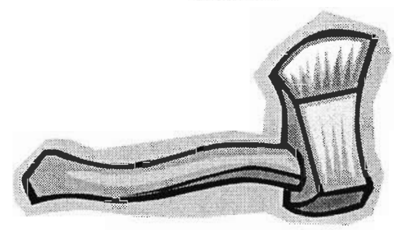
With this simple machine, we can lift up a heavy object off the ground with a pivot point, called the fulcrum. __________________

Cumulative Worksheet

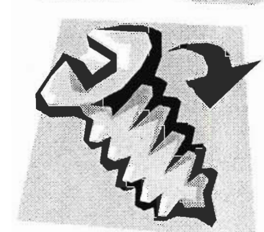
Screw



Wedge

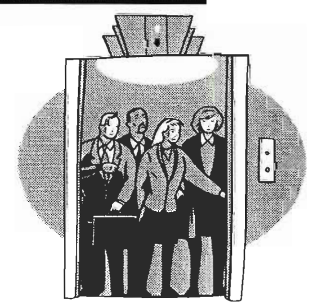


Lever



Pulley

Wheel and Axle



Inclined Plane

Unit Plan – Solids, Liquids, & Gases

Unit Title -- Solids, Liquids, Gasses

Grade Level -- Second

Unit Time – Four hours

Summary – Students will learn about energy levels in the states of matter and about uses for changes in matter states while watching demonstrations and engaging in creative activities.

Subject Area(s) – Engineering; Solids, Liquids, and Gases; Energy and Motion

Educational Standards –

Worcester Public School (WPS) Benchmarks –

Skills of Inquiry – Students will…

02.SC.IS.01 Ask questions about objects, organisms, and events in the environment.

02.SC.IS.02 Tell about why and what would happen if?

02.SC.IS.06 Discuss observations with others.

Additional Learning Objectives – none

Essential Questions –

What happens when water boils?

How can we use changes in the states of matter to help us?

Why does the salt stay behind?

What happens when water boils?

How can the higher energy of gasses be used by people?

What made the pinwheel spin when over the boiling water?

What will happen if we fill the plastic containers with water and freeze them?

What is the minimum amount of water that is needed to break the plastic containers when frozen?

What is the best type of container to use?

What observations can you see about each container?

What are the measurements of water in each container?

What will happen to the ice cream when it is exposed to higher temperatures?

How is ice cream like the water that we froze?

What would happen if we heat the ice cream up?

Lessons -- Evaporation and Condensation, Steam and Gas Energy, Melting and Freezing

Pre-Requisite Knowledge – Simple machines, states of matter, vague idea of energy

Vocabulary List – Boiling, Desalination, Dehydrated, Condensation, Energy, Generator, Turbine, Hypothesis

Summative Assessment/Evaluation – none

Unit Background and Concepts for Teacher – Simple machines, states of matter, vague idea of energy

Unit Extension Activities – none

Attachments – Energy level visual

Unit References – From Anne Marie Helmenstine, Ph.D., Your Guide to Chemistry http://chemistry.about.com/cs/howtos/a/aa020404a_p.htm

Comments –

Redirect URL –

Owner ID – WPI

Contributors – Calvin Chu, Chris Donoghue, Amanda Hines, Michael Raimondi

Key Words – Science, Technology, Engineering

Evaporation and Condensation ***and*** **Steam and Gas Energy**

Summary – As an entire class, students will watch water change from a liquid to a gas and back again while thinking about the possible practical uses of this. Students will then watch a brief experiment using steam as a source of energy and learn how it can make electricity through turbines and generators.

Materials-

Infinite water supply

Hot plate

A tea kettle

Tape

Saran wrap

3x 2-foot long ¼ inch dowels - Included with kit

Pinwheel - Included with kit

Procedure –

1. Prepare the pot filled with salt water or clean water and the plastic wrap tent.
2. Introduce the island scenario.
3. Discuss what happened during the experiments and why the salt was left behind.
4. Prepare the pot filled with clean water and the pinwheel.
5. Introduce the idea of generators and how they work.
6. Discuss what happened during the experiments and why the pinwheel spun.

Troubleshooting Tips – When working with heat sources and open flames, be sure that, should an accidental fire occur, it can be dealt with quickly and without harm to the students.

Lesson Plan

Lesson Title – Evaporation and Condensation

Grade Level – Second

Lesson Time – About one hour

Instructional Mode – Classroom demonstration and discussion.

Team/Group Size – Whole class

Summary – Students will watch water change from a liquid to a gas and back again and think about the potential practical uses of this.

Learning Objectives – Worcester Public Schools Benchmarks (WPS) for 2nd Grade:

Skills of Inquiry – Students will…

02.SC.IS.01 Ask questions about objects, organisms, and events in the environment.

02.SC.IS.02 Tell about why and what would happen if...

02.SC.IS.06 Discuss observations with others.

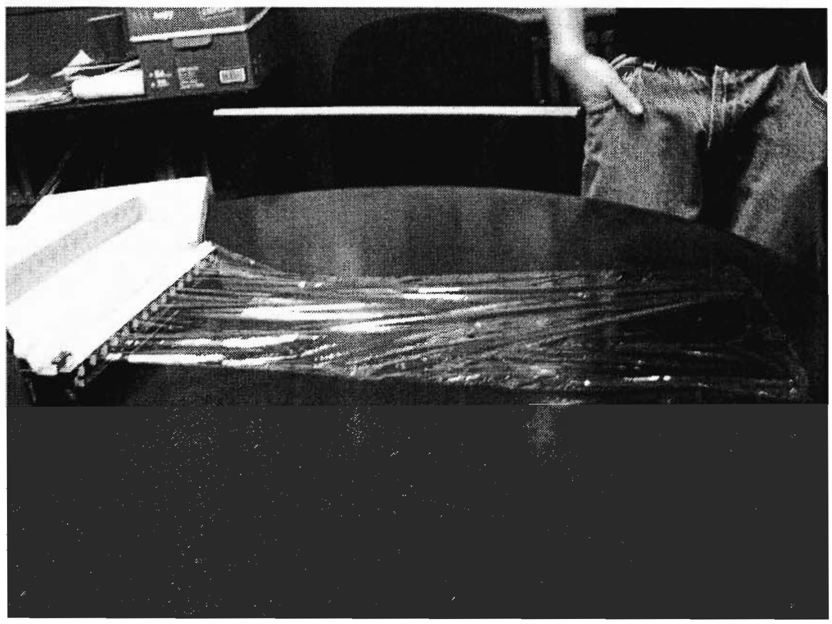
Essential Questions –

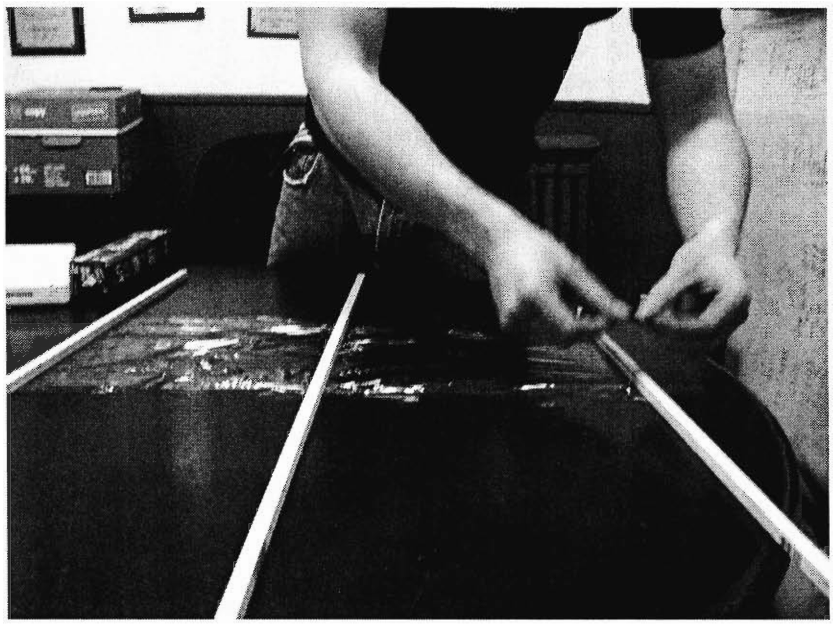
- What happens when water boils?
  - Energy is added to it in the form of heat and allows the liquid to become a gas.
- How can we use changes in the states of matter to help us?
  - It can separate out different materials, etc.
- Why does the salt stay behind?
  - It needs more energy to turn into a gas. It was a solid to begin with and would need to change to a liquid then a gas.

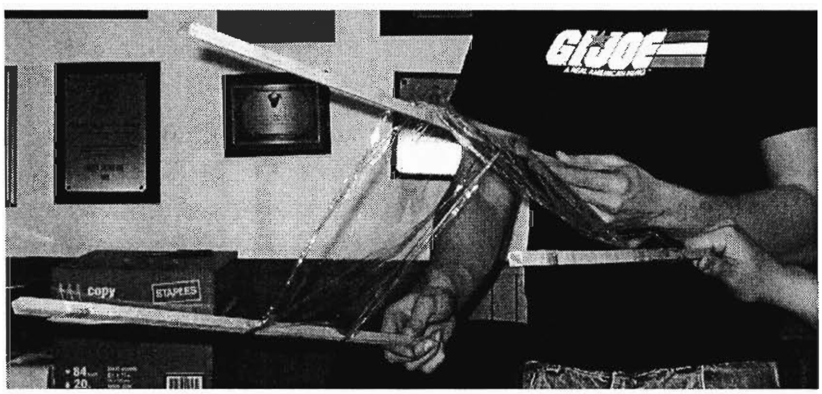
Introduction / Motivation – Water desalination experiment.

Procedure –

1. Before class, set up a pot of salty water, stirring it well enough that most of the salt is dissolved in the water. Create a tent from the saran wrap, dowels, and tape angling it toward the bowl.







2. Ask students to recall the states of matter. Ask how liquids can be turned into gasses. Ask if they know of any uses there could be of boiling a liquid to produce gas. Students may answer with “cooking, making cocoa, or ironing clothes.”
3. Now ask students to imagine their stranded on an island. There are some trees on the island, but no ponds or streams. The only water source is the salt water in the ocean. They can’t just drink the salt water because it tastes bad and they will become dehydrated, so they need to use engineering to find a way to remove the salt from the water. Ask if any of them have an idea of how to do it. Some students may say “filter it” or something to that effect. Try coaching them to an answer by telling them they could use changes in the states of matter, and eventually to boiling the sea-water.

4. Have the students move closer to the hot plate and the tent and pot, reminding them not to touch anything as they are hot and near enough the hot plate to catch fire if knocked over.
5. Start boiling the salty water, making sure that as steam begins to come out the saran wrap tent is positioned to catch as much steam as possible. Tell students to watch the wrap and observe what is happening to it. Ask if any of them can explain why it is doing that. Continue boiling the water until it has all evaporated. A white film of salt should remain in the pot. Explain that the water boiled off into steam and then condensed on the film. Ask them why they think the salt did not go with the water. Answers will probably include "the salt was too heavy" or "it got stuck to the pan."
6. Explain that the salt, which is a solid, would need to be much hotter to turn into a liquid state first then a gas state, so remained behind as the water turned into steam.

Materials List –

Infinite water supply
Hot plate
A cooking pot
Saran wrap
Pipe cleaners
Tape

Vocabulary with Definition –

- Boiling – The change in state from a liquid to a gas
- Desalination – Removing salt from water
- Dehydrated – The condition of the body when it has lost too much water
- Condensation – The change in state from a gas to a liquid
- Energy – The ability to do work, or the excited state of matter.

Assessment/Evaluation of Students – none

Lesson Extensions – none

Attachments – none

Troubleshooting Tips – none

Safety Issues – There is a risk of fire if something is knocked onto the hot plate. The pots will also become hot during this lesson, so students should not touch anything in front of them.

Redirect URL –

Key Words – Science, Technology, Engineering, Solids, Liquids, Gasses, Energy

Lesson Plan

Lesson Title – Steam and gas energy

Grade Level – Second

Lesson Time – About one hour

Instructional Mode – Classroom demonstration and discussion.

Team/Group Size – Whole class

Summary – Students will watch a brief experiment using steam as a source of energy and learn how it can make electricity through turbines and generators.

Learning Objectives – Worcester Public Schools Benchmarks (WPS) for 2nd Grade:

Skills of Inquiry – Students will…

02.SC.IS.01 Ask questions about objects, organisms, and events in the environment.

02.SC.IS.02 Tell about why and what would happen if...

02.SC.IS.06 Discuss observations with others.

Essential Questions –

- What happens when water boils?
  - Energy is added to it in the form of heat and allows the liquid to become a gas.
- How can the higher energy of gasses be used by people?
  - Fill balloons, make rockets, launch paintballs, etc.
- What made the pinwheel spin when over the boiling water?
  - The high energy of gases makes them move quickly to fill whatever container they are in.

Introduction / Motivation – Steam power experiment.

Procedure –

1. Fill the kettle with water and begin boiling it. When steam begins to come out, hold the pinwheel over the spout. The pinwheel should spin as the escaping water vapor leaves the pot. Ask students why they think this happens. Introduce the idea that different states of matter have different amounts of energy in them. Solids have the least while gasses the most.

2. Ask students if they can think of any useful purpose of the spinning action that the steam caused the pinwheel to make. If they are unfamiliar with how generators turn movement into electricity, explain that the steam could be used to move turbines that in turn power a generator to make electricity. Show the illustration of the turbine and ask what simple machine it resembles. They should respond "screw."
3. Ask them to keep energy in mind, but recall the desalination experiment. Ask them what heating the water did. Try to elicit the response that it added energy to the water. Then, ask them what happened after the steam hit the saran wrap. Try to get them to say that the steam lost some of its energy.

Materials List –

Water

Hot plate

Pinwheel

Tea kettle

Vocabulary with Definition –

- Boiling – The change in state from a liquid to a gas
- Energy – Energy – The ability to do work, or the excited state of matter.
- Generator – A machine that uses a spinning magnet to create electrical power
- Turbine – A screw that works like a propeller in reverse

Assessment/Evaluation of Students – none

Lesson Extensions – none

Attachments – Turbine illustration

Troubleshooting Tips – none

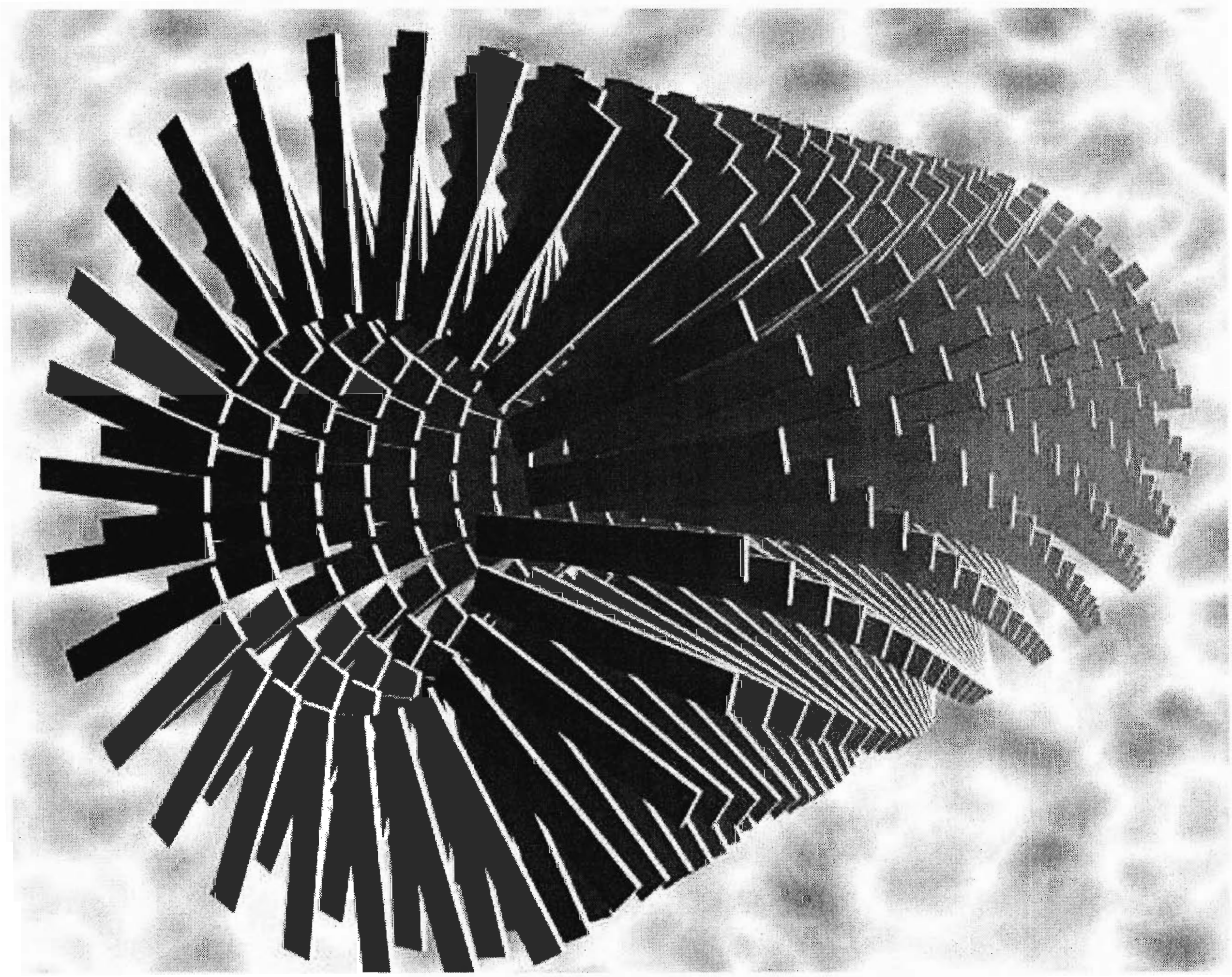
Safety Issues – There is a risk of fire if something is knocked onto the hot plate. The pot and kettle will also become hot during this lesson, so students should not touch anything in front of them.

Redirect URL –

Key Words – Science, Technology, Engineering, Solids, Liquids, Gasses, Energy

Does this remind you of a Simple Machine?

Which one?



Melting and freezing

Summary – As an entire class, they will estimate the effects of water freezing in plastic containers

Materials-

Five (5) 20 oz. water bottles

Infinite amount of water

Freezer

White board or large paper to record ideas and results

Procedure –

1. Discuss the stages and properties of water and give examples of water freezing.
2. Introduce the containers (water bottles) and ask about what the students think will happen if water was put into the bottles and then frozen.
3. Fill the bottles with 5 different amounts of water (be sure to make one fully filled and one fairly low in level) to put into 5 equally sized bottles that will be frozen overnight.
4. Record their hypotheses and ask them what they think will happen with each bottle of water and why.
5. The next day take out the bottles and show the students.
6. Discuss water freezing and what they thought would happen and what really happened. Then discuss why they think some bottles broke and some did not.

Troubleshooting Tips – Be aware that the ice will melt in the classroom so take proper precautions

Lesson Plan

Lesson Title – Melting and freezing

Grade Level – 2nd grade

Lesson Time – 2 days

Instructional Mode – Whole class activity and discussion, Group discussion and observation

Team/Group Size – Whole class/ Four-student groups

Summary – Students will estimate the effects of water freezing in plastic containers

Learning Objectives – reinforce ideas of taking measurements, design process

Essential Questions – What will happen if we fill the plastic containers with water and freeze them? What is the minimum amount of water that is needed to break the plastic containers when frozen? What is the best type of container to use? What observations can you see about each container? What are the measurements of water in each container?

Introduction / Motivation – Explain the properties and stages of water

Procedure –

1. Discuss the stages and properties of water and give examples of water freezing.
2. Introduce the containers (water bottles) and ask the students what they think will happen if water was put into the bottles and then frozen.
3. Then fill the bottles with 5 different amounts of water (be sure to make one fully filled and one fairly low in level) to put into 5 equally sized bottles that will be frozen overnight.
4. Take their hypotheses down and ask them what they think will happen with each bottle of water and why.
5. The next day take out the bottles and show the students.
6. Retouch the discussion about water freezing and what they thought would happen and what really happened.
7. Then discuss why they think some bottles broke and some did not.

Materials List (per class, per group and / or per student) – three water bottles per group, freezer,

Vocabulary with Definition –

Hypothesis – a guess.

Lesson Extensions – Ice cream lesson

Troubleshooting Tips –Be aware that the ice will melt in the classroom so take proper precautions

Melting and freezing pt. 2

Summary – Students, in the large group or in smaller groups, will analyze the properties of ice cream at each of its stages

Materials List (per student) --

- 1/2 cup milk
- 1/2 cup whipping cream (heavy cream)
- 1/4 cup sugar - Included with kit
- 1/4 teaspoon vanilla or vanilla flavoring (vanillin) - Included with kit
- 1/2 to 3/4 cup sodium chloride (NaCl) as table salt or rock salt - Included with kit
- 2 cups ice
- 1-quart Ziploc™ bag - Included with kit
- 1-gallon Ziploc™ bag - Included with kit
- thermometer
- measuring cups and spoons
- cups and spoons for eating your treat!

Procedure – http://chemistry.about.com/cs/howtos/a/aa020404a_p.htm

1. Add 1/4 cup sugar, 1/2 cup milk, 1/2 cup whipping cream, and 1/4 teaspoon vanilla to the quart Ziploc™ bag. Seal the bag securely.
2. Put 2 cups of ice into the gallon Ziploc™ bag.
3. Use a thermometer to measure and record the temperature of the ice in the gallon bag.
4. Add 1/2 to 3/4 cup salt (sodium chloride) to the bag of ice.
5. Place the sealed quart bag inside the gallon bag of ice and salt. Seal the gallon bag securely.
6. Gently rock the gallon bag from side to side. It's best to hold it by the top seal or to have gloves or a cloth between the bag and your hands because the bag will be cold enough to damage your skin.
7. Continue to rock the bag for 10-15 minutes or until the contents of the quart bag have solidified into ice cream.
8. Open the gallon bag and use the thermometer to measure and record the temperature of the ice/salt mixture.
9. Remove the quart bag, open it, serve the contents into cups with spoons and ENJOY! "

Conduct discussion about the ice cream and what caused it to melt. Then discuss possible discussion questions:

- What will happen to the ice cream when it is exposed to higher temperatures?
- How is ice cream like the water that we froze?
- What would happen if we heat the ice cream up?

Troubleshooting Tips – this lesson will be messy. Make sure to conduct it in an area that can be easily cleaned or use some type of cover on the area that can be cleaned or thrown away.

Safety Issues – students may have food allergies or sensitivity to certain foods.

Lesson Plan

Lesson Title – Melting and freezing

Grade Level – 2nd grade

Lesson Time – 2 days

Instructional Mode – groups /large group

Team/Group Size – 4-5 students per group

Summary – Students will analyze the properties of ice cream at each of its stages
Learning Objectives – reinforce ideas of taking measurements, design process

Essential/ Discussion Questions – What will happen to the ice cream when it is exposed to higher temperatures? How is ice cream like the water that we froze? What would happen if we heat the ice cream up?

Introduction / Motivation –Tell them they're going to make ice cream!

Materials List (per student) --

- 1/2 cup milk
- 1/2 cup whipping cream (heavy cream)
- 1/4 cup sugar
- 1/4 teaspoon vanilla or vanilla flavoring (vanillin)
- 1/2 to 3/4 cup sodium chloride (NaCl) as table salt or rock salt
- 2 cups ice
- 1-quart Ziploc™ bag
- 1-gallon Ziploc™ bag
- thermometer
- measuring cups and spoons
- cups and spoons for eating your treat!

Procedure – http://chemistry.about.com/cs/howtos/a/aa020404a_p.htm

"Make Ice Cream in a Baggie

From Anne Marie Helmenstine, Ph.D., Your Guide to Chemistry.

Freezing Point Depression and Colligative Properties

1. Add 1/4 cup sugar, 1/2 cup milk, 1/2 cup whipping cream, and 1/4 teaspoon vanilla to the quart Ziploc™ bag. Seal the bag securely.
2. Put 2 cups of ice into the gallon Ziploc™ bag.

3. Use a thermometer to measure and record the temperature of the ice in the gallon bag.
4. Add 1/2 to 3/4 cup salt (sodium chloride) to the bag of ice.
5. Place the sealed quart bag inside the gallon bag of ice and salt. Seal the gallon bag securely.
6. Gently rock the gallon bag from side to side. It's best to hold it by the top seal or to have gloves or a cloth between the bag and your hands because the bag will be cold enough to damage your skin.
7. Continue to rock the bag for 10-15 minutes or until the contents of the quart bag have solidified into ice cream.
8. Open the gallon bag and use the thermometer to measure and record the temperature of the ice/salt mixture.
9. Remove the quart bag, open it, serve the contents into cups with spoons and ENJOY! "

Conduct discussion about the ice cream and what caused it to melt. Then discuss and enjoy the results. See essential questions for possible topics to discuss.

Vocabulary with Definition –

Troubleshooting Tips – this lesson will be messy. Make sure to conduct it in an area that can be easily cleaned or use some type of cover on the area that can be cleaned or thrown away.

Safety Issues – students may have food allergies

Redirect URL – http://chemistry.about.com/cs/howtos/a/aa020404a_p.htm

Unit Plan – Historic Toys

Unit Title -- Historic Toys

Grade Level -- Second Grade

Unit Time -- Three hours

Summary – This unit will relate some simple toys to previous lessons about balance and motion, forces, and simple machines.
Subject Area(s) – Push/pull, balance, motion, design process

Educational Standards –

Worcester Public School (WPS) Benchmarks –

Skills of Inquiry – Students will…

02.SC.IS.01 - Ask questions about events in the environment.

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Physical Science – Students will…

02.SC.PS.01 – Recognize that under some conditions, objects can be balanced.

Additional Learning Objectives – none

Essential Questions – What forces affect an airplane as it flies? What properties make an airplane fly longer? What push and pull forces are moving the cup and ball?
How would you use the engineering design to make a better cup and ball?

Lessons –

1. Paper airplane endurance contest.
2. Cup and ball.

Pre-Requisite Knowledge – Push/Pull, Balance, Measuring

Vocabulary List – Force, Balance, Gravity, Lift, Drag, Thrust, Properties

Summative Assessment/Evaluation – none

Unit Background and Concepts for Teacher – Forces, lift, drag, thrust.

Unit Extension Activities –

Attachments – Diagram of forces on an airplane, Cup and Ball Activity

Unit References –

- http://science.uniserve.edu.au/school/curric/k_6/toys.html
- http://www.grc.nasa.gov/WWW/K-12/airplane/forces.html

Comments -- none

Redirect URL – none

Owner ID – WPI

Contributors – Calvin Chu, Chris Donoghue, Amanda Hines, Michael Raimondi
Key Words – Science, Technology, Engineering

Lesson Plan

Lesson Title – Historical Toys – Paper Airplane Competition

Grade Level – 2nd Grade

Lesson Time – One hour of class time

Instructional Mode – Individual and group experiment and discussion

Team/Group Size – Individual design. Discussion with two to five students.

Summary – Students will utilize the design process to create a paper airplane that stays in the air the longest.

Learning Objectives –

Worcester Public School (WPS) Benchmarks –

Skills of Inquiry – Students will…

02.SC.IS.01 - Ask questions about events in the environment.

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Essential Questions – What forces affect an airplane in flight? What properties make the plane stay in flight longer? How can designs be improved to make the planes fly longer? What keeps an airplane up? What brings an airplane down?

Introduction / Motivation – Have the students sit silently for twenty-eight seconds. When the time has passed, ask them if they could make a paper airplane stay in the air for that long. Inform them that Ken Blackburn holds the world record for level paper airplane flight at 27.6 seconds.

Procedure –

1. Show students a diagram illustrating the forces that act on an airplane in flight. Describe the effect and source of lift, drag, thrust, and gravity on the airplane.

    Gravity – A downward pull from the Earth, keeps you on the ground.

    Lift – The force created by an airplane's wings to make it lift into the air.

    Drag – The force of non-moving air pushing against a moving object.

    Thrust – The pushing force from engines that makes an airplane move forward.

2. Ask students what characteristics they think will produce the longest flying airplane. Offering solutions at this point is not necessary. Students may respond with gravity
3. Pass a piece of paper to every student and ask them to use the design process and make a paper airplane that will stay in the air for as long as possible.
4. Divide the classroom into small groups of 3 – 5 children. Have the children each test their design by standing in one corner of the room or in a hallway or gymnasium and giving the plane a gentle push to make it soar as long or far as possible. Use a stopwatch and a consistent time keeper to measure the flight time. Use yard sticks, a measuring tape, or the number of tiles covered on the floor to determine which airplane flew the farthest.
5. Have each student write their name on a chart listing the numbers 1 through 50 for feet or 1 through 100 for tiles, placing their name at the largest integer interval their airplane covered. For example, if using tiles and the airplane lands ten and one half tiles away, have that student place their airplane at the tenth tile. If using yard sticks to measure, place the airplane at the closest foot or yard to where it landed. If multiple airplanes land the same distance from the throwing spot, they should be placed side by side to show students what the most frequent distance the planes traveled and illustrate how longer flying designs are different.
6. After all the planes have been tested, have the students return to their seats for a discussion with fellow students about what properties they thought made the planes fly the longest. Ask students with the farthest or longest flying airplanes to stand show the entire class their planes.
7. In a class discussion, try to get the students to name some properties that will make a plane fly longer. Have them compare the designs that flew the farthest to their own and note differences. Some appropriate responses should include big wing surfaces, thick fronts, and vertical surfaces for stability, balanced or symmetrical sides, and back-swept wings. Ask students why they think these properties make the plane fly longer (more lift, balance, and less drag). Coach

the students to these answers with comments referencing the features of airplane wings and bodies, fast cars, or animals.

8. Pass a new piece of paper to each student and ask them to use the design process to either improve their design or create a new design based on the ideas from the discussion to make their plane stay in the air the longest.
9. Test each airplane in the same manner as in Step 4. Determine which airplane stayed in the air the longest and which flew the farthest using a chart or table comparing changes made to the increase in distance or time flown.

Materials List –

- Paper. Lots of paper.
- Yard Sticks or measuring tape
- A stopwatch

Vocabulary with Definition –

Force – A push or a pull.

Gravity – A downward pull from the Earth, keeps you on the ground.

Lift – The force created by an airplane's wings to make it lift into the air.

Drag – The force of non-moving air pushing against a moving object.

Thrust – The pushing force from engines that makes an airplane move forward.

Properties – Traits or characteristics, things that can be observed about an object.

Assessment/Evaluation of Students – None

Lesson Extensions –

- **http://science.uniserve.edu.au/school/curric/k_6/toys.html**

Attachments – Diagram of forces on an airplane.

Troubleshooting Tips – If students do not know how to fold a paper airplane, it might be necessary to show them several design ideas that can be found on the internet.

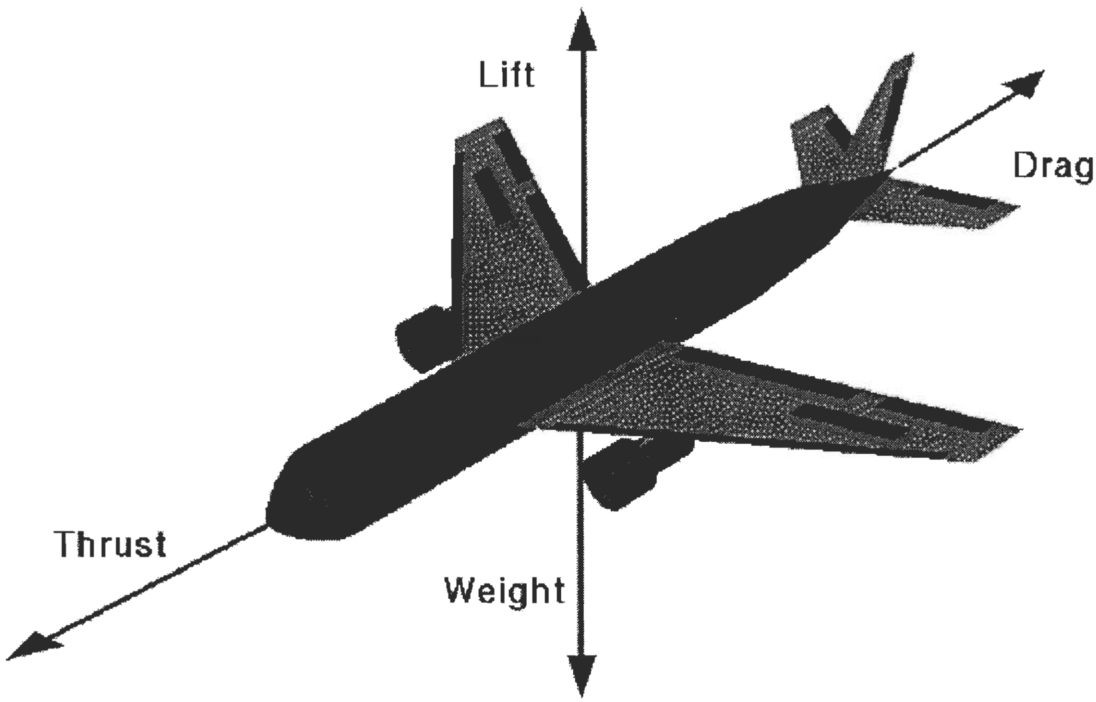
Safety Issues – Have students stand behind the thrower for every test flight. Being in front of them could lead to minor injuries or eye injuries.

Redirect URL – None

Key Words – Airplane, forces

Four Forces on an Airplane

Glenn Research Center



Courtesy of NASA

http://www.grc.nasa.gov/WWW/K-12/airplane/forces.html

Lesson Plan

Lesson Title – Cup and Ball Activity

Grade Level – Second Grade

Lesson Time – 1 Hour

Instructional Mode – Individual Activity with group discussion

Team/Group Size – Individual Student

Summary – The students will construct a Cup and Ball toy, a historic toy that was developed in many different parts of the world.

Learning Objectives – Learn about a historic toy that improves hand-eye coordination.

To strengthen the ideas about the engineering design and motion and forces.

Essential Questions – What push and pull forces are moving the cup and ball? What sized balls are easiest to get into the cup? Which are hardest? What sized string works best? What size is worst? How would you use the engineering design to make a better cup and ball?

Introduction / Motivation – They will make a historic toy and we will discuss motion and forces along with the engineering design and how it relates to this exercise.

Procedure – Have students complete the Cup and Ball activity. (Attached)

Materials List (per student) –

1 paper cup

String

1 ball that will fit into the cup with 2 holes

(Feel free to use various sized balls and sting to show how the properties of the ball may affect the ease to get it into the cup.)

Vocabulary with Definition –

Force: a push or a pull

Motion: movement of an object

Gravity: a downward pull, keeps you on the ground

Lever: a simple machine usually used to lift. Has a fulcrum. (in this case, the students' arms are levers and their elbows are fulcrums.)

Fulcrum: the pivot of a lever

Assessment/Evaluation of Students – None

Lesson Extensions – None

Attachments – Cup and Ball Activity

Troubleshooting Tips – Make sure that the children stay focused and do not hit each other with their cup and ball toys.

Safety Issues – Make sure the string length is safe and that balls stay away from children's eyes.

Redirect URL – None

Key Words – None

Cup and Ball Activity

History:

This game developed in many different parts of the world, including Japan, Europe, North America, and Mexico. It most likely developed from equipment that travelers carried with them. There is evidence that the game was played in the Royal Courts of Europe as well as on the streets.

How to Build Your Own:

Materials (per student)

1 paper cup
String
1 ball that will fit into the cup with 2 holes

Steps:

1. Punch two holes into the bottom of the cup.
2. Tie the string to the bottom of the cup so that the string comes out of out of middle of the cup.
3. Tie the string to the ball.

How to Play:

Hold the cup in one hand. Swing the ball upward. Try to catch the ball in the cup.

Now try it with a different ball, a different piece of string or both!

Unit Plan – Structures

Unit Title -- Structures

Grade Level -- Second Grade

Unit Time – 4 Hours

Summary – Students will learn about physical structures through hands-on exercises and group discussions.

Subject Area(s) – Structures, Science, Engineering and Technology

Educational Standards –

Worcester Public School (WPS) Benchmarks –

Skills of Inquiry – Students will…

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Technology/Engineering – Students will...

02.SC.TE.02 – Identify and explain some possible uses for natural materials and human-made materials.

02.SC.TE.03 – Identify and describe the safe and proper use of materials and tools to construct a simple structure.

Additional Learning Objectives – none

Essential Questions –What are the different properties of structures?

What jobs do they do?

What are structures made from?

Do properties of materials affect construction?

Which shapes are strongest?

How can you build a stronger structure with the same materials?

What shapes do you typically see in structures, especially bridges?

If your design did not work, what should you do next?

How can the design process be used to make a structure better?

Why did the strongest structure support the amount of weight it did?

Lessons -- Design Your Own Structure, 3 Little Structures, Designing Straw Structures

Pre-Requisite Knowledge – Push/Pull, Balance

Vocabulary List – Properties, Structure, Truss
Summative Assessment/Evaluation – None

Unit Background and Concepts for Teacher – Structures, trusses,

Unit Extension Activities – None

Attachments – Design Your Own Structure Worksheet, Bridge pictures, Truss Pictures

Unit References – none

Comments – none

Redirect URL – none

Owner ID – WPI

Contributors – Calvin Chu, Chris Donoghue, Amanda Hines, Michael Raimondi
Key Words – Science, Technology, Engineering

Lesson Title – Design Your Own Structure

Summary – The students will learn about structures, why they are made, and the different properties of different structures.

Materials List –

Worksheet (attached)

Colored Pencils/ Crayons

Introduction / Motivation – Review of the different properties of structures, the students will draw their structure.

Procedure –

1. Talk to the students about properties. Remind them about the different properties of solids.
2. Explain to the students that many structures are made from special types of solids in diverse patterns to do different things. Show them a picture of a bridge. Tell them that the bridge has to go across things like rivers, survive in different weather and hold up cars and trucks. Tell them that the bridges look different and that bridge one uses steel and cables, while bridge two only uses steel. Bridge one goes over larger areas than bridge two does. (bridge pictures are attached)
3. Ask the students what they notice about the two bridges, what they have in common, what is different.
4. Have the students complete the Design Your Own Structure Worksheet (attached).

Troubleshooting Tips – The student may be confused about the different properties of structures and solids.

Safety Issues – None

<u>**Lesson Plan**</u>

Lesson Title – Design Your Own Structure

Grade Level – Second Grade

Lesson Time – 1 Hour

Instructional Mode – Activity

Team/Group Size – 1 Student

Summary – The students will learn about structures, why they are made, and the different properties of different structures.

Learning Objectives –

<u>Skills of Inquiry</u> – Students will…

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

<u>Technology/Engineering</u> – Students will...

02.SC.TE.02 – Identify and explain some possible uses for natural materials and human-made materials.

02.SC.TE.03 – Identify and describe the safe and proper use of materials and tools to construct a simple structure.

Essential Questions –

- What are the different properties of structures?
    - The different properties of structures are the same as those of solids. They can be strong, flexible, have color, or smell
- What jobs do they do?
    - Structures are around us everywhere. Even the school building and your body are structures. They are bridges to let people cross rivers, or keep the rain off of our heads.
- What are structures made from?
    - Structures are usually made from solids in different shapes.

Introduction / Motivation – Review of the different properties of structures, the students will draw their structure.

Procedure –

1. Talk to the students about properties. Remind them about the different properties of solids.
2. Explain to the students that many structures are made from special types of solids in diverse patterns to do different things. Show them a picture of a bridge. Tell them that the bridge has to go across things like rivers, survive in different weather and hold up cars and trucks. Tell them that the bridges look different and that bridge one uses steel and cables, while bridge two only uses steel. Bridge one goes over larger areas than bridge two does. (bridge pictures are attached)
3. Ask the students what they notice about the two bridges, what they have in common, what is different.
4. Have the students complete the Design Your Own Structure Worksheet (attached).

Materials List (per class, per group and / or per student) –

Worksheet (attached)

Colored Pencils/ Crayons (to be provided by the teacher

Vocabulary with Definition –

Properties- a special quality of something (sweetness is a property of sugar)

Structure- something constructed

Assessment/Evaluation of Students – Worksheet

Lesson Extensions – None

Attachments – Design Your Own Structure Worksheet, two bridge pictures

Troubleshooting Tips – The student may be confused about the different properties of structure and solids. Have an introductory lesson on solids and structures first.

Safety Issues – None

Redirect URL – None

Key Words – properties, structure

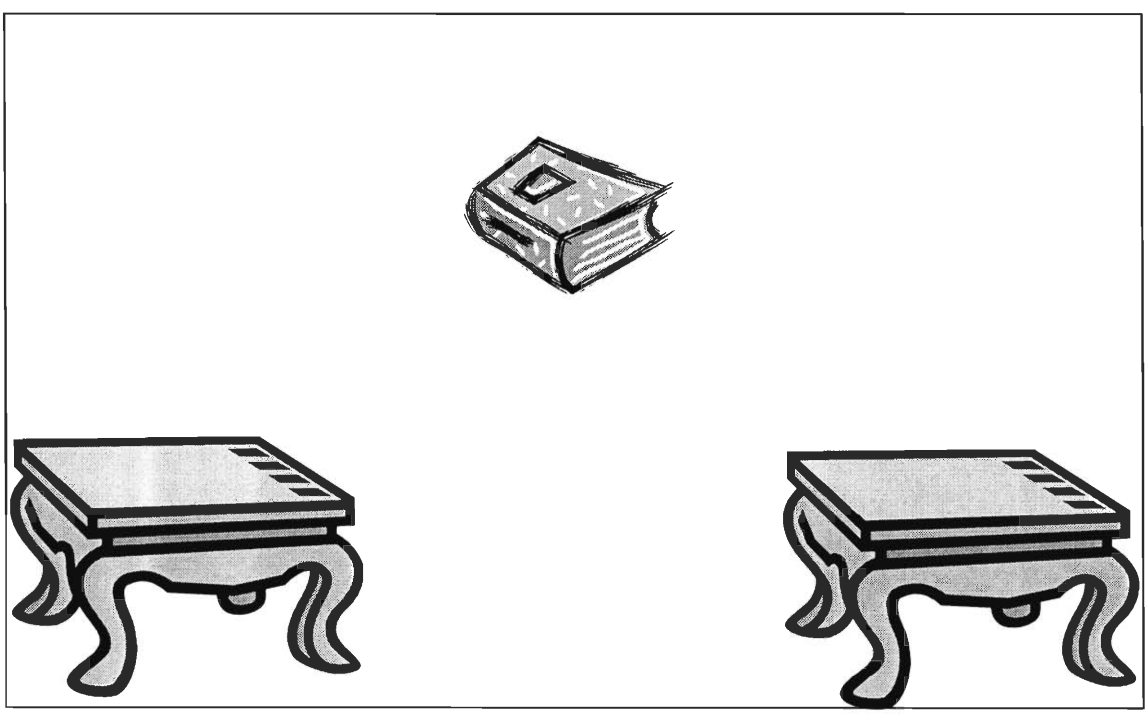
Design Your Own Structure

Name:_______________________________________

Mary wants to place a book between the two tables. She knows that she needs a structure, but she does not know what properties the structure needs. Can you help Mary?

What properties does your structure have? What is it made of? What shape is it?

Draw Your Bridge.



Roebling Suspension Bridge

Walking Bridge

Lesson Title – 3 Little Structures

Summary – As a whole class, students will observe the importance and difference of materials of construction.

Materials List –

“Wind” Mechanisms like hair dryers or fans.

Straws

Toothpicks

Lego’s

Introduction / Motivation – Either reintroduce or reread the story of the three little pigs to the students.

Procedure –

Have the students break into three groups. Assign each group to a material what its going to build a tower (with sticks, straws & Legos). Have each group record what they think will happen with their individual structure, then have the students state what they think will happen with the other types of material.

Have the students design and assemble structures out of “straw” (Straws), “wood” (Toothpicks) and “bricks” (Legos).

Then after the students have finished, you will test their designs against the different types of wind. You could use a fan, hair dryer or have the students try to blow the structures down. The point is to have a range of strengths of wind, from gentle to strong and to have as many structures fall over so that the students are aware of which material is best to build with.

After all the structures have been tested, revisit guesses and discuss the results. Touch upon which materials worked best and why.

Troubleshooting Tips – Try to keep the students focused on building a proper structure as they may want to build something else. Also, building structures with straws and toothpicks may be difficult so the groups dealing with those materials may need some extra attention. You will probably want to make the straws into triangles or squares so that they can stack better.

Safety Issues – Misuse of materials maybe an issue.

Lesson Plan

Lesson Title – 3 Little Structures

Grade Level – Second

Lesson Time – 1+ hour

Instructional Mode – Whole Class Discussion then Group Work

Team/Group Size – Whole Class then Groups of 4 or 5

Summary – Students will observe the importance and difference of materials of construction.

Learning Objectives –

Skills of Inquiry – Students will…

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Technology/Engineering – Students will...

02.SC.TE.02 – Identify and explain some possible uses for natural materials and human-made materials.

02.SC.TE.03 – Identify and describe the safe and proper use of materials and tools to construct a simple structure.

Essential Questions – Do properties of materials affect construction? [Yes]

Introduction / Motivation – Either reintroduce or reread the story of the three little pigs to the students.

Procedure –

Have the students break into three groups. Assign each group to a material what its going to build a tower (with sticks, straws & Legos). Have each group record what they think will happen with their individual structure, then have the students state what they think will happen with the other types of material.

Have the students design and assemble structures out of "straw" (Straws), "wood" (Toothpicks) and "bricks" (Legos).

Then after the students have finished, you will test their designs against the different types of wind. You could use a fan, hair dryer or have the students try to blow the structures down. The point is to have a range of strengths of wind, from gentle to strong and to have as many structures fall over so that the students are aware of which material is best to build with.

After all the structures have been tested, revisit guesses and discuss the results. Touch upon which materials worked best and why.

Materials List –

“Wind” Mechanisms like hair dryers or fans.

Straws

Toothpicks

Lego’s

Troubleshooting Tips – Try to keep the students focused on building a proper structure as they may want to build something else. Also, building structures with straws and toothpicks may be difficult so the groups dealing with those materials may need some extra attention. You will probably want to make the straws into triangles or squares so that they can stack better.

Safety Issues – Misuse of materials maybe an issue.

Redirect URL –

Lesson Title – Designing Straw Structures

Summary – Students will plan the construction of a structure that must hold a certain weight and use a specified amount of materials. Then students will actually build their structure and test it to see if it will support the required weight. A discussion of which designs worked and which did not will take place and students will be asked to think about improvements at home. Next, students will redesign their structures the following day using the ideas discussed in class and their ideas from home to try to design the strongest structure they can from the same materials.

Materials List –

3 rolls of pennies

Enough drinking straws to give 15 to each pair of students

1 roll of masking tape

1 foot-long piece of string

1 paper clip

Introduction / Motivation – Show the students some pictures of truss bridges, oil rigs, or radio towers and ask them what they have in common. Ask the students why they think the structures were designed the ways they were.

Procedure –

1. Prepare for this lesson by taping together the three rolls of pennies and a piece of string. Bend a paper clip so that it can act as a hook over the straws.
2. Divide students into pairs or groups of three and ask them to try to come up with a design that will support the weight of the pennies hanging from their structure using fifteen drinking straws and tape.
3. Offer some ideas or assistance as they try to come up with designs and try to make sure that all ideas are heard, no dictators.
4. When it seems as though all the groups have designs they are going to utilize give each group fifteen drinking straws and about four feet of masking tape.
5. Allow them to begin construction of their structures.
6. As soon as all the groups finish, begin testing their structures.
7. Start a class discussion about what the students observed about the strongest structures, shapes, height, size of the base of the structure.
8. Tell students that the lesson will be continued the next day, but to go home and think about how to make a stronger structure from the same materials, taking into consideration the things discussed in class and full-size structures they have seen.

Troubleshooting Tips – Try to keep the students focused on building a proper structure as they may want to build something else. Try to keep the activity a group effort.

Safety Issues – Misuse of materials maybe an issue.

Lesson Plan

Lesson Title – Designing Straw Structures

Grade Level – Second

Lesson Time – Two one hour class periods

Instructional Mode – Group exploration, discussion, and design exercise.

Team/Group Size – Small groups of two to three students.

Summary – Students will plan the construction of a structure that must hold a certain weight and use a specified amount of materials. Then students will actually build their structure and test it to see if it will support the required weight. A discussion of which designs worked and which did not will take place and students will be asked to think about improvements at home. Next, students will redesign their structures the following day using the ideas discussed in class and their ideas from home to try to design the strongest structure they can from the same materials.

Learning Objectives –

Skills of Inquiry – Students will…

02.SC.IS.02 - Tell about why and what would happen if..?

02.SC.IS.03 - Make predictions based on observed patterns.

Technology/Engineering – Students will...

02.SC.TE.02 – Identify and explain some possible uses for natural materials and human-made materials.

02.SC.TE.03 – Identify and describe the safe and proper use of materials and tools to construct a simple structure.

Essential Questions –

- Which shapes are strongest?
    - Triangles will be best here, but domes are strong as well, if any of the students can make one.
- How can you build a stronger structure with the same materials?
    - Make the structure lower, thicker, or incorporate stronger shapes.
- What shapes do you typically see in structures, especially bridges?
    - Triangles, domes, and rectangles.

- If your design did not work, what should you do next?
  - Look at the engineering design process to find ways to improve your design.
- How can the design process be used to make a structure better?
  - Identify the problem, research the problem, develop ideas, select the best idea, build and test again.
- Why did the strongest structure support the amount of weight it did?
  - It should be stout, sturdy, and use the strongest shapes.

Introduction / Motivation – Show the students some pictures of truss bridges, oil rigs, or radio towers and ask them what they have in common. Ask the students why they think the structures were designed the ways they were.

Procedure –

1. Prepare for this lesson by taping together the three rolls of pennies and a piece of string. Bend a paper clip so that it can act as a hook over the straws.
2. Divide students into pairs or groups of three and ask them to try to come up with a design that will support the weight of the pennies (about one and a half pounds) hanging from their structure using fifteen drinking straws and tape, emphasizing that it is a group effort.
3. Offer some ideas or assistance as they try to come up with designs and try to make sure that all ideas are heard, no dictators.
4. When it seems as though all the groups have designs they are going to utilize give each group fifteen drinking straws and about four feet of masking tape.
5. Allow them to begin construction of their structures, offering help or suggestions when it appears as though a group is struggling.
6. As soon as all the groups finish, begin testing their structures. Hang the weights from whichever point the students in the group choose and see if it will support the weight. Test the next group in the same manner until each group has had their design tested.
7. Start a class discussion about what the students observed about the strongest structures, shapes, height, size of the base of the structure.

8. Tell students that the lesson will be continued the next day, but to go home and think about how to make a stronger structure from the same materials, taking into consideration the things discussed in class and full-size structures they have seen.
9. When continuing the lesson, have students again meet in their pairs or groups and discuss the ideas they have come up with since the previous day.
10. Again, have each group decide on a design and give them the materials to build their structure.
11. When all the structures are finished, use the cup to again test the structures, this time adding more and more weight until the structure breaks. Hold a final discussion of what design aspects made the strongest structure.

Materials List –

3 rolls of pennies

Enough drinking straws to give 15 to each pair of students

1 roll of masking tape

1 foot-long piece of string

1 paper clip

Vocabulary with Definition –

Truss - A structural framework that is made up of individual beams fastened together in a triangular shape.

Assessment/Evaluation of Students – none

Lesson Extensions – none

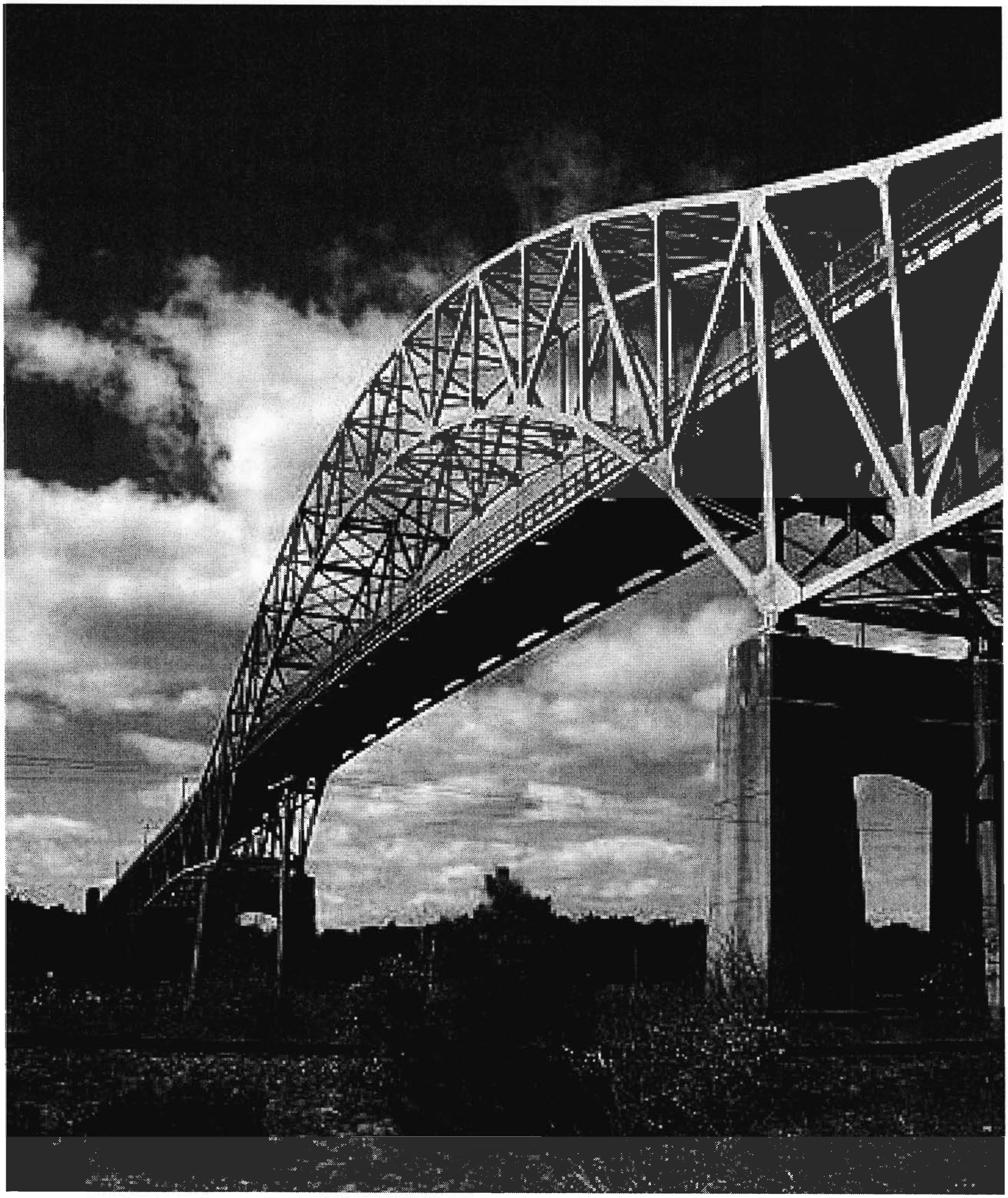
Attachments – Structure pictures

Troubleshooting Tips – Try to keep the students focused on building a proper structure as they may want to build something else. Try to keep the activity a group effort.

Safety Issues -- Misuse of materials maybe an issue.

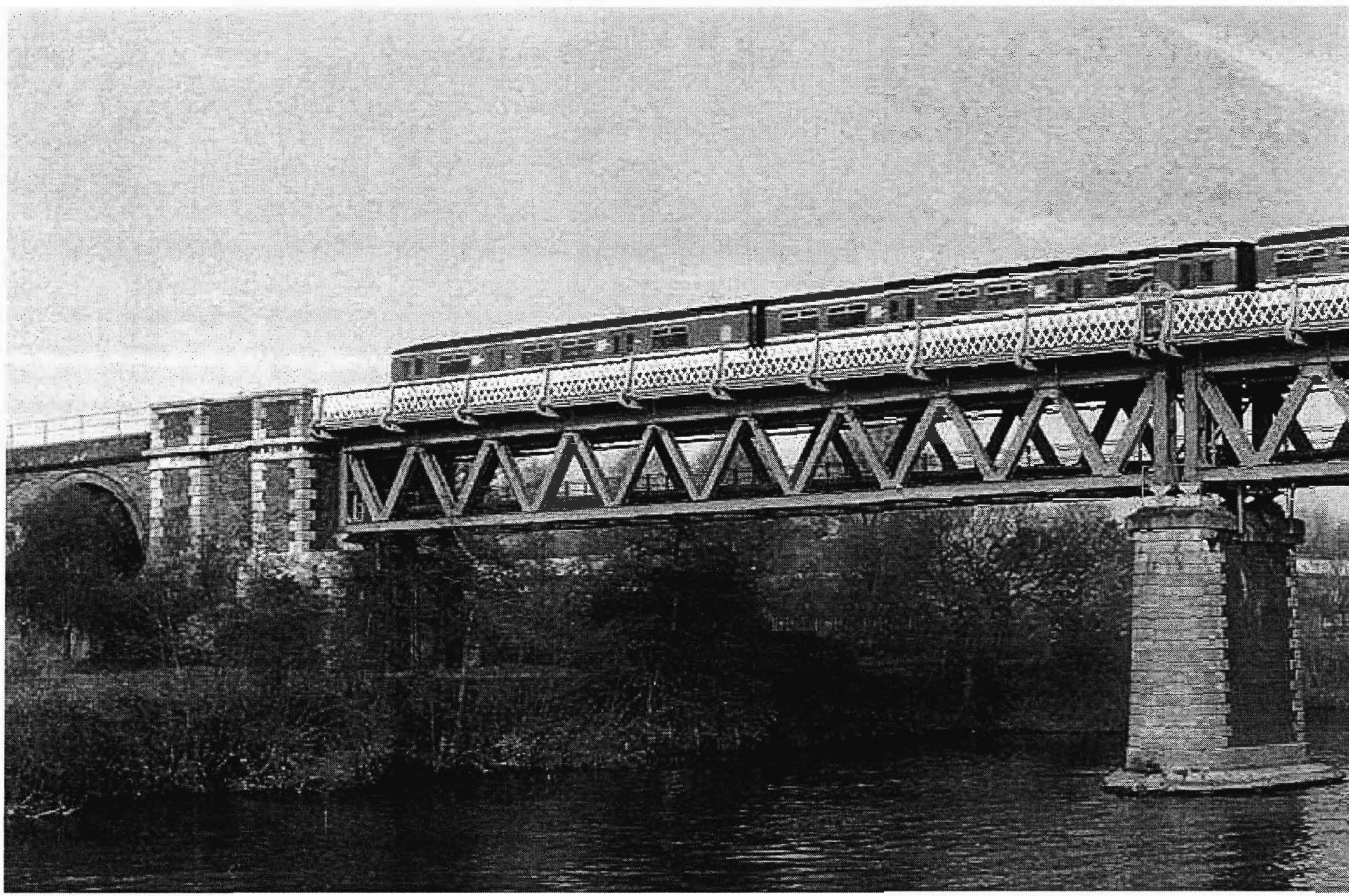
Redirect URL – none

Key Words – Science, Technology, Engineering



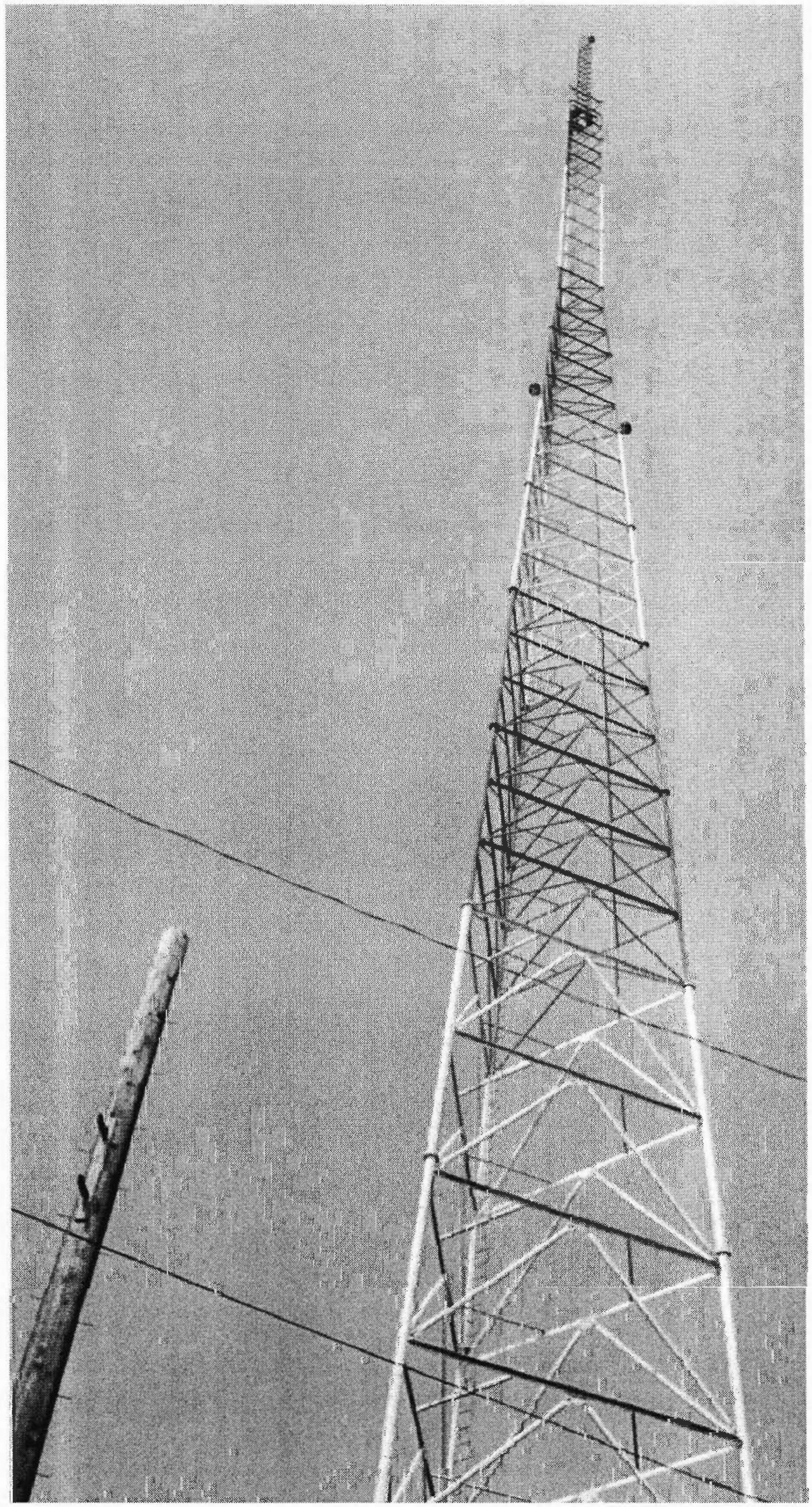
The Bourne Bridge

A Truss Bridge for Trains



A Truss Bridge for Trains

A Tower Crane



A Radio Tower

Appendix C - Bulletin Boards

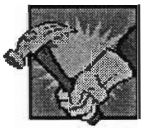
Carpentry Tools

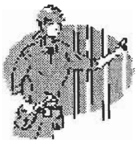
Carpentry Tools

Simple and complex machines

Hammer

- A hammer is a simple tool.
- A hammer can be used with nails to nail things like wood boards together.
- A hammer and your arm form a **lever**.
- A **lever** is a simple machine.





Drill

- A drill is a complex machine.
- Drills are made of many simple machines like **inclined planes** and **gears**.
- Drills make holes in things like wood.

Saw

- A saw is a simple machine.
- A saw is a **wedge**.
- Saws can cut things like trees and boards.

Axe

- An axe is a simple machine.
- An axe is a **wedge**.
- An axe and your arm form a **lever**.
- Axes can chop things.
- Lumberjacks used axes to cut down trees.

Wheelbarrow

- A wheelbarrow is a complex machine.
- A wheelbarrow is made from many simple machines like **wheels**, **axles**, and **levers**.
- Wheelbarrows are used to move heavy objects.

Lesson Plan

Lesson Title – Carpentry Tools Bulletin Board

Grade Level – Second Grade

Lesson Time – One Month

Instructional Mode – Bulletin Board

Team/Group Size – None

Summary – A bulletin board with pictures and descriptions of what carpentry tools are and what they do.

Learning Objectives –

Technology/Engineering

02.SC.TE.04 – Identify tools and simple machines used for a specific purpose.

Essential Questions – What do carpentry tools do?

Introduction / Motivation – Invite students to study the bulletin board during lunch or snack times.

Procedure –

1) Put up bulletin board
2) Discuss the tools with the class

Materials List (per class, per group and / or per student) –

Sheets (attached)

Vocabulary with Definition –

Hammer- A tool with a hard head with a handle designed for pounding

Drill- A tool for making holes in hard materials

Saw- A tool for cutting materials

Axe- A tool for splitting materials

Wheelbarrow- A tool for moving objects horizontally

Assessment/Evaluation of Students –

Lesson Extensions – None

Attachments – Bulletin Board sheets

Troubleshooting Tips – None

Safety Issues – None

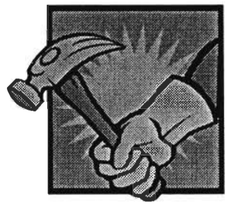
Redirect URL – None

Key Words – hammer, drill, saw, axe, wheelbarrow

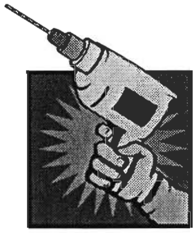
Name ______________________________

Date ______________________________

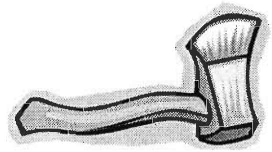
Directions: Match the carpentry tool with the simple machine that it uses to do work.

1. 

A. Wedge

2. 

B. Lever

3. 

C. Inclined Plane

4. 

D. Wheel and Axle

1 – B: the bulletin board describes the hammer used with the arm as a lever. Because of the length of the shaft of the hammer and the length of a persons arm, the user can swing the head of the hammer with much more force than they could without wither of them. Imagine using a hammer without a shaft on it. It would be difficult to swing it with enough force to hammer in a nail.

2 – C: This is probably the most difficult problem in the sheet as it is the most difficult to imagine. The bulletin board describes the drill as a tool that is made of many simple machines like the inclined plane and gears. The inclined plane is the most obvious simple machine used. The tip of the drill is like an inclined plane that is wrapped around a piece of metal. When this inclined plane spins it moves pieces of wood up the edge.

3 – A: The axe is used to split wood. Splitting things is the primary function of the wedge. The axe is also described as a lever in the bulletin board as the shaft of the axe allows the user to swing it with much more force than you would without it. However the primary function is to split things.

4 – D: The wheelbarrow primarily uses the wheel and axle as a simple machine. The bulletin board describes the wheelbarrow as using both the lever and the wheel and axle. The wheel and axle is more important, because the contents of the wheelbarrow may not be heavier than you can lift. It is the way that they are moved that is more important.

Lab Tools

Lesson Title – Laboratory Tools Bulletin Board

Grade Level – 2nd Grade

Lesson Time – 20 minuets

Instructional Mode – Discussion and Worksheet

Team/Group Size – Class, Individual

Summary – The students will go over the bulletin board and talk about the different laboratory tools; they will then do the Laboratory Tools Worksheet.
Learning Objectives – Students will learn what tools are used in laboratory experiments.

Essential Questions – What kinds of tools do scientists use in laboratories.

Introduction / Motivation – The children will be able to see pictures of different lab tools and learn what scientists use them for.

Procedure – Go over the bulletin board with the class, and then have the students do the worksheet (attached).

Materials List (per class, per group and / or per student) -- None

Vocabulary with Definition –

Laboratory- a place made for making scientific experiments and tests

Microscope- an instrument made of a lens or many lenses for making enlarged or magnified images of small objects

Beaker- a deep cup or glass with a wide mouth and usually a lip for pouring

Bunsen Burner- gas burner that produces a very hot blue flame

Thermometer- an instrument for measuring temperature

Balance- an instrument used for measuring mass or weight

Assessment/Evaluation of Students – Laboratory Tools Worksheet (attached)

Lesson Extensions – None

Attachments – Laboratory Tool Worksheet

Troubleshooting Tips – None

Safety Issues – None

Redirect URL – None

Key Words – laboratory, microscope, beaker, Bunsen burner, thermometer, balance

Laboratory Tools Worksheet

Name: ______________________________

Draw a line between each laboratory tool and its picture.

Bunsen Burner

Beaker

Thermometer

Balance

Microscope

Fill in the blanks with the laboratory tool name.

Microscope Beaker Bunsen burner Thermometer Balance

______________________ are used to take the temperature of solids and liquids.

A ______________________ is used to weigh things.

Scientists use ______________________ to hold liquids.

______________________ are used to see very small things like germs.

______________________ are used to heat liquids in beakers.

Inventors

Inventor of the Month - February

Lonnie Johnson

Inventor of the Super Soaker

Worked as a spacecraft systems engineer

Conventional water guns did not get people wet enough

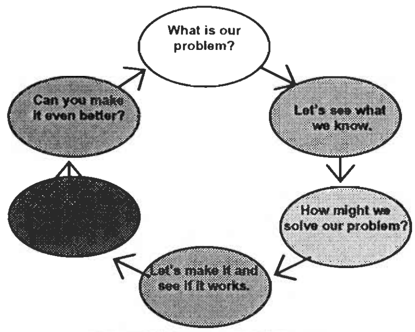
Water guns work by supplying pressure to the chamber with the water

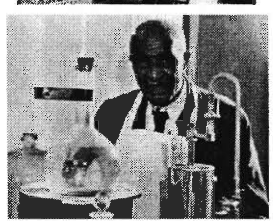
If we provide more pressure we will be able to shoot more water more quickly

Lonnie made a first version of his water gun and called it the "Power Drencher"

[redacted]

Larami has been making improvements to the water gun ever since with Lonnie's help





George Washington Carver

Found over 300 uses for the peanut

Worked as a researcher

Farmers relying on cotton production were using all the nutrients in the soil

There are other crops that would help replenish the soil, such as peanuts and pecans

George invented over 300 uses for the peanut to make peanut farming more profitable

He tested his inventions in a laboratory in Tuskegee

[redacted]

George did not patent his numerous ideas so that they would be available to many people.

Lesson Title – Inventor of the Month: February

Grade Level – 2

Lesson Time – 15 Minutes

Instructional Mode – Whole Class

Team/Group Size – Whole Class

Summary – Observe how the real people use the design process to make inventions.
Learning Objectives – *Broad Concept:* Engineering design requites creative thinking and consideration of a variety of ideas to solve practical problems.

Essential Questions -

Introduction / Motivation – Inventors like Lonnie Johnson and George Washington Carver knew how to use the design process to guide them to successful innovations and inventions. By examining how they use the design process we can become better at using it ourselves.

Procedure –

- Go over the design process.
- Compare each step of the design process to what the inventors did.

Materials List (per class, per group and / or per student) –

- 1 Inventor of the month Bulletin Board per class

Vocabulary with Definition –

Nutrients – something that helps a living thing grow

Replenish – to fill up or build again; replace

Assessment/Evaluation of Students – Quiz attached

Lesson Extensions –

Attachments –

Troubleshooting Tips –

Safety Issues –

Redirect URL –

Key Words –

Name ______________________________

Date ______________________________

Directions: Circle the correct answer to each question.

1. Who invented the Super Soaker water gun?

   a) George Washington Carver
   b) Lonnie Johnson
   c) Nikola Tesla

2. What plant did George Washington Carver find 300 uses for?

   a) Peanut
   b) Venus Fly Trap
   c) Aloe

3. What was the name of the water gun before it was called the Super Soaker?

   a) Amazing Water Shooter
   b) Power Drencher
   c) The Best Water Gun Known to Mankind

4. George Washington Carver wanted farmers to grow peanuts because another farming product was using all of the nutrients in the soil. What was the product that was using all of the nutrients?

   a) Palm trees
   b) Blue Berries
   c) Cotton

Answer key for February inventor of the month quiz

1. b
2. a
3. b
4. c

Appendix D – Surveys

Student Survey

I am a girl boy
I would describe myself as;

African/Black American
American Indian/Eskimo
European/White American
Hispanic/Latin American
Pacific American
International/Non-American
Interracial American
Other

- If you would answer yes to the question, circle the ☺.
- If you would answer no, circle the ☹.
- If you are unsure how you would answer, circle 😐.

Did you like learning about the engineering process?	☹	😐	☺
Did you like learning how science ideas are used in engineering?	☹	😐	☺
Do you think you may want to study engineering in college?	☹	😐	☺
Do you think you may want to work as an engineer after college?	☹	😐	☺
Did you know anything about what engineers did before this school year?	☹	😐	☺
Do you think you have a better understanding of what engineers do now?	☹	😐	☺
Do you think the engineering process can be used in other types of jobs?	☹	😐	☺
Do you think you can use the engineering process in other types of school work?	☹	😐	☺
Are you interested in rockets and space travel?	☹	😐	☺
Are you interested in how things work?	☹	😐	☺
Are you interested in tools and building things?	☹	😐	☺
Are you interested in the Earth?	☹	😐	☺
Are you interested in the sun, moon, stars and planets?	☹	😐	☺
Are you interested in living things?	☹	😐	☺
Are you interested in machines?	☹	😐	☺
Are you interested in energy?	☹	😐	☺
Are you interested in electricity?	☹	😐	☺
Are you interested in motion and forces?	☹	😐	☺
Are you interested in engineering?	☹	😐	☺
Are you interested in doing science projects?	☹	😐	☺

Teacher Feedback Survey

1. What did you like and dislike about the lessons? Why?

2. Where do you see room for improvement?

   ~How would you like to see these improvements applied?

3. How many lessons did you find useful?

   ~If there were lessons you did not use, why did you not use them?

4. Were the lessons too difficult to apply?

5. Was the language too technical?

6. Was there enough detail and description in the lessons?

7. How do you feel about the number of lessons?

8. What do you feel about the format of the lessons?

9. What would you have liked to see us do?

10. Do you feel you are ready to teach other teachers about these lessons?

    ~If not, where do you need assistance?

11. Any other questions or comments?

Teacher Conclusion Survey

1. To you, what gender represents engineers?
   a. Male
   b. Female

2. What race represents engineers?
   a. African American
   b. Caucasian
   c. Asian

3. Do you think this is something that needs to change?
   a. Yes
   b. No

4. How important is it that efforts are made to keep diversity in engineering?

a. Extremely Important
b. Very Important
c. Mildly Important
d. Not Important

5. Recently, engineering has decreased in terms of its popularity as a field of study, why do you think that is?
    a. Lack of exposure
    b. Lack of understanding
    c. Poor market for jobs
    d. Fear of technology

6. Does the decreased interest concern you?
    a. Yes
    b. No

7. Do you consider engineering a desirable field of study to pursue?
    a. Yes
    b. No

8. What would you say your understanding of engineering is?
    a. Poor
    b. Fair
    c. Good
    d. Excellent

9. In your experience, how does exposure to college students affect elementary students?
    a. Positively
    b. Negatively
    c. Has no effect