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Engineering Lessons for a Fifth Grade Classroom

An Interactive Qualifying Project Report

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1. Engineering
2. Education
3. Teaching
4. Fifth Grade
5. Massachusetts Frameworks

Abstract

As part of the Partnerships Implementing Engineering Education program funded by the National Science Foundation, the authors wrote, tested, implemented, and archived engineering lesson plans for the Worcester Public School system's fifth grade classes. These lessons were designed to be incorporated into the existing science curricula and include pulleys, sound waves, magnetism, and space probes. Several fifth grade classrooms within the Worcester were visited throughout the year for observations. These observations assisted the creation of content-appropriate lessons.

Acknowledgements

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1. Introduction

Eight months before finalizing this paper, we submitted a proposal to integrate engineering into Elm Park Community School's 5th grade classroom as part of a larger project known as the Partnerships Implementing Engineering Education. The project spanned the WPI school year from August 2004 when we were writing the proposal to May 2005 when we completed our task. During this time we retrofitted several of the school's pre-existing science curricula to include engineering concepts. We then tested these changes in two different classrooms. Along the way we invested tremendous time to the project and we received extensive support from the teachers involved and Worcester Polytechnic Institute. This is an indicator of the importance of integrating engineering for us and all those involved, however, the question remains on why this is so.

Our reason is a confluence of two related factors. The first factor is the current state of affairs in Education. The adaptation of a standardized Massachusetts Comprehensive Assessment Test, known as the MCAS, creates a real need for school systems to conform to state standards for education. These standards define the material that Massachusetts public school children are expected to know for any given grade level. Engineering education is a new field that is being phased in. Additionally, the No Child Left Behind act was signed into law by President Bush, which supports standardized testing and provides incentives for schools to perform up to standards. The abruptness of this addition of engineering has resulted in a lack of knowledgeable, qualified teachers who can provide this kind of education.

The second factor is that engineering education is very important. This is because our society values technological progress and provides extensive benefits for technologically proficient citizens. Our schools have the responsibility of creating those citizens. The WPI students behind PIEE5 are all engineering students, and for that reason they have been able to use their knowledge and skills to help the Worcester Public School teachers make the transition to a new educational curriculum that includes engineering. What follows is a documentation of our attempt to incorporate engineering into the fifth grade Worcester Public School system and precipitate a move to an improved civil society.

2. Background Research

During this project, we performed research into the intricacies of education. The following is an attempt at describing how the PIEE project is organized, what role the No Child Left Behind act plays in shaping the future of education, and the baselines for student knowledge set by the Commonwealth of Massachusetts. In addition to this, we performed research into teaching methods, how other higher education organizations have tackled the problem of engineering education integration, and issues relevant to teachers. It is our hope that our lesson plans for the 5th grade level have benefited from this information.

2.1 The PIEE Project

The Worcester Polytechnic Institute's (WPI) Partnerships Implementing Engineering Education (PIEE) is an education project funded by the National Science Foundation (NSF) to improve engineering instruction in public schools (16). The project has received grant funding from the NSF for its initial three years, during which the project's participants will work with grades K through six of select elementary schools within the Worcester Public Schools (WPS) system.

The PIEE project has three major goals. The first of these goals is to develop a partnership between five entities: WPI, the WPS, the elementary school teachers and students, the WPI faculty, and finally WPI's Interactive Qualifying Project (IQP) students. The second goal is to assist in the development of curricula which meet the requirements of the Massachusetts Science and Technology/Engineering Curriculum Framework (MSTECF) in the grades K-6. The third goal of this project is to create engineering oriented lesson plans which have been refined through trial and error to the point where they can be implemented in other schools. The culmination of these three goals is the development of specific teaching strategies and lesson plans which WPS teachers can leverage to augment their current science, math, reading and writing curricula. The desired final outcome is a self-sustaining educational ecology where the participating WPS teachers possess the confidence and knowledge to not only teach engineering concepts but also to integrate other teachers into the program.

The overall goals of the PIEE project are further subdivided into yearly tasks. This is because the school year, both at WPI and at the Worcester Public Schools, necessarily ties the turnover of project participants to a yearly cycle. Therefore, in the interest of efficiency, each group of participants, and consequentially each year, is assigned different tasks. These tasks can be seen in table 1 and are described in detail below.

Table 1: Overall Project Plan

Year	Team(s)	Task
2003-2004	Initiation	Generate initial lesson plans
		Plan next two years
2004-2005	Initiation Adaptation	Integrate additional school systems
		Generate additional lesson plans
2005-2006	Initiation Adaptation Sustainability	Integrate all grades in K-12
		Finish lesson plans
		Implement sustainability

During the first year (2003-2004) the PIEE project worked with grades four through six at Elm Park and Midland schools. There was one team per grade level consisting of WPI and WPS faculty, undergraduate and graduate fellows, and IQP students. These groups developed and implemented the first set of engineering lesson plans. This was primarily a trial stage to allow both the WPI and WPS participants to plan the course of the project for the next two years.

This year (2004-2005), we have expanded the project to include multiple schools and incorporate grades two through six. Like before, each grade level has one team assigned to it. While the overall makeup of these teams remains the same, their size has been expanded to accommodate the additional schools. The goal of the teams this year is to develop and implement grade-appropriate engineering lesson plans.

During the third and final year of funding, the number of grade level teams will be expanded to cover the full K-6 range. The lesson plans developed and refined earlier will be implemented at other WPS schools. The primary goal of the third year is to sustain the teacher's interest and self confidence which will enable them to continue to both produce new lesson plans and teach the ones created under the project.

The NSF expects to receive three main benefits from this project. The first and most direct outcome is that educating young minds about engineering leads to a school population better prepared to perform well in the mandatory MCAS testing provided by the state of Massachusetts. Next, they expect that an early education will help bias young people who are predisposed to do well in engineering activities towards a future career in engineering. Those students will have more of an incentive to study math, science and technology in their formative years, thereby preparing them to succeed. This will hopefully get the right people into the right jobs. This is in contrast to other students who want to go into engineering, but did not have the benefit of an early engineering education. Such students may have a more difficult time gaining the required background to pursue an engineering degree in college. Lastly, the NSF hopes that by involving college students into the field of education they may like it enough to stay there.

2.1 Massachusetts Frameworks and Worcester Benchmarks

The Massachusetts Frameworks is a basic overview of what is expected of students by the state of Massachusetts. It details what topics these students should know in terms of their grade level and gives a brief explanation of the important ones that are crucial for development at each particular grade level. This standard is then used to generate the Massachusetts Comprehensive Assessment System (MCAS) tests which are applied to 4th, 8th, and 10th grades. The test serves two purposes: it provides a benchmark for how well the public schools are implementing the frameworks and it serves as a metric by which to judge individual students and whether they are eligible to graduate (Massachusetts Science and Technology/Engineering Curriculum Framework, published by Massachusetts Department of Education).

Before the frameworks were created in 2001, much of the curriculum that was implemented for science was based on ideas of inquiry for primary education. The idea behind inquiry based learning is to mix what children want to learn with what society needs them to learn, in the hopes that a compromise will help them remain self-motivated learners (24). The introduction of rigid frameworks and new areas that need to be taught, such as engineering, makes reaching such a compromise that much harder. This is because it limits the flexibility to plan lessons around the desires of the individual child. Therefore, teachers have drifted away from the inquiry based approach. This project addresses the balance by providing activities that kids will enjoy while learning about topics required by the state of Massachusetts.

The frameworks divide science into four different groups or strands. The four strands are Earth and Space Science, Life Science (biology), Physical Sciences (Chemistry and Physics), and Technology/Engineering. The strands were designed to help organize what students should be expected to know upon graduation from high school. Table 2 shows a breakdown of the strands of science located in the frameworks.

Table 2: Strand Topics Grades K-12

Strand	Topic
Earth and Space Science	Mapping the Earth Earth's Stucture Heat Transfer in the Earth's system Earth's History Earth and Space Science The Earth in the Solar System
Life Sciences (Biology)	Classification of Organisms Structure and Function of Cells Systems in Living Things Life Sciences (biology) Changes in Ecosystem over Time
Physical Sciences (Physics and Chemistry)	Properties of Matter Elements, Compounds, and Mixtures Motion of Objects Forms of Energy Physical Sciences (Physics and Chemistry) Heat Energy
Technology/Engineering	Materials, Tools, and Machines Engineering Design Communication Technologies Manufacturing Technologies Construction Technologies Transport Technologies Technology/Engineering Bioengineering Technologies

The frameworks were designed with help from the Education Reform Act of 1993 along with the Partnership Advancing the Learning of Mathematics and Sciences (PALMS) (Massachusetts Science and Technology/Engineering Curriculum Framework p 6). Technology and Engineering are a big part of the frameworks and rightly so. In an age where humanity is taking giant leaps in technology, it is important to lead children in a direction which will enable them to function in an ever growing technological society. According to the National Science Foundation:

> Since 1980, the number of nonacademic science and engineering jobs has grown at more than four times the rate of the U.S. labor force as a whole. (28)

Therefore, since science and engineering are fields with some of the best opportunities for children to grow into, we need to stress the fundamentals of the investigation and experimentation process with our young students. Those two traits are vital parts of the development of our children's' education. By setting a higher standard, Massachusetts hopes that the new frameworks will enable graduating students to leave with the ability and opportunity to explore one of the many new and demanding technically oriented jobs.

In addition to the Massachusetts Frameworks, in 2002 the Worcester Public School system created a companion set of benchmarks. The object of these benchmarks was to take the ideas brought forth in the frameworks and break them down to more specific achievable goals and requirements. This was done out of a desire to enable teachers to create appropriate lessons without needing an extensive or firm knowledge of the frameworks. This is because it is easier for teachers to understand the frameworks when they have been broken down into categories and grade levels. Teachers then use this information to set up their own curriculum for the year. Table 2 shows the benchmarks for technology and engineering for grade 5 that were derived from the Massachusetts Frameworks (Massachusetts Science and Technology/Engineering Curriculum Framework, Massachusetts Department of Education, May 2001).

Table 3:Framework Requirements

Students Will…

05.SC.TE.01	Identify materials used to accomplish a design task based on specific property, i.e., weight, strength, hardness, and flexibility.
05.SC.TE.02	Identify and explain the appropriate materials and tools (i.e., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.
05.SC.TE.03	Identify and explain the difference between simple and complex machines, i.e., hand can opener that includes multiple gears, wheel, wedge gear, and lever.
05.SC.TE.04	Identify a problem that reflects the need for shelter, storage or convenience.
05.SC.TE.05	Describe different ways in which a problem can be represented, i.e., sketches, diagrams, graphic organizers, and lists.
05.SC.TE.06	Identify relevant design features (i.e., size, shape, weight) for building a prototype of a solution to a given problem.
05.SC.TE.07	Compare natural systems with mechanical systems that are designed to serve similar purposes, i.e., a bird's wings as compared to an airplane's wings.

By creating the MCAS tests, Massachusetts is trying to place itself as one of the premier states for primary and secondary education. With their frameworks and benchmarks, both Massachusetts, and by transitivity, the WPS, have created high standards that they hope will result in a highly competent graduating class in all Massachusetts public schools. In fact students must be proficient in all areas covered by the framework to even be allowed to graduate from high school.

2.3 No Child Left Behind Act

The No Child Left Behind (NCLB) act was signed into law by President Bush on January 8, 2002 (9). This act is based on four "pillars": Stronger accountability for results, more freedom for states and communities, proven educational methods, and more choices for parents (10). These pillars all exist in some form in the NCLB act as described below, however the manner in which NCLB chooses to provide these accountabilities, choices, and freedoms has both proponents and detractors. Regardless, the first three pillars of this act form an intersection with the established goals of the PIEE project.

The quest for stronger accountability for results starts with state standardized assessments of individual schools. While NCLB describes reading, math, and science as the targeted areas for reform, it is up to the states to create the required assessment goals. As a consequence, while NCLB does not describe, and hardly mentions, improvement in engineering education, Massachusetts has made it one of the cornerstones of their achievement test, the MCAS.

NCLB also defines a minimum segmentation of the results of these tests to ensure improvement occurs across the economically disadvantaged students, the major racial and ethnic groups, the disabled students, and the students with limited English proficiency (NCLB 1111.b.2.C.v.III). Moreover, all students are held up to the same standards:

> "(B) SAME STANDARDS- The academic standards required by subparagraph (A) shall be the same academic standards that the State applies to all schools and children in the State." (NCLB 1111.b.1.B).

While this has led to considerable consternation over the wisdom of holding diverse groups up to identical standards rather than triaging as appropriate, it is the law, and failure to adhere has negative consequences. Therefore solutions that improve instructional material for all students without sacrificing any student's quality of education are desirable. The PIEE project is one such solution that fits the need.

The second pillar of NCLB is the desire for greater freedom for states and communities. This freedom is primarily a greater discretion in distribution of funding among school programs.

The last pillar encourages the use of proven educational methods. These are methods that have been shown to work through controlled studies using statistically valid scientific techniques. This measure is primarily to discourage "teaching fads" that have hurt the education of students unfortunate enough to be schooled under them. For instance, starting in the 50s, a reading instruction philosophy called "whole word reading" was popular (22). This philosophy teaches reading by recognition of the entire word. This was perhaps driven by the misconception that visual recognition of words is a function of the word shape, or the Bouma model of word recognition (23). Controlled tests by Foorman and Fletcher found that the older phonics technique was much more effective (11). NCLB itself provides a proven reading instruction framework called Reading First.

While the PIEE is an attempt to formally improve the teaching curriculum of Worcester Public Schools in the area of engineering, it does not address the methods of teaching these curricula. We do not believe that this absence of teaching methods will excuse the PIEE project from requiring formal testing. This is because the What Works Clearinghouse, a project that collects information about such testing for NCLB compliance, includes assessments of math curricula (12). If the math curricula should be tested under NCLB, then the science and engineering curricula should be tested as well. Therefore, it is important to note that the PIEE curriculum design process does not include formal testing of the final curricula and therefore does not create the rigorous standards of proof required by NCLB.

NCLB specifically encourages the collaboration between higher educational institutes such as WPI and public schools:

> "(1) improve and upgrade the status and stature of mathematics and science teaching by encouraging institutions of higher education to assume greater responsibility for improving mathematics and science teacher education through the establishment of a comprehensive, integrated system of recruiting, training, and advising mathematics and science teachers;" (NCLB 2201.a.1)

In particular, NCLB specifically encourages improvements in math and science curricula:

> "(4) develop more rigorous mathematics and science curricula that are aligned with challenging State and local academic content standards and with the standards expected for postsecondary study in engineering, mathematics, and science; and..." (NCLB 2201.a.4)

These requirements should improve the state of education in Massachusetts through the required collaboration and curricula improvements. This goal is shared by all involved in Partnerships Implementing Engineering Education. So while NCLB is a politically charged and highly debated legislation, it is extremely supportive of the goals of the PIEE program.

2.4 What Ways Are There To Teach Children?

There are several basic ways to teach children: lecturing, explaining, and hands-on experimentation. Research performed by other members of our project team show that with some subjects, such as English and social studies, students can learn through oral and written instruction such as that used in lectures. However, while it is possible to teach concepts and theories of science and technology in a lecture format, it is far easier for children to learn about these things through hands-on experimentation. There are two considerations that directly stem from these factors: first, lesson plans should ideally involve hands-on experimentation to maximize instructional efficiency. But hands on lesson plans are more difficult to teach, leading to the second factor: in order for the teachers to convey the material effectively, they need to be able to easily understand it themselves. So, to satisfy both issues, the lesson plans need to use an effective lecture style to present an effective hands on experiment.

Lecturing to students is not always the most effective method for teaching science and technology. This is because the lecturing process merely overloads the student’s senses with information which leaves them to formulate their own understanding of the material. Another reason lecturing is a poor method for teaching children science and technology is because of the short attention span of young children their attention spans. These children find it very difficult to remain focused unless they are fully involved in the material that is being taught. If they do not feel as though they are involved, they will quickly lose interest and this will make it almost impossible for them to learn the material. In short, lecturing is an ineffective way to teach students science and engineering principles because it lacks the personal involvement which is important for children's understanding of this subject.

Another common method of teaching children has been explanation. Explanation leaves it up to the students to ask probing questions to the teachers. This is a more effective method of teaching than lecturing because it gets the children thinking and involved in the learning process. By asking questions, the students are forced to think the problem through first, and when they get stuck, ask for help. Doing this helps because it puts the information they receive in a certain context that makes sense to them rather than just giving them a list of information to internalize. However, explanation has its own limitations. First it is up to the student to get himself involved. This is a problem because students who feel as though they are behind the class or don't understand things will sometimes not seek the help they need, thereby failing to learn the material and putting themselves in a more difficult position from which to learn successive material. The other limitation of explanation is that it requires the students to do a certain amount of work before they reach a point in which they need help. In fact, like most people, most children don't like to admit their lack of knowledge, and so they may not have the confidence to ask questions. In short, explanation helps children easily assimilate the information they are given, but it requires them to take the initiative in their learning process, which they are not always capable of. Lesson plans that use explanation as the main form of teaching therefore creates a schism between those who are interested in the subject and can motivate themselves to learn a lot, and those who are not interested in the subject and find themselves floundering.

Now that the Massachusetts frameworks and benchmarks include a lot more Science and Engineering aspects, the teachers need a way to effectively teach these concepts. With this in mind, hands-on experimentation is by far the best method for teaching children things about Science and Technology. Because the concepts in science are difficult to grasp by listening alone, they need a more direct way to experience the Science/Engineering concepts for themselves. Through the engineering design process, the students not only gain a valuable tool in problem solving, but they gain a lot of first hand experience with every lesson they learn. For instance, it is one thing to try and explain to a child how when light passes through a medium with certain refraction it divides the single beam of light into many different colored beams of light, and it is quite another thing to show them a prism which demonstrates this phenomenon. It is this sense of proving it which helps students fully understand the knowledge rather than just having them take the information without questioning it and not knowing if it really is true.

After some speculation it becomes quite clear that to effectively teach students Science and Engineering concepts, the hands-on experimentation style of teaching is desirable. This is because it doesn't possess the restrictions of lecturing and explaining and gives children the physical proof they need and deserve to shape their views of the physical world. By making lesson plans that incorporate hands-on experimentation, it gets every student involved in the learning experience and has a bigger chance of getting children who aren't interested in Science or Engineering attracted to the subject matter.

Because this project requires us to create engineering lesson plans that conform to the Massachusetts frameworks and the Worcester Benchmarks, we have decided that our lesson plans, or activities, will be geared towards the hands-on experimentation style of teaching. However, before any lesson plan can be implemented most effectively, it must be known how much information the students know about the topic being taught. For example, the Sound Waves Lesson Plan includes a great deal of background information about musical instruments and sound itself. While this lesson has been developed to stand alone, a teacher implementing this lesson may spend time re-teaching information without realizing it. This is because teachers are pressed for time, which means that if the teacher implementing such lesson plans does not know what the students know, they will waste precious time re-teaching material.

2.5 How have other institutions implemented engineering education?

Before we began building our lesson plans, we decided to do some research on what other institutions have done towards engineering education in the K-6 grade levels. The number of organizations involved in the idea of engineering outreach is quite numerous; however, there have been very few outreach programs working towards implementing engineering education in the K-6 grade levels. Most of these outreach programs focus strictly on high school and middle school, or the 6-12 grade levels. Schools such as Tufts, BU, and WPI, under a grant from the National Science Foundation (NSF), have created programs where college students formulate engineering lessons that work in conjunction with the preexisting science curriculum for pre-college schools. These college students are also responsible for helping teachers implement the lesson in the classroom. These schools all share a common goal of creating a community supportive of engineering, and increases the students' engineering knowledge and skills.

We have found that each of these program contain similar elements. Examples of what each of these schools are doing are given below. Tufts seeks to improve teacher development by immersing K-12 teachers in a college research environment to help learn about engineering outside of the classroom (1). This is called their Research Experience for Teachers (RET) program. Tufts also appears to be working towards getting their graduate students studying teaching to gain a greater appreciation for K-12 education and outreach. On the other hand, Boston University seeks to use their college students as role models by having them participate in classroom activities of K-12 schools. By using people that are passionate in their field of study, BU hopes that this passion will be infectious towards other students pursuing such a field (2). Lastly, the program at WPI appears to include both of these activities by having IQP students both create engineering lesson plans, but also have them involved more closely by having them participate in the classroom.

Another school which is working towards engineering outreach is Kansas State University which also provides an NSF funded RET program like Tufts, which focuses on embedded systems with Lego Mindstorms kits (3). Other organizations have also funded projects similar to the NSF's. One example is the New Jersey Commission for Higher Education Fund, which is a grant by which the NJIT Newark College of Engineering performs instruction and outreach for K-12 students and educators (4). This is a program that they call Pre-IOP. The college’s main goal of this program is to increase the enrollment of engineers.

> "The Education and Training Institute, the instructional component provides middle and high school teachers with pre-engineering curriculum and training that is aligned to the New Jersey Core Curriculum Content Standards (NJCCCS)." (4)

This instructional component of the Pre-IOP includes Project Lead the Way, a series of courses for K-12 educators to learn about engineering topics such as embedded systems design. This knowledge and know-how can then be applied to implementing engineering curricula effectively at the K-12 level. The instructional component also includes Integrated Curriculum Modules (ICM) which provides teachers with fully fleshed out engineering curricula. Additionally, Pre-IOP provides interactive CD-ROMs and web-based professional development.

The outreach component of the Pre-IOP involves partnerships with business and industry, educational groups, and professional organizations to improve the perception of engineering in K12 students. Means to this end include teleconferences, career workshops and presentations, summer programs for students, hands on activities and projects, planning for college seminars, competitions, and in-class support for teachers (4).

One great reason for engineering outreach is to increase the interest of young people towards engineering and science. The National Academy of Engineering offers its own advice for teachers on the subject of creating interest in engineering. This advice falls along three axes: career exploration activities, engineering design projects, and pre-engineering courses. For career exploration activities, teachers can talk about what engineers do and what engineering jobs are available. For more hands on learning, teachers can arrange field trips or guest speakers (5).

Engineering design projects are another means of providing hands on learning. These projects are large in scale by nature and require a dedicated amount of class time to complete. The National Academy of Engineering advises teachers to prepare students for the project beforehand by practicing skills such as brainstorming skills and listening skills. Furthermore, by teaming up with other teachers, the project can be given interdisciplinary scope across several classes. Lastly, teachers can reach out to local colleges and engineering firms to bring in mentors or guest speakers into the classroom.

The Institute for Electrical and Electronics Engineers (IEEE) is an engineering organization for electrical and computer engineers. Their goals are technical, political, and social, and thus they too address the issue of teaching engineering to K-12 children. They have a teacher in-service program where IEEE engineers show teachers how to present engineering topics to kids, they have freely downloadable curricula on electric motors, light waves, simple machines, etc. They also provide information on pre-college career prep, which helps potential engineers explore potential career interests to find out what field of engineering appeals most to them (6).

The Integrating Teaching and Learning program provided by the University of Colorado at Boulder takes a formal approach to creating engineering educators. They provide tested standards based curriculums and give teachers practical professional development training so that they may deliver those curriculums, and so that they may reach a high level of teaching competence based on hands-on work (7).

There are also programs that greatly contrast from the above models of teaching engineering through student submergence in the subject. Project STEP, or Georgia Tech's Student and Teacher Enhancement Partnership, operates on the principle that a strong mathematical background gives students the tools they need to gain a conceptual understanding of engineering concepts. So by integrating engineering topics into algebra and trigonometry rather than science, Georgia Tech hopes to produce a new breed of engineers (8). As examples of this tie-in, STEP provides curricula that teach linearity by demonstrating Ohm’s Law, Hooke's Law, and the principles of a balance arm.

2.6 Teacher Research

In addition to performing research about styles of teaching, and the benefits and drawbacks of each type, we also did research about teachers themselves. We tried to find information about what the thoughts, feelings, and concerns of today’s teachers are. Among other resources, we found teachers.net, a teacher collaboration and resource website, and signed up for several of their mailing lists including teach-talk, discipline, science-teachers, and fifth-grade. Because these lists are very low-volume, we were thankful that they kept archives which we browsed for further information.

So what do teachers talk about? The predominant subject is classroom discipline. Teachers, especially new ones, can be extremely frustrated in low-paying jobs with students who will not respect their authority. For this, some teachers claim the solution lies in providing a more structured classroom with rituals that encourage orderly behavior. These rituals are trained, practiced, and reinforced to internalize them into the children’s own behavior. Examples of such rituals are procedures for passing in papers to the teacher, procedures for entering the classroom and sitting down, and procedures for classroom dismissal. Interestingly, the correct way to have students pass in papers is along rows rather than columns, as it improves teacher visibility of the process and is less complex for students than passing papers over their heads. Regardless of the exact ritual, the point is to give students a clear set of expectations that they can follow. Without this, class breaks down.

Another problem in teaching is the localization of information. When a teacher leaves or retires from the school system, all the information localized within themselves, such as lesson plans and classroom procedures, leave with them. Thus, a talented teacher may not leave behind an enduring legacy. While there are suggestions, such as keeping a box of materials such as lesson plans and projects to be handed down to a successor, there is little that could be called a systematic attempt to preserve and pool knowledge.

This is particularly relevant to our project because we, as part of the PIEE project, are creating knowledge and archiving it, however no procedures exist for the information to be refined by successive generations of teachers.

This leads to an observation about the project as a whole: we appear to be building activity plans rather than lesson plans. The difference is that while activity plans describe activities, lesson plans describe lessons which ideally build activities and other instructional material into a coherent flowing story that builds from a kernel of knowledge into a crescendo over a long period of time.

What we do is try to come up with activities that integrate with state standards for both science and engineering, however these activities are largely self-contained. This is in a sense deliberate: self-contained modules can be re-used more easily than those with dependencies. We want to give teachers an assortment of re-usable activities that can be inserted into their existing class work.

But there is a distinction between activity plans such as these and lesson plans. Lesson plans are more organic. That is to say, they do not function individually but rather as a part of a unified whole. What makes an effective lesson plan is much like what makes effective writing: concrete ideas, continuity from previous lesson plans, and flow. And like writing, it is stylistic and different from teacher to teacher. However it is arguably more important than activity plans because while activities are a dime a dozen, effective lesson plans build up the material in a clear manner and are not so easily found or passed on. And this, rather than ad-hoc activities, is what teachers need.

3. The Project

This section covers the organization structure of the project, tasks performed under the project, and our experiences under the project. Most of these were set up during the inception of the PIEE project, such as the organization and tasks. These sections therefore describe how they apply specifically to us. The last section, our experience under the project,

3.2 Student Organization and Classrooms

Our team is one of many teams in the PIEE project, and we focus on the 5^{th} grade classrooms in Elm Park Community School and Midland Street School. Our team is composed of four students: Paul Ingemi, Robert Doughty, Tom Gramzow, and Shamballa Kawamotto. However, we have been split between two schools. Robert and Paul have been assigned to the Elm Park Community School, while Tom and Shamballa have been assigned to the Midland Street School. Because we have been assigned to two different schools, this report is solely for the Elm Park project members as opposed to one report from the whole fifth grade level team.

Table 4: Responsibility Chart

Team Member	School	Project Sub-team	Lesson Plans
Paul Ingemi	Elm Park Community School	A	Pulleys Magnetism
Robert Doughty	Elm Park Community School	A	Sound Waves Space Day
Tom Gramzow	Midland Street School	B	Structures Hot Wheels
Shamballa Kawamotto	Midland Street School	B	Gears Light, Color and Refraction

Within each of the two schools are two different classrooms which the project team members have been working with. Within the Elm Park School, Robert and Paul have both been assigned to Mr. Fran Mahoney’s classroom and Ms. Lisa Ansara’s classroom. Both of us have spent a pretty much equal amount of time in each of the two classrooms. Because neither of us have been assigned as the sole student within one of the classrooms, as other teams within the project have done, we have been able gain a broader sense of the organization and learning abilities of two different classrooms simultaneously.

3.1 The Role of the IQP Student

Each IQP student participating in this project has several roles. The primary role of each student is to create at least two engineering lesson plans. Furthermore, at least one needs to be implemented. The second role of the IQP student is to spend time in his or her respective classrooms as both an observer and a helper to the teachers and the fellows.

At the beginning of the project, we were given the curriculum map from the teachers (see appendix A). This curriculum map is the road map for the teacher describing what material needs to be covered for any given week of the year. Teachers design such maps for all of their subjects to conform to the Worcester benchmarks. We were given the curriculum map which pertains to science and engineering. As with our predecessors, we were instructed to create our engineering lesson plans to embrace several of the science objectives. This is intended to pack engineering content into an already saturated curriculum without sacrificing other content.

In accordance with the curriculum map, we created four engineering lesson plans. These were the pulleys lesson plan on the topics of pulleys, which is part of the simple machines objective, beach combing, which corresponds to the magnetism objective, design your own musical instrument, which is part of the sound waves objective, and design your own space probe, which is part of the Space Day Activities portion of the curriculum map. This breakdown is illustrated in table 5.

Table 5: Science Objectives and Corresponding Engineering Lesson Plans

Engineering Lesson Plan	Science Objective
Pulleys	Simple Machines
Beach Combing	Magnetism
Musical Instrument	Sound Waves
Space Probe	Space Day Activities

All of the lesson plans except for Space Probe have been implemented in both classrooms at Elm Park. In addition, we have implemented the pulleys and sound waves lesson plans in Midland School.

3.2 Classroom Visitation, Participation, and Implemented Lesson Plans

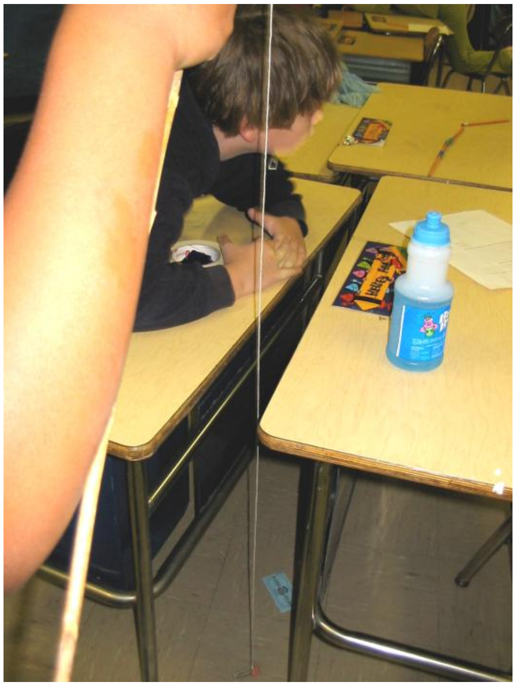
Throughout the year, each IQP student spent time in the classroom of their designated school. Our team spent the majority of this time as guests in Fran Mahoney and Lisa Ansara's classes at the Elm Park Community School. While there, we served in three capacities: primarily, we assisted the graduate fellow in our group in implementing completed lesson plans. Second, we tried out our own lesson plans, either teaching them or helping the teacher implement them. Third, we acted as both observers and teaching assistants during normally scheduled classes. These classes that we assist in are usually math and science, but have also been reading and writing classes.

During A term of the school year, our participation in the classroom was at its lowest. This was the time that we used to get acquainted with the school, the teachers, and the students. During the term, we delivered the Introduction to Science and Engineering lesson plan, the Money in the Pit lesson plan, the Sun Tracker lesson plan, and the Scale and Measurement lesson plan.

The Introduction to Science and Engineering lesson taught the students the differences between scientists and engineers while introducing the students to the engineering design process. The students were given several activities which challenged their understanding of what it means to be a scientist or engineer. The lesson distinguished between the design process that engineers use and the scientific method that scientists use.

The Money in the Pit lesson was a lesson which had the students use critical problem solving tools. It was the first lesson plan that our team participated in. The class had approximately 20 students arranged in tables in groups of four. We noticed the distinct personalities of each student. About a third of the students were very active, always performing some physical activity, either walking around or playing with something in their hands. Another segment of the class appeared content to sit at their seats and appeared bored. A majority of the class fell somewhere between these two extremes.

Figure 1: Fishing for Money



The lesson put the students into a hypothetical situation where they had to fish money out of a storm drain. The desks in the classroom were arranged to create a gap between them small enough not to permit a student's hand. Then, play money was placed on the floor beneath the gap formed by the desks. The student's task was to design an object which would enable them to retrieve the money from the gap.

We started by reviewing the engineering process flowchart. This was a very quick introduction before the class had settled down because it was covered during the previous day's class. Then, the teacher segued into a small discussion on how to brainstorm. She covered the process of enumerating possible solutions as a group and then culling the list down to the good solutions. After some question about what is a "good" solution, the teacher qualified her statement to mean a solution that "works". After the brief introduction to brainstorming came the actual activity: discovering the ways to retrieve a $100 bill from a drain.

Uptake of the activity was slow. It took a while for the kids to get into the mindset of doing the activity, and prodding from us and the teachers. "Well... how would you get the $100 out of the well? ... I see you have some good ideas, how about you write them down? Writing down ideas is how engineers share their ideas." Some of the kids were extremely focused on the task at hand, while others lost interest quickly. After the kids had written down a few ideas, the teacher passed around large sheets of paper for the groups to merge their ideas onto a single paper for presentation to the rest of the class. During these presentations, the kids did not appear to pay much attention to their peers presenting the ideas their group came up with.

After presentation, groups were asked to pick the best idea that they had come up with. Many ideas were variants of "Waterproof gum with a very long stick" and yet others involved a vacuum cleaner, or filling the drain with water. One group had "money detector," although at least one of the group members was skeptical about whether it was a good idea. We explained that "money detector," taken literally, would appear to describe something that detects money, without addressing how it detects money, nor addressing how this solves the problem of actually getting the money out of the drain.

Figure 2: Fishing Pole

During the next class, the students were able to build their designs and test them. Most designs did not work well, however the children persevered to make it work. They wanted it to work, even if they had to cheat a little to do it. For this reason, they seemed highly motivated to solve the problem, and sometimes in real life the solution is not to follow the rules, but rather to change the game.

The Sun Tracker lesson plan had the students build a sun tracker dome that they used to monitor the motion of the sun across the sky at different times of the day and year. The lesson emphasized record keeping so that the students could see for themselves that the suns position in the sky changes with the seasons. This phenomenon is a direct result of the rotation of the earth as well as the location of the earth during its orbit around the sun. Additionally, the lesson also showed the students that shadows change as the day moves forward.

Figure 3: Sun Dial

The final lesson which was implemented during A term was the Scale and Measurement lesson plan. This lesson plan taught students measuring techniques and introduced them to the notion of units and scale. The students were given a map of Worcester and where instructed to find various locations as well as measure the distance between them and convert from map distances to world distances.

During B term and C term we had more time and freedom to appropriately allocate our effort into the project. We used this opportunity to continually develop our lesson plans and spend more time in the classrooms we were assigned. While in the classroom, we tried to learn what methods of teaching and what types of activities the students enjoyed and learned from effectively. This enabled us to revise our lesson plans to fit the students.

During B term, we implemented the Barometer, Alka Seltzer Rockets, Erosion, and Biomes lesson plans. Then, in C term we implemented the Simple Machines, Complex Machines, Pulleys, and Periscopes lesson plans. During the Barometers lesson plan, the students were required to build a device which they could use to observe changes in atmospheric pressure. They then used these observations to make conclusions about atmospheric pressure and weather. The students were given plastic cups, modeling clay, and a straw. They built their barometer by first partially filling the straw with water and then capping one end with the modeling clay. When the other end of the water filled straw was submerged in a cup of water, it created an airtight seal. The surface area of the water in the cup allowed the outside air pressure to act against the trapped air in the straw. Therefore, as the atmospheric pressure rose and fell, the air in the straw compressed and expanded, and so the water level inside the straw rose and fell. The students observed these changes and were able to make predictions about the weather.

Figure 4: Barometer

The kids did not seem to find this lesson plan particularly interesting, however they were enthusiastic about the construction aspect of the lesson. Because there were no assessments made of the students' knowledge after the lesson, we do not know the depth of understanding that the students have for the barometer. However, while they probably do not understand the intricacies of how the pressure and surface area of the water relationship affect the water level, they do know what high and low pressure systems indicate about the weather. This is important because understanding the relationship between pressure and weather is the framework's goal for fifth year students.

The next engineering and science lesson took place outside. The task: to build a rocket out of film canisters and various chemicals including Alka-seltzer™, baking soda, and water. This proved to be one of the most enjoyable lesson plans that we implemented. Originally, our graduate fellow had used Vinegar, a mild acid, and baking soda, a mild base, as propellants; however they reacted too quickly for a film canister rocket. Instead, we used Alka-Seltzer and water, which when combined creates a large amount of carbon dioxide. When these materials were put together into a film canister and sealed, the pressure build up from the carbon dioxide would increase to the point where the cap would pop off. This occasionally took upwards of a minute to occur, which proved trying for kids' patience. Kids got discouraged when the rocket did not immediately blast off, even after fizzling for a while. They would always blast off when least expected.

The students were given other materials such as baking soda and Tums in addition to the Alka-Seltzer, however, they were not told which substance would work. Not only were the students required to make trial and error experiments to find this out but they were also instructed to take notes on their observations.

The next lesson plan we implemented was the erosion lesson plan. The students were given a hypothetical problem: a major rain storm caused soil from the side of a hill to become loose and slide down a mountain. At the bottom of the mountain is a village in danger of being buried. The students had to design a dam that would allow the water to pass through but block the passage of the soil. The students designed their dam on paper based on a list of materials which they had available to use.

The erosion lesson plan includes a stress test of the students' designs. This test is known as the erosion pan. It is a set of two metal pans filled with water and soil to simulate soil runoff on a small scale. After the students built their dams, they tested them in the erosion pan. If a design did not work the first time, the students were able to make modifications and try again. This lesson has solid engineering in the sense that the students were given a problem and they had to design and test a prototype which would solve this problem.

Figure 5: Erosion Test

The kids had a ball with this lesson. Although motivating them to read about erosion and answer questions on the topic was as difficult as ever, they dove into the task of constructing the dam. They liked drawing a picture of how they planned to construct it as well as the actual construction operation. And then they were anxious to test what they had built.

Finally, the last lesson that we presented during B term was the Biome lesson. The students were split into teams and were given a specific climate zone. They performed research on where the climate zone exists, what types of plants and animals live there, and what the weather is like. The students were then instructed to design a biome which represented their climate zone. Using magazines and other arts and crafts materials, they constructed their biome on the inside of a shoe box.

Figure 6: Biome

The children were very enthusiastic about this, especially the more artistic children who saw it as an opportunity to apply their talents. Some children made animals out of clay for their biome. Others worked to construct a pleasing landscape arrangement based on the pictures they cut out of the magazine. Due to the level of immersion that this fantasy biome construction provides, the students learned a lot about their particular biome. This includes information such as what the weather is like, the landscape, where the biome is found, as well as the plants and animals that inhabit the biome. Unfortunately, the students didn't really learn about other biomes that their peers were researching. Perhaps in future implementations of this lesson plan, each group can work with another group to come up with the similarities and differences between their biomes. From this, they can also predict where the interfaces between the biomes will exist. Hopefully, with this approach students can bring discovered knowledge across group boundaries.

The first lesson plan that was implemented during C term was the Simple Machines lesson plan. This lesson plan introduces the idea of problem solving using simple machines. The students were given a set of cards where each card depicts a simple machine on one side and the definition of it on the other. Next, each student was given a worksheet that contained a list of problems that needed to be solved. The students were required to decide which of the simple machines would best solve the problem, and explain why.

After we presented the Simple Machines lesson plan, we implemented the Complex Machines lesson plan. During this lesson we showed the students several movies of machine art known as kinetic sculptures. This art uses the idea of mechanical motion to perform a mundane task in an artful way. One example of this was a machine that sat in a pool of oil and continuously scooped and poured oil onto itself. The kids were fascinated with the videos.

Figure 7: Complex Machine

Mrs. Ansara demonstrating the complex machine that is an egg beater.

After watching the videos, they were instructed to design a machine on paper that would perform a simple task such as change a page in a book, or remove clothes from the laundry dryer. Unfortunately they were confounded by this task. This appeared to be because they focused on the aesthetic aspects of the sculpture rather than the mechanical aspect, but while they were drawing fancy sculpture designs, they had no idea how to integrate a mechanical component.

We tried helping some of the kids by advising them to start with simple machines and link them together. This is the approach his teachers used in grade school when they were told to actually build a Rube Goldberg machine. Unfortunately, this approach creates Rube Goldberg machines rather than aesthetically pleasing kinetic sculptures, and is therefore less satisfying for the kids. We suggest changing the movies to Rube Goldberg machines and suggesting the bottom up approach of building out of simple machines.

After the complex machines lesson plan, we presented the pulleys lesson. This was the first lesson created by this project team to be implemented. We first presented it in Mrs. Ansara's classroom in two parts: creating a single pulley system and creating a double pulley system. The first part was fairly well received, however there were two elements that kept it from being the perfect lesson plan: first, the spools used for the pulleys are not ideal pulley wheels. We need something thinner with larger rims on the side. So we changed the second part of the lesson plan which experiments with pulley systems to use pre-made pulleys.

Figure 8: Wheel and Axle

Some kids made wheel and axles instead of pulleys.

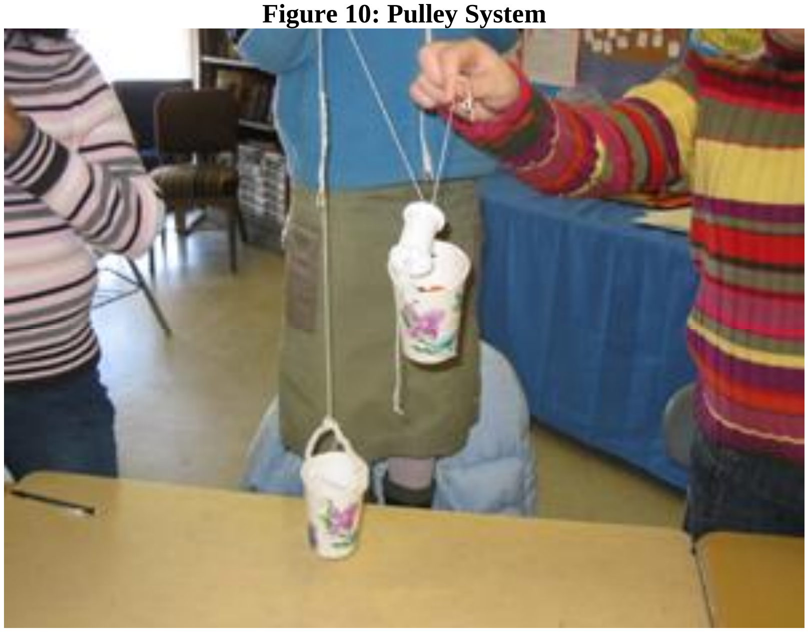
The second part, creating the double-pulley system, was similar in nature to the first part, however the complexity doubled. Part of the problem is you need more than one person to hold together a double pulley system. We later improved on this by providing a freestanding board upon which the pulley system could be mounted. Consequentially, we helped the group farthest along to complete the double pulley and demonstrate it to the class so that the other groups had inspiration to complete theirs.

Figure 9: Pulleys

These are weighted cups and the remains of the pulleys.

We had similar success in Mr. Mahoney's classroom, with a few key differences. Mahoney's classroom was somewhat more innovative compared to Mrs. Ansara's classroom. For example, in Mrs. Ansara's classroom, some of them threaded string through the spool rather than around it to gain more stability out of the spools at the expense of frictional losses.

Figure 10: Pulley System



This is the double pulley system in action.

Mr. Mahoney’s class was harder to motivate, and did not finish the double pulley system. We extradited the matters by completing our own double pulley system and demonstrating it to the kids. Mr. Mahoney mentioned afterwards that the demonstration of how the double pulley system could enable a light object to lift a heavier one was very visual. He stated that the kids who paid attention understood the concept afterwards.

In an attempt to fix the oversized spool problem, we included rubber grommets in the materials that Mr. Mahoney’s class could use. Unfortunately, none of the people using the grommets completed their double pulley system. Our opinion is that the frictional losses from the grommet would be too great.

The final lesson plan presented to our classrooms in C term was the Periscopes lesson. In this activity, students constructed small periscopes using reflective paper and construction paper. The lesson attempted to demonstrate the phenomenon of reflection of light and how it can be exploited to see around corners. In keeping with the idea of following an engineering process, the students had to design their periscopes on paper before they were given the supplies to build it.

We expected the task of orienting mirrors to set up a periscope to be fairly self-evident and intuitive. We were wrong. The students had significant difficulty aligning the mirrors or even deciding where to place them. For example, some designs required the laws of physics to change to allow light to bend around corners. Many students wanted to set up the mirrors to directly face each other. Because students lack an intuitive understanding of the reflection property of mirrors, we suggest that perhaps they can play with two hand mirrors before designing their periscope. This would hopefully give children the opportunity to explore angles of reflection.

After C term, we ramped down on the amount of time spent in the classroom. We still continued to visit the school on a weekly basis, just not as often. As the project advanced into D term, we still needed to implement the remaining lesson plans that we created and participate in the presentation of the pre-made lesson plans from previous years. So to summarize, in D term we presented the Sound Waves lesson plan, the Magnetism Lesson plan, and the Maglev lesson plan.

The first lesson plan of D term was the Sound Waves lesson plan. The lesson required the students to design their own musical instrument using assorted materials. They were given several worksheets which tested their knowledge of sound waves and musical instruments. They were then given a list of easily obtainable materials from which they could design their instrument. Only after the students had a design on paper and a bill of materials would they receive the materials to actually build it. The lesson enabled the students to design, test, and redesign their instrument before being presented to the class.

Along with the design worksheet and the construction tasks, the lesson plan contains a question worksheet that that students were required to complete. This worksheet instructs the students to match musical instruments with their classification and presents the students with challenging questions to answer. Most of the students were able to match the instruments correctly; however, most of them had difficulty completing the challenging questions. According to the Worcester Benchmarks, the students should be able to relate the frequency of the vibration with the pitch of the sound. To assess whether the students are capable of this task after completing the lesson, the worksheet contains the question “How could do you change the pitch of a guitar when you are playing it?” Many of the students were not able to answer this question correctly, however, when we asked them probing questions, they were eventually able to conclude the correct response.

The next lesson plan to be implemented was the Magnetism lesson. This was one of the four lesson plans that we created this year as part of the project. Initially the Magnetism lesson was not supposed to be implemented this year, however, with a little extra time on our hands we were able to go ahead and demonstrate it. Like many of our other lesson plans, it follows the design, construct and test process. Students were asked to design a filter that would accept a mixture of sand, various small trinkets and iron filings. This filter needs to remove everything from the sand. The students were given cups, magnets, paper bags, pipe cleaners, and any other material in the classroom to design their filters with. Once the students finished their design, they built their filters and tested it out with a prepared sand mixture.

Due to time constraints in our schedule, we were not there when the filters were constructed and tested. However, we did observe the students response to the design portion of the task. The students needed a lot of help clarifying what was expected of their filter. They needed reinforcement on the idea that they needed to separate sand from small magnetic particles and from large particles. Furthermore, some students could not conceptually link the idea of using the magnetic property of iron filings to remove them. We suggested to the teacher that this idea could be indirectly reinforced by going over the properties of matter. When the teachers and our graduate fellow finished the lesson plan with the kids, they told us that it went over very well.

The final lesson plan which was implemented in the classroom for both the school year and D term was the Maglev lesson plan. This lesson plan used a magnetic levitation track which was constructed by one of the IQP teams from the year prior. The students were instructed to design a maglev car which could ride the track from one end to the other. After they designed their maglev car on paper, the students were given cardboard, four relatively strong magnets, and shiny paper for decorations to build their car. Several of the students had difficulty attaching their magnets with the correct poles in the right direction, however, this allowed the students to test and redesign their cars.

Many of the students had grand plans for their maglev cars drawn on their papers. One of them included a Hummer Stretch Limo maglev car. These students were disappointed when they received their materials of cardboard and shiny paper. Some students had problems with their measuring skills. Many of the students either forgot to measure the track, or measured the track incorrectly such that when they assembled their cars, the cars would not fit on the track. Furthermore, many of the student’s designs were far more complex than they needed to be. When the students began to build their complex cars, they quickly realized the folly in doing so. Perhaps at this point in the lesson plan for future implementations, the teachers should reinforce what the students learned instinctively with a discussion on the principle of parsimony. Many of the students required their designs to be heavily simplified before they could get them to work properly.

This lesson plan laid down a concrete foundation on the principle of magnetic polarity. This is because the lesson required that all of the magnets on the students' cars be oriented in the correct direction to achieve the magnetic levitation effect. Some of the students learned this the hard way by simply constructing their cars with the magnets in random order. When they tested their cars they were perplexed at how the cars wouldn't stay on the track. Other students, remembering the polarity experiment shown as an introduction to the lesson, brought their magnets to the track to determine the correct orientation for levitation to occur, however, sometimes they would lose track of the direction by the time they returned to their desks. Whatever the case may be, the students either understood magnetic polarity and designed their cars accordingly, or discovered that their cars didn't work and learned the principles by trial and error. In both cases, the magnetic orientation requirement of the Worcester benchmark is satisfied.

Near the middle of D term we were given the opportunity to present two of our lesson plans in Midland Street School, our sister school in the project. We chose to implement the sound waves lesson plan and the pulley lesson plan. These lesson plans went over well in Midland Street School which reinforced the idea that our lessons are appropriate for the grade level we had been assigned.

When we introduced pulleys to the Midland Street schoolchildren, they were very active listeners and participants. They worked effectively in teams to design their pulley systems. Because we gave them a freestanding board containing two hooks on which they could mount their pulleys, they designed their pulleys to be supported on two sides. This is in contrast to the earlier trials at Elm Park where the students created pulleys that only needed one support. Furthermore, one student even tried to exploit mechanical advantage. He looped his string around the pulley several times. While he was correct that exploiting mechanical advantage in pulley systems generally involves loops of string, we needed to use the Socratic method of teaching by questions to convince him that he was not achieving any mechanical advantage and therefore his understanding was incorrect. Despite that, it was impressive that he had a reasonably complete model of how mechanical advantage worked. The students all constructed working pulley systems and enjoyed the lesson.

When the sound waves lesson was implemented in Midland it was used as a reward for the "good" students as the teachers call them. The two fifth grade classes at Midland assembled students who the teachers felt deserved a fun engineering lesson. Most of the other students worked on MCAS material because they needed to work on improving their test scores. Many of the students who were selected for the engineering lesson already had a firm knowledge of sound and music, which enabled the lecture and the design portions of the lesson to go quickly. During the design phase, we saw far more variation of ideas than we saw at Elm Park. We had one group of students try to build a guitar and found out that the materials were not strong enough, while we had several other groups try to assemble large drum sets. Regardless, the majority of the students ended up creating a maraca style instrument. All of the students enjoyed the lesson plan and were happy to present their creations to their fellow students.

3.3 Midland Street After School Program

As part of this project, we worked with the Midland Street School with their after school program. The after school program enables students to participate in fun academic activities weekly. We were assigned one of the 5^{th} grade groups that competed in the Toshiba/NSTA ExploraVision Awards. The National Science Teachers Association (NSTA) joined with the electronics company Toshiba to form a competition as a way to get students to use their imagination and knowledge to explore science and technology.

This design challenge consists of students in teams of two, three, or four members. The students participating in the program met once a week for over an hour for a period of 2 months in order to complete the challenge. Each team, which acted as a fictional research and development team, is assigned a team coach and a team mentor. Midland Street School's coach was the teacher who was running the after school program, and their mentor was an IQP student from this group. The team coach's role was to assist the students and ensure that they followed the competition rules while providing guidance to the students about how to conduct research projects. While the team mentor provided assistance to the coach, his primary role was as a resource person. In this role, he assisted the students with their typing and edited their final submission.

The competition required that each design team pick a technology to research. After they make their choice, each team must fulfill several requirements. First, they must research several aspects of their chosen technology such as how the technology came to be invented, how the technology has changed since the past, and how they believe the technology will be different in twenty years. In addition to those requirements, the teams must do research describing why their vision for the future is not a reality today, along with what other types of technologies need to be discovered before their future can become that reality. Finally, each team must be able to elaborate on the societal benefits that accompany their future technology. Most importantly, however, they must be able to explain what the consequences of their chosen technology are to society and the environment.

Each first place team member will receive a $10,000 savings bond at maturity, and each second place winner receives a $5,000 savings bond at maturity. Previous winners for grades 4-6 involved a remote plant removing device that would prevent waterways from clogging by removing invasive aquatic plants, and a personal compost device that would cut down on landfill waste while at the same time producing fuel for home boilers.

4. Budget and Lesson Costs

The PIEE project at WPI is funded by a grant provided by the National Science Foundation. The NSF has a long history of providing funds to institutions for outreach programs such as the PIEE project. The Foundation also has had a long relationship with WPI such as their involvement with the Women in Engineering program, and the WPI Research Experience for Undergraduates in Industrial Mathematics and Statistics program. The funding provided by this grant makes it possible to purchase the needed materials and supplies required for the implementation of both new and previously created lesson plans.

In addition to these benefits, the grant money has also made it possible for us to assemble sustainer kits for each of the participating classrooms. Sustainer kits provide the teacher with the lesson plan themselves along with any non-consumable materials that the lesson plan requires. Some of the non-consumable materials for the lesson plans created during this year include the tuning forks for the Sound Waves lesson plan and the magnets and miscellaneous metal objects for the Magnetism lesson plan.

Despite these kits, each lesson plan may require the teacher to purchase low cost consumable materials such as the paper plates and plastic cups for the Sound Waves lesson plan and the pipe cleaners and string for the pulleys lesson plan. The consumable materials for the Sound Waves lesson plan can be obtained through purchasing them at a store, however, some of the materials such as plastic bottles may be easier to obtain by having the students save bottles which they have previously used. This act of saving previously used material will also instill valuable ecology awareness skills that the students should have such as recycling. For this project, we purchased materials for two classrooms of about twenty students, which for the sound waves lesson plan cost about $17.00.

Consumable materials for the Pulleys lesson plan can be purchased for a one time fee of about $20 while materials for the Magnetism lesson plan can be purchased for about $10.00. The Space Day Activities lesson plan does not require any purchased materials for execution. This is because the materials required for the Space Day lesson plan, such as paper, pencils and coloring materials, should be abundant in any fifth grade.

5: Sustainability

The sustainability of the lesson plans is a measure of how effectively they can be re-used. This is tied directly to the resources required to execute the lesson plans, however there are several resources involved. These resources are people, processes, and products.

The most important resource in any process or project is people, because without them, the project will never get off the ground. In the case of delivering lesson plans, the people who need to continue the effort are the K12 teachers in the Worcester Public Schools. Unfortunately they are heavily occupied by the tough realities of being a teacher: long hours, unsatisfying pay, and an energy-draining day. Therefore, it is not reasonable to expect most of them to attend a technical school in order to obtain an engineering degree. That's where we come in. Rather than requiring a larger amount of effort on the part of the people who teach in the WPS, this project improves the processes and tools to make their job easier.

The sustainability of the processes, specifically our lesson plans, is a question of how well we have explained them to the teachers in the Worcester Public School system. While we took every effort to make our lesson plans easy to follow, our user testing is not extensive. While the teachers we worked with can execute the lesson plans, there is no guarantee that it will be done as intended or that other teachers will also be able to follow them.

One of our goals in creating the lesson plans was to provide effective tools at a minimum cost. When possible, we used household items that are easily available. For example, the sound wave lesson plan uses a variety of items such as rubber bands, soda bottles, and cups, all of which can be found around the house. In the true meaning of sustainability, these can even be recycled. The space day lesson plan is even lighter on resources, requiring only commonplace 5^{th} grade items such as pencil and paper. However, this re-use of abundant resources is not always possible. In particular, while we originally intended the pulleys lesson plan to involve building pulleys using common household materials, the results do not work well enough to scale to systems involving multiple pulleys. Therefore, we augmented the lesson plan to include store-bought pulleys so students could experiment with the mechanical advantage tradeoffs inherent in real world systems. The magnets lesson plan uses common items such as cups and various metal trinkets, as well as common sand, however to improve the learning experience we needed to include iron filings. These are relatively low cost, and can be recovered and saved between lessons if necessary.

This brings us to the notion of sustainability kits. For each of the lessons which we have created, we have assembled a sustainability kit that the teachers within the WPS can draw from. These kits will include many of the things that are required to implement each of the lessons. They will contain the written portion of the lesson plan as well as materials that may not be easily obtained. The materials within the sustainability kits will be reusable from one execution to the next, such as the iron filings which can be saved after each use and the tuning forks from the sound waves lesson plan.

We have found that many of the WPS teachers have been very reluctant to teach the engineering lesson plans on their own. We have observed that they tend to be turned off by the sole idea that they are teaching engineering, not because the lessons are hard, but because their understanding of engineering has given them a preconceived image of what the lessons will be like. These teachers tend to think that because they have not gone to college for engineering, they can not teach it. However, we have noticed that these teachers are capable of teaching complex science ideas to the students with the aid of their lesson plans. The lesson plans that the teachers use to teach reading are very easy to follow and are far from intimidating. We wanted to use the format of these reading lesson plans in our own engineering lesson plans which we hope will be familiar enough to the teachers for them to feel more comfortable teaching them. Unfortunately time constraints prevented us from fully realizing this goal.

In order to make our lesson plans more accessible to the teachers, we have undertaken the challenge of making a web-accessible Access database of lesson plans. This will enable any of the teachers within the WPS to access these lesson plans quickly, easily, and over the internet. We hope that with the lesson plans on the web, teachers from not only the WPS, but all over the Massachusetts and the United States will have access to a broad base of K-6 engineering lesson plans and ideas. As more states adopt technology and engineering into their curriculum, we hope that these measures will make it easier for not only further projects to continue in our footsteps, but also enable teachers from all over to feel comfortable with teaching this material. We have provided a detailed explanation to the creation process of this database in the following section.

6. Lesson Plan Databases

The most important aspect of the PIEE program is the development and sustainment of curricular materials and to prepare teachers so the lessons can continue to be taught after the grant from the NSF expires. Massachussetts introduced technology and engineering into the states curriculum frameworks in 2001 due to an acknowledgement of the importance of engineering in our modern lives. The importance of engineering in society today is evident in our everyday lives. With engineering firsts such as the Zakum Bridge in Boston, and the latest cell phone technology, to the sudden boom in new products all over the world you can see that various forms of engineering are vital to how the world is run today. Engineering is a vital part of our future and thanks to this program we are able to help young students from the Worcester area learn these key engineering fundamentals. This, in turn, will hopefully improve not only their MCAS scores but their chances of getting a high quality job as well. Now, since we're only on a three year grant for the project here in Worcester the importance of getting the fundamentals established quickly is vital. This statement works on many levels, from the teachers getting the most important tidbits of knowledge solidified in their student's minds to IQP Professors making sure the IQP students know exactly the fundamental principles they need to convey in their lessons. Also, since the turnover rate of the participants in this project is high, good documentation with records of past lessons and projects are vital to the continuing success of the program as a whole as well as easy access to those records. These records will help the IQP students next year, as well as many teachers in the area to come in the future with how to effectively teach the fundamental engineering skills children will need from grade to grade.

6.1 Website Analysis

As explained previously, a good way to help future students and teachers is by having good documentation and records. Good records from year to year with a consistent outline of information will not only make the task of using the lessons in the classroom easier, but it will help make sure that the same mistakes aren't made twice. Right now, the center of all the information on the project and research is in our individual groups. That, coupled with very little communication between groups makes it difficult to develop a central database structure. The PIEE website, which we have as a link of our own WPI website, was first intended to support the program and was not originally meant to contain all the databases we are planning on implementing. This is a problem that we need to fix because it's not only important to share the information and findings we have gathered, but to share it effectively so that it's easy to find, comprehend, and teach. If the information we share isn't shared effectively, then the purpose for the website is lost.

PIEE Website: http://www.wpi.edu/Academics/PIEE/About

Most of the problems with the WPI, PIEE website come from not the interactions of the website, but the information available online. The PIEE website doesn't have enough information for teachers or students on there for it to be used effectively. For instance, there is no database of lesson plans on it, there isn't a clear listing of project expectations, no database of materials, not even a listing of the benchmarks, and no message board for discussions. Without these things, the site remains being of no immediate value to its users.

These aspects are absolutely necessary for the website to be an educational tool as it is intended. Without a database of lessons, teachers and other project groups cannot see what has been done before in the projects. This isn't good because students cannot see what has been done, what's worked, or what hasn't worked in the past, and this leads to a constant "reinventing of the wheel". In addition, without a clear description of project expectations, the teachers and students alike, have no guidelines to base grading of lesson plans on. Also, the frameworks and benchmarks, which all the lesson plans are based upon, are no where to be found on the website. This makes it difficult for the PIEE students to know what information they need to include while developing lesson plans.

In addition, while it is not of equal importance as a database of lesson plans, a message board would truly help the communication between the students, fellows, teachers, and advisors. Having a message board would also enable outsiders to make suggestions or comments that may help. Also, the "About" tab, though a good introduction to the topic, needs a bit more information to help not only with the users' understanding of the project and the sites purpose, but the credibility of the information as well.

On a good note, the visual aesthetics of the website are quite nice and the speed of the site is great, unfortunately it's the lack of information that takes away from the usefulness of this site, as well as its potential. To ameliorate that situation, we have looked at 8 different websites and chose to analyze those that gave us the best ideas, finding both good things to integrate into our own system and negative aspects to keep in mind when developing the site so as not to fall into those same traps. Also, even though you can find information on grade level teams and the people in them, there are no real ways of seeing what they have done or accomplished.

Proteacher.com: http://www.proteacher.com

The website Proteacher.com is a website that caters to teachers of different grade levels, states, and subjects. Because it connects a community of teachers as well, it has many features useful to teachers. This website, like any other, had many positive things on it, but also a few negative aspects. The good things about the website include: an easy interface, community set-up, an ideas archive, a books and materials section, and links to other state education departments. However, it also had a few problems including: not having actual lesson plans, time consuming searches, and not being geared towards national education standards.

Our PIEE website would benefit from including some of the abilities that Proteacher.com includes on its website. For example, the interface is simple with lesson plan ideas separated by grades as well as topics. The website even has information for substitutes to include when teaching in addition to a place to post messages. Because this website was set up by a community of educators, it also has an invention and technology section along with links to assistive websites. This enables teachers to not only come up with engineering type lesson plans, but also gives them the necessary background information to teach the information. Another good thing about the site is that its links to state education departments allow teachers from any state to view the standards set forth by their individual educational departments/school districts without worrying about whether or not they will be of use.

This website, however, also has a few problems with it that make its use not so efficient. One of the main problems is that the website has no actual lesson plans presented on the site itself; it merely gives ideas and links to other sites which may or may not have lesson plans on them. Also, the search engine for the website should be made more efficient as they are quite time consuming as it is. The last problem is that the website isn't geared towards any national standards, which shows itself in that they only have ideas for lesson plans, not the lesson plans themselves.

Utah State University: http://www.engineering.usu.edu

A website designed for Utah State University, this site is not an educational resource website, but it addresses many similar needs in its accesibility. In terms of interface and information availability, the website www.engineering.usu.edu is a good model/standard of what the PIEE website should resemble. While the appearance of it needs to be changed, the information available on the website is among best in all aspects including the ease of searching. In terms of site layout, this would be a good model to follow when making changes to the current WPI, PIEE website.

This website makes finding lesson plans easy while at the same time giving descriptive lesson plans and help options if there are problems. On the website, they have lessons divided by grade ranges: Grades K-2 are in the first level, grades 3-4 are in the second group, and grades 5-6 are in the third group. Along with being easy to find, the lessons are very descriptive and easy to comprehend as well as conveying core concepts exceptionally well.

Despite the great website layout and information given in the lesson plans, there are still things which remain to be improved. For example, while the lesson plans are well developed, there are only 11 lessons for every grade grouping. This is a problem because when they are divided into the individual grades, it only leaves a few lesson plans available for each individual grade level. Also, the lessons only meet the Utah State educational standards. In addition, the website itself is very plain and could use a revamping. This is important because even if the site has the best information, people will not want to spend time browsing the website if it is not eye catching or aesthetically pleasing.

Gateway.org: http://www.thegateway.org

As defined on its home page, Thegateway.org is “a consortium effort to provide educators with quick and easy access to thousands of educational resources found on various federal, state, university, non-profit, and commercial internet sites.” Thegateway.org, like the other websites, has a few good features but has much detraction as well. The positive aspects of the site include the subject coverage, the search method, special links for current events, and its eye catching appeal. However, because this is a government run site, there were lesson plan ideas rather than the actual lesson plans on them.

The best thing to include from this website is its search method. The browser has 7 search categories to help narrow the search. You can browse the website and narrow searching by subject, type of educational tool, grade level, keywords, mediator, beneficiary, and price codes. I found this searching to be very efficient and easy to use. In addition, the website layout was designed so that everything on the site was easy to see and directly connected you to what you wanted.

Another nice feature are the links on the main page relating to events of potential educational value which they “Spotlight”. For example, through out the month of April, Gateway.org featured five environmental links for teachers interested in environmental studies and projects in honor of Earth Day. One link provided ideas for implementing year round environmental projects. They also offered a study guide which addresses environmental issues and include the study of a particular country, its culture, and geography. The site also featured an education program for teachers and students interested in environmental issues. The most creative one was a project in which students analyze their energy use, tally up the costs in dollars and environmental impact, and think of ways to save.

The main problem with the gateway website was in that it didn’t have any actual lesson plans on it. This was problematic because after finding exactly the information you are looking for, you couldn’t print out or even view the lesson plan you wanted. In fact, you had to go search other sites which this site had links to.

Exploratorium.edu: http://www.exploratorium.edu

Exploratorium.edu is a website which is a self-described museum of science, art, and human perception. Its strengths were its amount of topics, having a good amount of hands on activities, the depth of topics, and creativity. The website also had a couple weaknesses which are the number of lesson plans for each topic and having a limited amount of technology oriented activities.

This website was a good website to draw examples from overall. The “Hands-on Activities” section of the site featured many different categories to choose from. The categories offered were: Observatory, Planet Earth, Machines and Tools, Living Things, Food, Sport Science, Human Body, Mind and Perception, Society and Culture, and Activity Collections. Each category had a number of activities relating to it which gave a lot of background information, detailed instructions, discussion topics, and extensions for further study.

The most important aspect of this website to learn from is its creativity. One very creative aspect of it was in its foods category. This category offered recipes, background information on foods, scientific explanations of food, and a section dedicated to candy. This is a very creative way to teach young students scientific concepts because everyone enjoys food. Another creative way to teach science to young students was in the Sport Science section. This category included activities such as rolling feet, twisting feet, science of baseball, science of cycling, and skateboarding.

Drawbacks of the site were its lack of lesson plans per topic and having a limited amount of technology specific activities. While the site covered many different topics, it spreads itself out too much so that they can only have a handful of lessons for each category. Also, the lessons plans offered in the technology category are primarily related to structures. The section has other lesson plan topics, but they don't cover the same technology issues as our program.

Beacon Learning Center: http://www.beaconlearningcenter.com

The Beacon Learning Center is an online, educational resource and professional development center. Like other websites, it has its positive and negative aspects which can both be learned from. Strengths to be taken from this website include simplicity, variety of topics covered, ease of searching, well developed lessons plans, and offered extensions and the concept of learner levels. Negative aspects of the website include its unattractiveness, lack of technology lesson plans and in the fact that it is only geared towards Florida's educational standards. Overall, the important ideas to learn from this website are in its layout and not creativity.

For example, on the home page there were different services to choose from which uncovered a drop down list when the mouse was put over the service. This drop down list had more specific service offerings, such as lesson plans, unit plans, MyClassroom websites, the education standards tree, online articles, and resources & documents under the Teacher Solutions section. The website also covered all types of topics besides the standards, including applied technology, theater, health, dance, physical education, and visual arts. Besides subjects, lesson plans are also divided by learner levels which cover a range of grades relating to general knowledge. For instance, learner level two includes grades 3-5 because they share about the same level of general knowledge compared to grades in higher or lower levels. One more important offering was that of extensions. The extensions are other topics of interest which relate to certain lesson plans and they offer links and background information in case students wish to pursue an interest.

One important piece of learned information from the negative aspects is that of the importance of attractiveness and creativity. Because the site is so boring and simplistic, it gives off the wrong impression of being of lesser value than other educational sites. In this way, teachers browsing the internet may find the website, but pass it on for a "flashier" site with less substance. Also, the applied technology section had just a single lesson plan in the second learner level. This may have to do with the third problem, which is that the lesson plans are meant to only satisfy Florida's educational standards.

6.2 Solution System

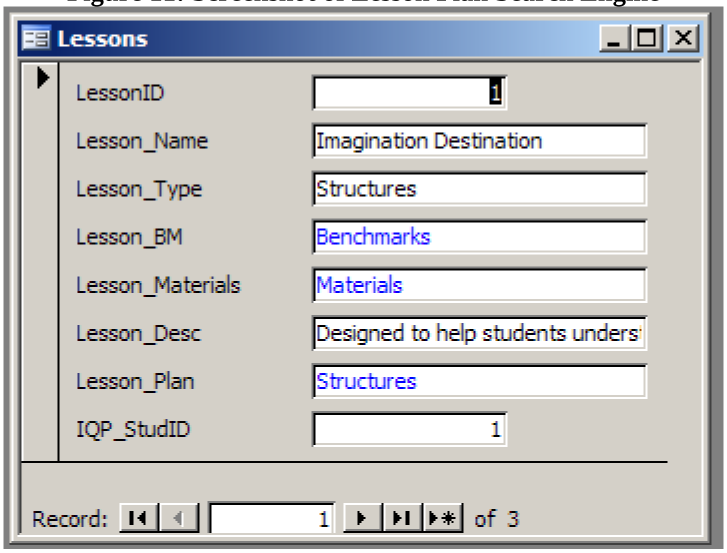
The goal of our system is to create a website which offers teachers a useful tool for educating elementary school students in technology and engineering. It includes many features from small database systems in order to keep track of everything from IQP student information and contributions, to teacher information and of course many detailed, extremely effective and easy to follow lessons. The technology we are using to implement such a system is Microsoft Access with a Visual Basic front end. The website is divided into three main parts: An actual lesson plan database, a section for IQP student/professor information and usage, and a section for the Worcester Public Schools with their information and privileges. There will be some minor sections such as a links page, history page, project information page, etc. as well. Below we have listed the features that will be available on the new PIEE website:

Table 6: Features of new PIEE website

• Easy search criteria
• Lesson plans; with steps, materials, and extensions
• The addition, deletion, and editing of lesson plans
• Links to other educational websites/back ground information
• Specific information on grade level teams during the year
• Information on the schools and teachers helping with the implementation
• A communication forum for all viewers/users of the website

The model for the lesson plan database portion is similar to the Utah State University website. The way that this site is structured and organized is very easy to follow and the lessons are very descriptive. By following the same model, the PIEE website at WPI would allow users to search for all the lessons created by name, grade, creator, benchmarks met, etc. Due to the fact that the information will all be stored in a common form, once lessons are found they are easy to understand and reproduce. Below, in fig. 11, is a screenshot of a lesson search.

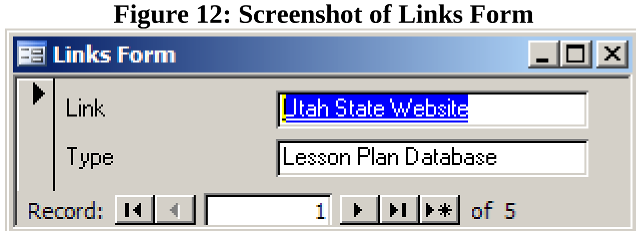
Figure 11: Screenshot of Lesson Plan Search Engine



The lesson plans will be very descriptive and easy to follow for the teachers. Steps, required materials, extensions, as well as all other important information regarding the lesson and background information will be recorded in the lesson plan forms that were provided to us at the beginning of the project. The only problem we foresee with this setup is that the website will be biased towards the Massachusetts academic standards.

A small section that will be implemented in the PIEE website is links to the other websites. These links will contain valuable information regarding teaching methods or lessons that educators can teach to students besides our own. Some links will include helpful background information on various educational topics. Features such as the PIEE program, other programs similar to PIEE, extensions of topic interests, and even links to educational search engines would add value to the site. An additional feature to implement would be a "headlines" or "spotlight" section which would have links to teaching resources relating to seasonal or current events. This would include, for example, having links to programs and projects regarding the environment for the month of April in honor of Earth Day. It would just be a small form list of links, so the overall work needed to create that page will be simple. The screenshot in fig. 12, shows an example. As you can see the link is given with a little description of what type of website it is (whether it's a Lesson Plan Database, Search Engine, and Creative Learning) The buttons make it so you can quickly click through all of the available links on the website.

Figure 12: Screenshot of Links Form



The next major section we plan on implementing is the IQP region with its information and privilege's. This portion will contain contact information for and on all IQP students and professors as well as subsections to talk about grade level teams and their responsibilities. The privileges mentioned previously are the abilities for IQP students and professors to add, delete, or edit lesson plans to and from the database. When adding a new lesson the users will be brought to the form where they will just need to input the information requested on the form. Deleting will automatically delete completely, the selected lesson from the lesson plan database. The editing feature will allow the user to change any or all the information in any or all of the fields of a particular lesson in the database.

Next, the Grade Level Team subsection will have all the information regarding the actual projects taking place throughout the year. Users will be able to view photos of each individual team along with their advisors and fellows. This will include a public discussion board for anyone to add suggestions. Also, all contact information in regards to the individual members, the curriculum map(s) being followed, the benchmarks that are being covered by the group in detail, as well as quick links to the groups lesson plans will all be available in this section. This should help facilitate communication not only within groups, but within the entire project community.

The last section that we have planned on implementing in the new PIEE website revolves around WPS and the analysis of our project’s implementation. Under this section, the users will be able to find out information regarding the schools involved in the project. Information such as the school name, address, teachers involved, their grade and possibly some selected student logs of classroom time analysis will be available for viewing in this section. Also, a message board for the teachers involved is an idea that we would like to include for teacher comments on lessons.

The goal for the new system we have created is to use the analysis we’ve made of the problems and benefits taken from different educational websites and other outlets for lesson plan information, in order to improve WPI's own PIEE website. In the end, the website will be able to benefit many future generations of teachers and students in terms of helping not only the WPS, but everyone all over the United States involved in incorporating engineering and technology in an easy, fun, and efficient way. The lessons supplied for the website will be easy to use and implement as well as find, in order to make the progress of the project as efficient as possible. The IQP students and professors will have the ability to change, create or delete lessons to help with the constant updating of academic standards. The WPS part will include information involving the schools, teachers involved, and analysis of the project from their point-of-view. In this analysis we hope that, if we are unable to, someone could compare MCAS scores in the grades and schools participating in the program from before it started until now and the future to see how successful, or unsuccessful we were.

While a beta version of the final site will be possible for release by the end of D term, a fully functional site, which is also bug free and contains all the past information that could be collected from groups and professors, would have to be another IQP in its own. It is apparent to us that this website could be very effective as a teacher resource for years to come as long as the proper information and features are included.

To create this database we used Microsoft Access due to its powerful capabilities to handle this kind of database. It was organized so that upon arrival to the site you would have a few options on what you would like to do depending on your needs. It would allow for outsiders to be able to search through the database to see all of the different lessons that WPI has to offer for engineering. Also sections for teacher privledges such as adding, editing, or deleting lessons plans, IQP professors, teachers, and students on the project, and Worcester schools and the teachers involved.

The website will act like a search engine for the people involved in the project, the lessons created in the project, and have the ability to search other related sites that have been checked and approved by the project team. Updating the database will be very simple because as I stated before teachers and students will have the ability to add to the database, and IQP professors will also be able to delete and edit lessons their students created as well. Also the IQP professors will be able to add new WPS teachers to the database, in addition to WPS schools.

6.3 Implementation Overview

A complete website plan was slated to be completed with this project; however it became evident that this was too big a task for one person to do alone in seven weeks. Future additions to this database project would best be attempted with knowledge of MIS2720 or higher or knowledge of Microsoft Access and how it works with some Visual Basic experience mixed in. Any MIS major with access to Microsoft Office 2003 Tutorial Book, which can be obtained from Professor Strong at the MIS department, can meet these requirements.

All of the tables and their relationships have been established so that the information in the database is working together correctly. There are six different tables containing various pertinent information fields. These tables are: Grade Team, Professors, Students, Lessons, Links, Teachers, and WPS. Also various queries, forms for the tables, and reports were created to help make the html data access pages that were appropriate for what the site was supposed to do. (See the Technical Analysis from the Appendix of the IQP)

Tables:

Grade Team

The Grade Team table is a small table that records the Curriculum map that an IQP group is working on, along with a picture link that has a picture of the professor and students involved, the ID of the Professor that is working with this group, and the ID of the school that the group is working with.

IQP Professors, Students, and Teacher

These three tables have identical schemas with the exception of a few text fields that are special cases specific to the table. All of the tables contain first and last name of the person being referenced by the record along with contact information. Also the Professors table has a field for their office. The Students table has a field for their major, and the lesson plan created. The Teacher table has a field for the number of years a particular WPS teacher is involved. All tables also give each person a unique ID number for easy access and reference.

Lesson

This table was created to hold the lesson plans that would be the heart of the database. In this table there are links for the Benchmarks for WPS for engineering and technology, the materials needed for the lesson, and the actual lesson outline with step by step instructions and other pertinent information for successful completion of the lesson. Also in this table there are fields for a short description, its name and type and the ID number for the student who created it. Each lesson will also similarly be given a unique ID number.

WPS

This is a small table that keeps information about the schools that are involved in the program. It contains fields for the schools name, address, number of grades involved, and a place for a website if there is one.

Links

This table was created with two fields, one is the actual link to educational websites that we have analyzed thus far this term, and the other is a type field just to make for easier breakdown of the websites.

Queries, Reports, Forms and Pages:

The queries were created to mask the information that the user don't need to see so that we can distinguish between users and administrators (IQP students and professors). This information can then be replicated in the reports so that the information will be presented in a nice easy to read format.

The Forms were created so that the user can update the database without having to actually go into the database and change the fields themselves. Instead an efficient form lets you click each field and enter the information required. Also you are be able to search through the database record by record to keep the amount of information on the screen to a minimum, as well as add and delete records. No need to overload the user with too much information in one spot. From here the forms are then recreated into aesthetically pleasing html pages that make the experience nicer on the senses and allows for the database to be accessed on the internet.

What Needs to be Finished

What is left is some visual basic work so that a main menu can be created along with a module. This will allow for the HTML pages to now be run as a program without having to open them one by one in access. This is the biggest part of the website that needs to be finished along with getting the clearance and approval of the school to put it up. These are issues that are out of our control. Once that is done it's just a matter of getting some user input on the design and if there is anything that could be changed. There is a small bug that requires the links on the HTML pages to work correctly, the work correctly on the forms but not on the HTML pages.

Recommended Additions to the Database

The following improvements can expand the current functionality and usefulness of the database:

1) More queries on information that the user would like to be able to access simultaneously. These queries should be implemented as reports to make them visually pleasing.

2) The database should be populated with real data. This will take a great deal of time due to the fact that there is a lot of information that needs to be updated. The current information is just a test case to make sure that the system works correctly.

3) Some aesthetics such as field sizes on the entities to help make the HTML pages and reports look nicer.

6.4 Database Research Thoughts and Conclusions

During the course of our research we have learned that there is a large amount of engineering information online, in libraries, or in catalogs. We have researched quite a few websites with tens of thousands of websites that have yet to be looked at, and we know the importance of having good resources.

We found websites varying from the really well organized and informative to being extremely unorganized and practically useless. So the sites that we have listed in our appendix and on the website itself, are the ones we found to be the most helpful and informative. Such lists help teachers cut down on the time it takes them to make a lesson because they won't have to waste time surfing the internet for lesson plans or worry about whether a website has valuable information on it.

We feel that the implementation of this new website will help teachers find and create very informative lessons on engineering. The easy to follow forms will make teaching engineering a breeze and the information contained in each lesson contained in the database will have touched upon many basic engineering principles. However, this is only going to be successful if the standards are kept with developing the lessons as well as adding new ones properly. A problem with the constant updating of academic standards is that it could become time consuming as well. Overall, the website is a definite bonus for teachers in that it will be very informative and helpful in regards to engineering. Hopefully, someday this will be used for a model for other educational websites in the future to help further the education of our children.

7. Discussions and Recommendations:

During the past year, we were observers in the Elm Park Community School and Midland Street School classrooms. We noticed that the group dynamics of the students between the two schools are very different. Like night and day. The academic abilities of the students in Elm Park are noticeably below that of the students at Midland Street School. For example, Elm Park's MCAS performance is well below the state average (Last Year's IQP Report). One causal factor is the demographics of the two schools. For the most part, the students at Elm Park come from families in a lower income bracket then the students from Midland Street. We know this because the median income of Elm Park students' families is $31,521 compared to the median income at Midland which is $47,906, both of which are below the state average of $50,107 (25).

Additionally, we found it difficult to motivate some of the students to participate in our lessons. Typically we could motivate students through the use of physical activities such as constructing engineering prototypes; however some consistently failed to be persuaded to join in on our lessons. These students were generally classified by the teachers as "troublemakers".

Although we would love to use physical activities all the time, it is not always possible. This year, the Midland Street School's after school program involved students in a research and writing project. This is because reading and writing skills help children learn. But, as a consequence, much of the work involves sitting in one spot and performing research. Some students found it difficult to sit in one spot to do the research, take notes on their research, and document their sources. Because these skills are important for success in the academic world, and because ability to function in that world is a requirement under No Child Left Behind, this indicates an area that will require a lot of work and patience to help these kids improve.

Near the end of the school, the students were involved in a project fair were they were required to do a research project. Subjects of research included butterflies, jaguars, and the history of the National Football League. One of the IQP students went into the classroom during their scheduled time, as usual, and ended up helping several students perform their research. The teachers were quite upset because the students only had two days to get their information, and some of them had not even started. It was clearly noticeable that the students who had not started their research were not interested in their assigned subject.

As the year progressed, we noticed that when students were told to design something, they wanted to dive right into the materials and build it. To prevent this from happening, the lesson plans specify designing before building. Furthermore, some lesson plans such as the sound waves lesson plan have a design worksheet. This worksheet formalizes the process of designing the prototype on paper first. It reinforces the requirement that the design be finalized before the students can get material. The students were required to complete the design worksheet with a picture, a bill of materials, and a description of how the materials are used. This method worked very well with the students. At first, most students did not know what they were doing, but after some coaxing, we were able to get them to fill out each of the design worksheets before construction.

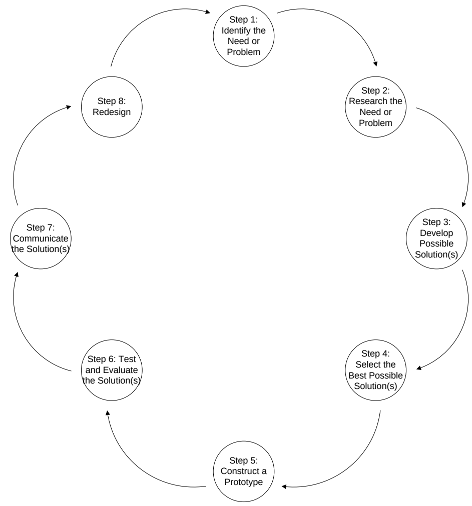
Teaching engineering to fifth graders can be difficult but rewarding. From teaching, we have several recommendations based on our observations. First, we noticed that hands on activities work very well with 5th grade students, and as such, we recommend making engineering lesson plans hands on and fun. Second, to emphasize the engineering process of design, build, test, and redesign, we recommend that the best way to accomplish this with children of this grade level is with a design worksheet. This sheet enables the students to dive into what engineering is really about without having them get into the nitty-gritty mathematical details that real engineers are required to do. Finally, because engineers need to be quite proficient with science and mathematics, we suggest that future engineering lesson plans be incorporated into both the mathematics and science curriculum.

Despite our best efforts to emulate the engineering design process that real engineers use, we feel that not enough emphasis was given to this process during a lesson implementation. We recommend telling students to refer to the engineering design process if they run across a problem while designing, building, and redesigning their creations. There have been many times when students have tested their creations to find that they do not work. Instinctively, these students tended to rebuild their creations. This is the test and redesign portion of the design process. We therefore recommend reminding the students of the link between the design process and their instinctive behavior, thereby reinforcing the link between the two. Later instruction can emphasize the benefits of following the linear sequence of the process.

Creativity is a necessary part of engineering new things, however often this creativity is stifled by the limits of the real world and design constraints. As technology expands new frontiers, it will become ever more prudent for engineers come up with more creative solutions to real world problems. Ideally, teachers should stress the importance of coming up with unique solutions rather than rote learning the “correct” answers. Therefore, as a suggestion to engineering teaching, we recommend that when students have a problem and can’t figure something out, they be given the opportunity to come up with their own solutions rather than being given one by the instructor.

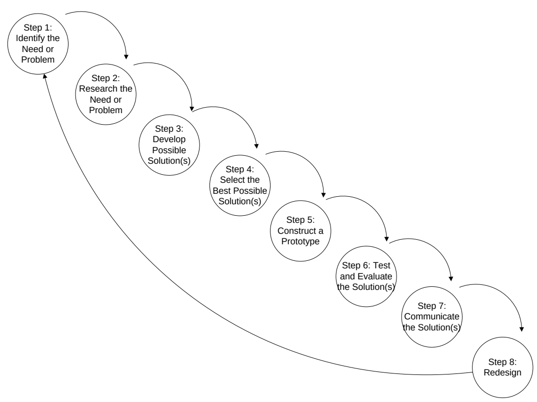
The engineering process itself deserves some contemplation. Processes are not stable, and change to reflect best practices over time. The scientific method is an example of such a change from less stringent knowledge discovery methods to formal provable knowledge discovery. Similarly, the processes by which we design is changing. The current development methodology, shown in figure 13, tends to follow a waterfall design process: evaluate the problem, propose a solution, design the solution, check if the solution works and deploy the solution (26).

Figure 13: 8 Step Design Process



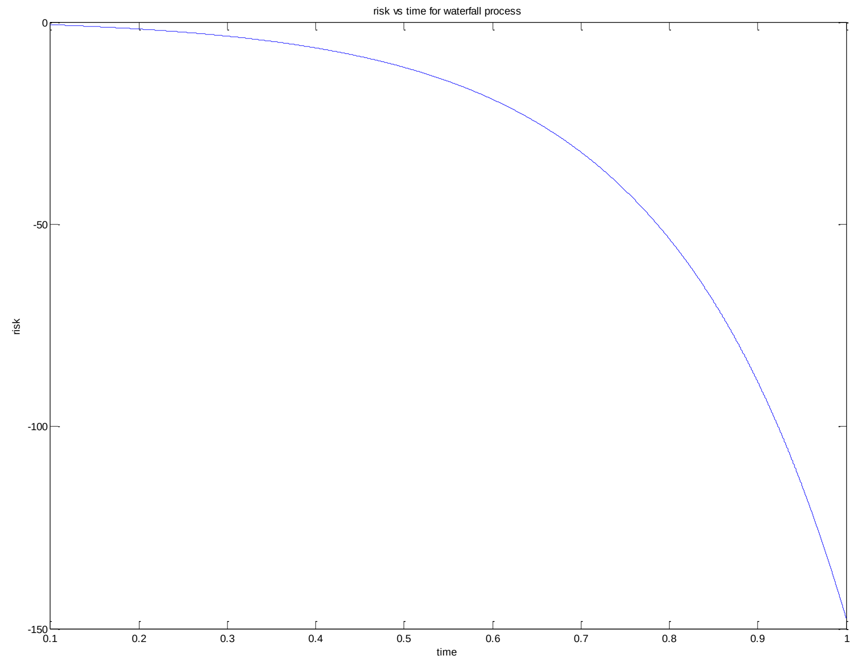
This is called a waterfall process because when graphed against time, each sequential step follows linearly after the previous one, resembling a waterfall. While this process is widely used and forms the basis for our engineering design process, it has flaws.

Figure 14: Waterfall



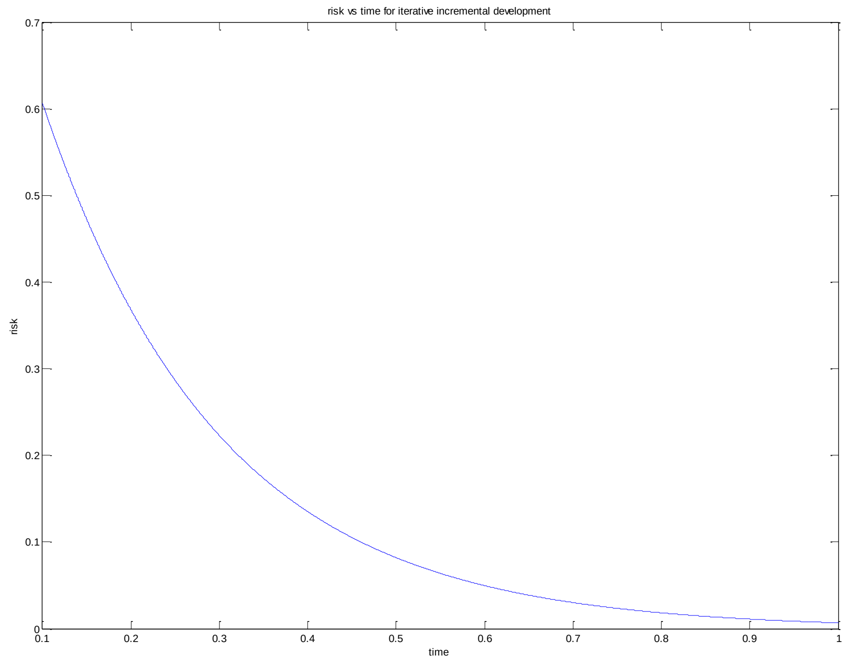
In a design project, one of the main goals is to reduce risk. The waterfall design process ameliorates risks slowly because it is only towards the end where the solution is built and checked. In a real world situation, this means severe problems could be detected at a point where a large resource commitment has already been made to the project. The figure below illustrates this risk falloff. Due to the subjective nature of risk, it should be interpreted qualitatively to illustrate the nature of the problem rather than as actual data.

Figure 15: Risk vs Time Curve for Waterfall Process



Another development process that is growing increasingly popular is known as iterative incremental development. The risk profile of this approach is shown in the figure below. This approach has two characteristics: the project is developed incrementally, with a working product early on and features gradually added, and at the same time it is iterative going through the normal waterfall stages of stating the problem, designing, testing, and deploying in a repeating cycle.

Figure 16: Risk vs Time Curve for Iterative Incremental Development



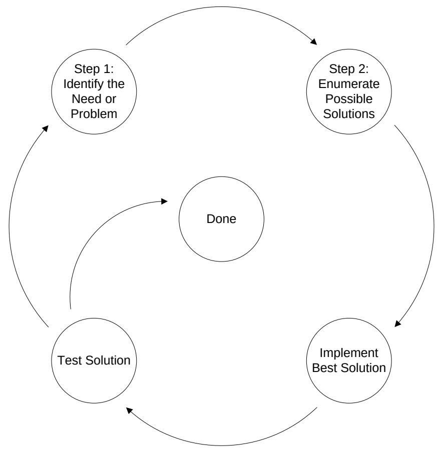
We've come across this methodology, and indeed, the larger agile movement that encompasses it, under many names in different fields. For example, in manufacturing, it is called lean manufacturing. Rather than predicting future demand and stocking warehouses, lean manufacturers attempt to keep their inventory low and produce what is needed when it's needed (27). Similarly, in engineering the process is called concurrent engineering. But beyond simply having a better design process, the agile movement also focuses on simplifying processes so that they are useful to people rather than red tape.

The question is then whether it is important to teach these skills to children. The current engineering design process has too many steps. It uses more than the seven plus or minus two that cognitive psychologist claim that we can handle in our working memory. In addition, the current design process may not represent best practices in many fields. On the other hand, while we can simplify the engineering design process down to four or five steps, fully implementing iterative incremental development may be too complicated at the time. Additionally, there is a question of how well teachers, parents, and the community will accept new teachings that go against what they may have been taught.

To strike a balance, our opinion is that full iterative incremental development should be avoided. However, the engineering development process should be simplified to make it more accessible to children… or indeed anyone. One example of the process reduced to four steps is shown in figure 17. Unlike the current design process being used, this one only has four states. Some of the state minimization occurs from eliminating redundancy. For instance, state eight of the design process being used, which is to redesign the system, can be replaced by a transition to the beginning of the design process. Other states are removed because they are unnecessary. State five of the current design process, which is to construct a prototype, is not necessary for engineering design.

What is necessary is some means of determining whether the design works, which is handled by the next state: “Test and Evaluate the Solution(s).”

Figure 17: Simplified Design Process



Furthermore, other agile values such as those listed on the following table should be gradually integrated into the curriculum.

Table 7: Agile Values

Agile Values

Move Valued	**Less Valued**
Individuals and Interactions	Processes and Tools
Working Products	Comprehensive Documentation
Customer Collaboration	Contract Negotiation
Responding to Change	Following a Plan

This list was taken from (http://agilemanifesto.org/)

8. Conclusions

This project has successfully met the goal of creating 5th grade engineering lesson plans for integration into the Worcester Public School system's science curricula. All of the teachers have expressed delight in the quality of the lesson plans we have produced. The lessons produced were the pulley, space probe, beach combing, and sound lesson plans.

Well educated citizens are important for a civil society. This society is technological, and therefore citizens need to be educated in engineering and technology to be productive members. As such, the Commonwealth of Massachusetts is one of the first states to impose a technology and engineering curriculum. The lesson plans created through this project are a direct result of these benchmarks created by Massachusetts and are designed to meet this need.

Throughout the year, we have gotten to know the teachers and students and we have impacted their lives such that we will not be forgotten. We have assisted students when they did not understand what was being taught. We fought against sleet, ice, and snow days, which are the thief of school time, to teach engineering when teachers were trying to play catch-up in their other subjects. We see the excitement in the students eyes when we arrive, and the disappointment when we leave. We hope that the hard work we have put into this project will allow more students who enjoy engineering the opportunity to discover that something in themselves and someday make a career in the field. We hope that the lessons which we have created will inspire these children to grow outside their comfort zone, push the envelope, and do more than they think they are capable of. We hope.

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Appendices

Appendix A: Lesson Plan Outlines
Appendix A.1: Pulleys Lesson Plan

Lesson Title – Make a pulley system

Grade Level – 5^{th} grade

Lesson Time – 2 hours

Instructional Mode – Whole class

Team/Group Size – 3-4 students

Summary –

Students groups will build pulleys and then use them in combination to construct a pulley system. Students will learn firsthand how a system of pulleys can make work easier.

Learning Objectives –

Worcester Public Schools Benchmarks for 5^{th} grade:

Physical Sciences

05.SC.PS.04 – … Recognize that energy is the ability to cause motion or create change.

05.SC.PS.05 – Give examples of how energy can be transferred from one form to another.

Essential Questions –

- Some students will believe that a single pulley makes work easier. To some extent, that is correct because the pulley redirects work towards gravity, making it appear easier. However, the mechanical advantage gained by a pulley system requires more than one pulley.
- What is mechanical advantage?
- How does mechanical advantage relate to the number of pulleys?
- What tradeoff is involved with mechanical advantage?

Introduction/Motivation –

Procedure –

1. Brainstorm how to create a pulley with common household items.
2. Give pulley system handout to each group as well as materials, and help them construct the pulley.

3. Students should test pulley to see if it makes picking up things any easier when using their pulley.
4. Students should also work with other groups to test arrangements of more than one pulley. Does it make lifting a heavy object any easier?
5. Explain that people who cannot use their legs can use pulleys to pull themselves up stairs.

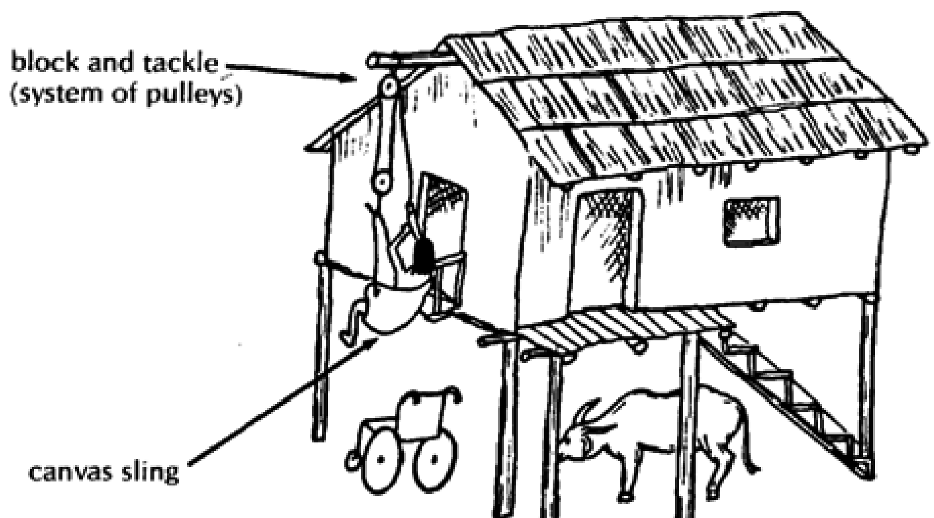

Image from "Adapting the Home and Community"

Ask students to design such a system. Provide a heavy object such as a rock to simulate the person. Also provide a lighter object to simulate the person pulling. When they succeed, make sure they observe the speed at which the two masses move in relation to each other.

6. Ask students to make an observation on effort required versus duration of the effort for various pulley configurations.
7. Give students the pulley design handout.

Materials List (per group) –

- Spool
- Several Pipe Cleaners
- String
- 2 Paper Cups

- A heavy mass and a slightly lighter mass.

Vocabulary with Definition –

Pulley – a wheel or set of wheels with grooved edges over which a rope or chain can be drawn in order to change the direction of a pulling force and increase the capacity for lifting weight.

Pulley System/Compound Pulley/Block and Tackle – A system of more than one pulley, which can provide mechanical advantage.

Mechanical Advantage – The tradeoff made between effort and duration of effort. To say that a machine has mechanical advantage means that the machine changes the effort required to do something, but it also changes the duration of the effort required.

Assessment/Evaluation of Students – Handout

Lesson Extensions –

Troubleshooting Tips –

1. Your masses need to be large enough to overcome static friction.

Safety Issues – None relevant

Key Words – Pulley, Simple Machines, Work

Credits –

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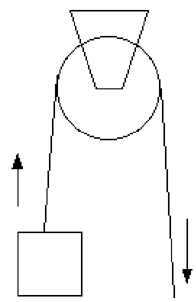
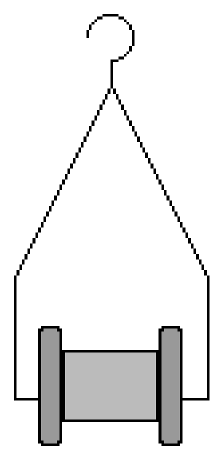
Pulley System

A simple machine is a machine that has only one moving part. A pulley is one type of simple machine. It has a wheel on an axle with a rope thrown over the wheel. This can allow you to pull down on a rope while the rope pulls up.



Simple Pulley

Archimedes was a Greek inventor who made a great many inventions out of simple machines. Legend has it that, with a system of pulleys, Archimedes could lift boats out of the water! Invaders were so afraid of Archimedes' inventions that Greek cities could throw ropes and pulleys around their harbor to scare away invaders who might believe them to be Archimedes' inventions.



You can make your own pulley with a pipe cleaner and a spool for string like this. Have a teacher help you construct your pulley.

Questions:

1. Does a pulley make it easier to lift a heavy object?
2. How does using more than one pulley allow you to lift a heavy object easier?
3. How does the distance you need to pull the string compare to the distance the object moves?
4. Do you think that the legend about Archimedes pulling ships out of the water is true? Why? Or why not?

Pulley Design

What is the difference between scientists and engineers? Scientists perform experiments to learn how the world works, and engineers use that knowledge of how the world works to design new things. Many people are both scientists and engineers. Earlier, you were a scientist experimenting with pulleys. For this exercise, you are going to be an engineer.

Jose weighs 120 pounds. He needs to enter a building, however he cannot take his wheelchair up the steps. Jose is an engineer, so he creates a pulley system so that he can lift himself up. If he uses one pulley, he will need to be able to lift up all of his weight. How many pounds does he need to lift up?

Doubling the number of pulleys decreases the weight that Jose has to pull by half. If Jose adds another pulley to the system, how much does he have to pull? This is half of what he has to pull with only one pulley.

If Jose can pull 70 pounds, will he be able to use the two pulleys to pull himself up?

Unfortunately, Jose can only pull 40 pounds. Draw a pulley system for Jose to lift himself up a set of stairs in the space below:

<u>Pulley Lesson Plan Patter</u>

Teacher: “How is everyone doing today? Does everyone remember simple machines? What are some of the types of simple machines?” … ramp, wheel and axle, pulley, lever, screw

Teacher: “Class, I have a problem. Do you see the cup in front of me? I want to lift it, however I would like to do it without hurting my back”

<teacher makes visible attempts to lift obviously lightweight cup to no avail, holds back in pain>

Teacher: “I have tried using a ramp, but I have to build a very big ramp to push the cup to here” <makes indication at abdomen level> “and my back just can’t take it! Are there any ideas about what we could do?”

<teacher takes ideas… eventually someone suggests pulleys>

Teacher: “A pulley. Good idea! It redirects the force of my motion, allowing me to pull down which is safe for my back in order to pull the cup up.” <points to engineering design process> “What part of the engineering design process have we just completed?”

Teacher: “Right. Ok class, lets form into our groups. We have pencils, spools, paper, pipe cleaner, etc to make a pulley with. Brainstorm designs for a pulley.”

<Afterwards, teacher gives out handout with pulley design we’re using, and kids make that pulley>

Teacher: “What parts of the engineering process have we completed now?”

<class tests pulley and completes archimedes worksheet. Then teacher discusses answers>

Teacher: “Many of you talked about a tradeoff between how easy it is to pull on the pulley and the distance needed to pull. With one pulley, pulling the object wasn’t any easier but with two or more, pulling the object seemed easier, but you had to pull farther to lift the object. This is called mechanical advantage. More mechanical advantage means it’s easier, but takes longer.

Do you think adding more pulleys creates more mechanical advantage or less?”

<class responds>

Teacher: “In villages in other countries, they do not have elevators. What is one way that a person in a wheelchair could get up stairs using a pulley?”

<class responds>

Teacher: “We are going to design a pulley that a person could use to pull himself up to a raised platform. This rock will represent the person. You need to design a system to easily pull the person up this distance <measures out about one to tw feet with hands>”

<class finishes activity>

Teacher: “By the way, elevators use pulleys too. But unlike what we’ve designed, elevators are pulled by motors.”

<give class pulley design handout>

Grading Rubric to evaluate student work

Students	Never (1)	Sometimes (2)	Often (3)	Always (4)	Points
Students were able to design their pulley on paper without having the supplies.					
Students successfully build their pulley.					
Students understand how their pulley construction project relates to the design process.					
Students successfully build pulley system.					
Students understand the tradeoff inherent in mechanical advantage.					
Students answered questions concisely in their own words.					
				Total Max 24	

Appendix A.2: Sound Waves Lesson plan

Lesson Title- Make a Musical Instrument

Grade Level- 5th Grade

Lesson Time- 2, one hour sessions

Instructional Mode- Whole Class

Team/Group Size- Pairs

Summary –

Students will be taught basic instruments and examples of them. They will also be taught the relationship between vibration and sound, and the difference between high and low pitch. Finally, the students will be supplied with different materials such as rubber bands and bottles. They will use only those materials to make an instrument that can make sound. It will show the students that sound can be produced in many different ways, but that it always has a vibrating source.

Learning Objectives

2002 Worcester Public Schools Benchmarks for 5th grade:

<u>Physical Science</u>

05.SC.PS.05- Recognize that sound is produced by vibrating objects and requires a medium through which to travel. Relate the rate of vibration to the pitch of the sound.

05.SC.PS.06- Use tuning forks to demonstrate the relationship between vibrations and sounds.

<u>Technology/Engineering</u>

05.SC.TE.06- Identify relevant design features (i.e., size, shape, weight) for building a prototype of a solution to a given problem.

Essential Questions-

How do instruments make sound?

Introduction/Motivation-

Ask the students to explain how instruments make sound. Reinforce the fact that sounds originate from vibrating sources. To demonstrate this, use a tuning fork. Tap the tuning fork so it hums, then place the bottom (handle) of the tuning fork on a hard surface like a desk top. The sound from the tuning fork should be quite audible. To demonstrate that the tuning fork is vibrating, strike the tuning fork and then quickly put it into a cup of water. The water should splash. If it is put into the water slowly, small ripples can be seen.

Procedure-

1) Write on the board the 4 basic types of instrument. The 4 basic types are woodwind, brass, percussion, and string. Ask the students if they know the difference between each of the instruments.
2) Show the students the provided pictures of different instruments. Make sure the students can recognize the difference between the instrument types. Ask any of the students if they can tell you how the instruments vibrate to make sound.
3) Using the tuning fork, ask the students what they think would happen if the tuning fork vibrated faster or slower when it is struck. The speed of this vibration is known as pitch and the faster the vibration, the higher the pitch. Sounds with higher pitches, sound higher than those with lower pitches. A flute, with a high sound, has a higher pitch than a tuba which has a low sound and thus a lower pitch.
4) Ask the students how the sound gets from the object to your ears. It travels through the air as a wave. A sound with a higher pitch would have faster waves as compared to a sound with a lower pitch which would have slower waves.
5) Using a slinky, stretch it out while keeping it suspended in the air. Have one student hold one end of the slinky. At the other end, move the slinky up and down slowly. A wave should move from one end to another fairly slowly. Tell the students that sounds move through the air in the same fashion as the wave moves through the slinky from one end to another.
6) Start moving the slinky faster so that the wave moves back and forth faster than before. Ask the students if the new wave pattern has a higher pitch or lower pitch than before. Ask the students how you could make the pitch even higher, and how you could make it lower.
7) Tell the students that they will now be designing a musical instrument. Hand out the first worksheet. Write on the board the materials which will be provided. Tell the students that using only the materials on the board, design an object that can make a sound in the same way that one of the types of musical instruments do. On the worksheet they should identify each material used and how it contributes to the sound it will make. To get the student's imagination going, show them an example which has been made before the class (This is optional depending on the teacher's teaching style).
8) Once each student has completed the first worksheet, hand out supplies to the students so they can begin building their instrument. Make sure that the supplies aren't handed out until each group has a design on paper. This emphasizes the design process before building a prototype.
9) After the students have built their instrument, they should test it to see how well it makes sound. They should then fill out the second worksheet. This second worksheet will test the student's knowledge of sound waves and instruments.

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

Rubber bands, plastic bottles, craft sticks, toothpicks, wax paper, plastic wrap, string, masking tape, paper plates, plastic cups, beads, tuning forks, slinky.

Vocabulary with Definition-

String Instrument- A musical instrument that uses vibrating strings to produce sound.

Woodwind Instrument- A musical instrument that uses the motion of blown air to produce vibrations, and thus sound. Does not actually need to be made of wood. Flutes and saxophones are woodwinds.

Brass Instrument- A musical instrument that uses the musicians vibrating lips to produce sound. Does not actually need to be made of brass.

Percussion Instrument- Is a musical instrument that produces sound by being struck.

Sound (Sound Wave)- Is a weak pressure wave which moves your eardrum which enables the brain to decode and allow you to perceive it as sound. It moves through the air like a wave does through water.

Pitch- The way we tell the difference between sounds. High pitch is synonymous with a "high" sound (soprano), while low pitch is synonymous with "low" sounds (bass). High pitch sounds have a higher frequency in their sound waves, while low pitch sound have a lower frequency in their sound waves.

Vibration- The method in which sound is produced.

Assessment/Evaluation of Students-

At the end of the lesson, students are given a worksheet which is to be graded. The work sheet tests the student's general knowledge of musical instruments and tests key concepts such as pitch. In addition, a grading rubric is provided to give a guideline to further grading.

Lesson Extensions-

Troubleshooting Tips-

Safety Issues –

Care should be taken if students are using scissors to construct their instrument.

References-

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Making Your Own Instrument

Procedure Worksheet

Name______________________________ Date:___________________________

Directions: Using the materials listed on the black board, design a musical instrument. Write down what each material does and how it contributes to the way your instrument sounds.

Material Used	How is it used?

Draw a picture of your instrument in the space below.

Making Your Own Instrument

Questions Worksheet

Name___________________________ Date:_________________________

Directions: Match the following pictures with the type of instrument. Then answer the questions.

1)  ___________

2)  ___________

3)  ___________

4)  ___________

Type of instrument

A) Wind Instrument

B) Brass Instrument

C) Percussion Instrument

D) String Instrument

1) How could do you change the pitch of a guitar when you are playing it?

2) How does a drum make sounds?

3) How does your voice make sound?

Grading Rubric to evaluate student work

Students	Never (1)	Sometimes (2)	Often (3)	Always (4)	Points
Students were able to design their instrument on paper without having the supplies.					
Students showed that they understood the use of each material they used in their instrument.					
Students were able to build the instrument that they had designed on paper.					
Students tested their instrument and made changes to make it better.					
Students understood what pitch is and know how to change the pitch on instruments					
Students are familiar with the vocabulary (woodwind, pitch, brass, percussion, etc…)					
Students answered questions concisely in their own words.					
				Total Max 28	

Appendix A.3: Beach Combing Lesson Plan

Lesson Title – Beachcombing for Iron

Grade Level – 5th grade

Lesson Time – 1.5 hours

Instructional Mode – Whole class

Team/Group Size – 3-4 students

Summary –

Students will use magnets to comb a small sandbox to find iron alloys as well as other magnets. They will also determine what metals magnets are attracted to and what metals they are not. In doing this, they will learn about design of filters based on physical properties of objects.

Learning Objectives –

Worcester Public Schools Benchmarks for 5th grade:

Physical Sciences

05.SC.PS.09 – … Recognize that magnets have poles that repel and attract each other.

05.SC.PS.10 – Identify and classify objects and materials that a magnet will attract and objects and materials that a magnet will not attract.

Essential Questions –

- Some students will believe that magnets attract all metallic objects. Hopefully this will persuade them otherwise.
-

Introduction/Motivation –

Procedure –

1. Fill a shallow box with sand and embed small metallic objects within the box. Iron filings are highly recommended as well, however if they are used, make sure the magnets are kept inside zip-lock bags. It is very difficult to remove iron filings once they have attached to the magnet.
2. Have students brainstorm a method to find the objects within the box with a magnet.

3. Have students comb the box with their inventions and determine what metals the magnet picks up.
4. Ask students what metals the magnet does not pick up. Are there any differences between the ones that get picked up and the ones that do not?
5. Brainstorm how to get the objects out without using a magnet.
6. Either use a strainer or the kids' own inventions to filter sand. A strainer for this purpose can be constructed from a paper bag with holes punched at the bottom.

Materials List (per group) –

- Box
- Magnets
- Iron filings
- Various metallic objects, some which contain iron and some which do not
- Sand
- Paper bag

Vocabulary with Definition –

Magnet -- A device that can attract or repel pieces of iron or other magnetic materials.

Pole – "one of the two ends of a magnet where the magnetism seems to be concentrated" (Webster)

Attract – Wanting to come together.

Repel – Wanting to push apart.

Filter – The process of separating things from a mixture.

Assessment/Evaluation of Students –

Lesson Extensions –

Troubleshooting Tips –

Safety Issues – Use magnets weak enough so that they can't severely pinch skin.

Key Words – Magnetism

Beachcombing

The process of separation is known as filtering. You do it every day, separating peas from mash potatoes, or quarters from cents. Chemical engineers, industrial engineers, electrical engineers, and many other types of engineers need filtering to do their job. For instance, a chemical engineer needs to be able to separate one chemical out of a mixture of many. An industrial engineer may need to separate pollutants out of factory smoke, so that the air stays clean.

Questions:

1. What objects can you separate from the sand with a magnet?
2. Examine the objects that are attracted to the magnet. What do these objects have in common?
3. Are all metals attracted to magnets?
4. Are magnets attracted to magnets? Are they repelled?
5. How do engineers use filters?
6. How do you use filtering in your life?

Grading Rubric to evaluate student work

Students	Never (1)	Sometimes (2)	Often (3)	Always (4)	Points
Students were able to design their filter on paper without having the supplies.					
Students understand that there are magnetic and non-magnetic objects.					
Students realize that in order to remove iron filings, they need to use a magnet.					
Students determine a method to sort the sand from all objects being used.					
Students successfully build and test their filter.					
Students can name other filters that they or other engineers use in daily life.					
Students answered questions concisely in their own words.					
				Total Max 28	

Appendix A.4: Space Probe Lesson Plan

Lesson Title- Design a Space Probe

Grade Level- 5th Grade

Lesson Time- ?

Instructional Mode- Whole Class

Team/Group Size- Individual

Summary –

Using basic restraints, such as mass, destination, and science objectives, the students will design a space probe. They will give justification for their decisions on mass, destination, and science objective along with drawing a picture of their probe. Please note that a lot of information is provided in this lesson plan. Most of this information is geared toward the teacher (and is provided simply as a resource) so that he/she has sufficient knowledge to execute this lesson.

Learning Objectives

2002 Worcester Public Schools Benchmarks for 5th grade:

05.SC.ES.08 Recognize that the earth is part of a system called the "solar system" that includes the sun (a star), planets and many moons. The earth is the third planet from the sun in our solar system.

05.SC.TE.01 Identify materials used to accomplish a design task based on specific property, i.e., weight, strength, hardness, and flexibility.

05.SC.TE.06 Identify relevant design features (i.e., size, shape, weight) for building a prototype of a solution to a given problem.

Essential Questions-

-How can you overcome the challenges of spaceflight in order for your spacecraft to achieve its mission of exploration?

Introduction/Motivation-

Show them pictures of planets and space probes. Tell them that the probes are built here on earth by engineers and are then sent into outer space. Tell them that they are going to design their very own space probe.

Procedure-

1) Have the students pick a planet (or moon) and have them do some research on the planet. They should know where the planet is, how many moons it has, if it has an atmosphere, and whether or not it is a gas planet, or a rocky planet. They should also do research about space probes that were sent to the planet and think of what kind of space probe they would like to design. This research can be done

at home or in class, which ever the teacher would find more appropriate. The research worksheet provided should give good guidance to what the students should do.

2) Instruct the students on the solar system. Inform them that space probes are sent all over the solar system and that they each have their own challenges to overcome. The following objects that are in Bold and Italics should be taught to the students. They are the basic things that need to be considered when building a space probe. They include radiation, temperature, electricity, propulsion, and science package. There is probably quite a bit of information to go through all of it, but the students should at least understand what role each of them have on spaceflight.
3) **Radiation:** All probes need to be able to be protected against radiation. Probes closer to the sun will receive more radiation than those further away, and will need more shielding (In reality, large planets with strong magnetic fields, such as Jupiter, also have strong, and dangerous radiation belts. For this project, however, we will ignore these radiation belts and assume that only probes going close to the sun need extra radiation shielding).
4) **Temperature:** All probes need some kind of temperature control device. Probes going close to the sun need a cooling system, while probes going out past Jupiter need a heating system (this is abstracted; in reality most probes need both). This bit of information is for reference and is hard to draw on their spacecraft. The students should still know that temperature influence space probes performance and design.
5) **Electricity:** All probes need to have electricity to function. For probes that are close to the sun (Mercury – Mars), Solar Cells can usually provide enough power. However, as the probe gets farther away from the sun, the amount of power that can be received through solar cells drops drastically. Probes that go far away from the sun (Jupiter – Pluto and beyond), need other power sources such as Nuclear Batteries (Radioisotope Thermal Generators, or RTGs, (this is a minor technical detail that the students do not need to know)).
6) **Propulsion:** All probes need some kind of propulsion device. For the most part, booster rockets are used to hurl the probe towards the planet with enough speed that an additional large propulsion unit is not needed. Mission planners will usually also make use of the gravity of other planets to slingshot the probe on a new path with a different speed. This enables the probe to reach farther places with a smaller amount of fuel, but it usually takes longer compared to a direct flight path. For this lesson plan the students will not need to worry about how their probe gets to their planet of interest, however, it should be noted that all probes are equipped with a small propulsion unit which enables it to perform course correction maneuvers and orbit changes once it arrives at its target.
7) **Communication:** Every space probe needs some kind of communication system which allows the probe to communicate with its controllers here on Earth. Probes which remain close to the Earth can usually get away with having just large antennae, however, the farther the probe gets from the Earth, the weaker the radio signal gets. For probes which explore the outer solar system, they need to have large radio dishes instead of antennae.

8) **Science Package:** Finally, all probes need some kind of science instruments to fulfill its mission. The kind of science instruments that a probe will have is dependant on its mission. Several types of instruments are given below.
9) *Cameras:* Cameras are always a good choice to put on a space probe, especially if it's the first time that a probe has visited a particular type of object. These could also include Infrared cameras which show the temperature of the object.
10) *Spectrometer:* Spectrometers are useful devices that can detect the individual elements that are present on an object at a distance. If a probes mission is to find water or oxygen on another planet, it will most defiantly have a spectrometer of sorts, or a similar device.
11) *Radar:* Radar is a useful tool for mapping the surface of a planet that is obstructed with clouds (like Venus). They are used primarily as a way to texture map large areas (i.e. hills and valleys etc…). They are also a useful tool for determining the distance to an object.
12) In class, each student will design their space probe individually. They will do this by filling out the worksheet provided.
13) The students should have a science objective for their probe such as looking for water, mapping the surface, or determining the chemical composition of the planet's atmosphere. They should recognize what kind of science instruments their probe will carry to achieve this mission.
14) The student should be able to understand why probes succeed, and why they fail. What kind of chances does their probe have on completing its mission?
15) Finally, the students should draw a picture of their probe. What does it look like? (A probe with solar cells should show them on their drawing) What does it need on the outside to achieve its mission? (Can you see the cameras and other instruments? Can you see the propulsion device? Etc...)

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

The worksheets and coloring supplies

Vocabulary with Definition-

Space probe: A spacecraft which carries advanced equipment and tools to explore the bodies of the solar system.

Rocket Motor: A device which converts chemical energy into kinetic energy. Used to maneuver spacecrafts.

Orbit: The path a spacecraft takes around the sun or a planet.

Power Generation

Solar Cells: An array of light sensitive panels used to generate electricity.

Nuclear Batteries: A battery that generates electricity from the decomposition of nuclear materials such as uranium or plutonium.

Space Hazards

Radiation: Solar and cosmic radiation are high speed particles that tend to damage computers and harm living creatures.

Extreme temperatures: Space has extreme temperatures which a spacecraft needs to be protected against. Temperatures range from -170 degrees Celsius in shadow, to 350 degrees Celsius in sun light (-238 F – 662 F).

Science Instruments

Spectrometer: A scientific tool used to determine elements within materials.

Radar: A device which uses radio waves to calculate a distance to an object.

Infrared Sensors: A tool which is used to determine the temperature of an object at a distance.

Assessment/Evaluation of Students-

Students are graded on their creativity, knowledge of the design process, and ability to remain on task. The worksheets which they will complete will play a key role on evaluating the students.

Lesson Extensions-

None

Troubleshooting Tips-

Safety Issues –

No Issue

References-

http://www.worldspaceflight.com/probes/
http://www.firstscience.com/site/articles/power.asp
http://www.encyclopedia.com/index.asp
http://www.spacetoday.org/SolSys/Voyagers20years.html
http://www.space-odyssey.de/graphics/cassini.jpg
http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=2001-014A
http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=1998-061A

Research Worksheet

Name__________________________ Date:________________________

What planet will your probe explore?

Where is this planet?

How many moons does this planet have?

Is your planet rocky or gaseous?

Does your planet have an atmosphere?

What is the atmosphere made of?

Have any space probes been sent to this planet before?

Why do you want to send a probe to this planet? What will the probe do?

Design Worksheet

Name___________________________ Date:_________________________

Using the information from your Research Worksheet, design your space probe on this sheet.

1) What kind of radiation protection does your probe need? Why?

2) What kind of temperature control device (heater/refrigerator) does your probe need? Why?

3) How does your probe generate electricity? Why can/can't your probe use solar cells?

4) What kind of scientific instruments does your probe have? How do they help the probe achieve its mission?

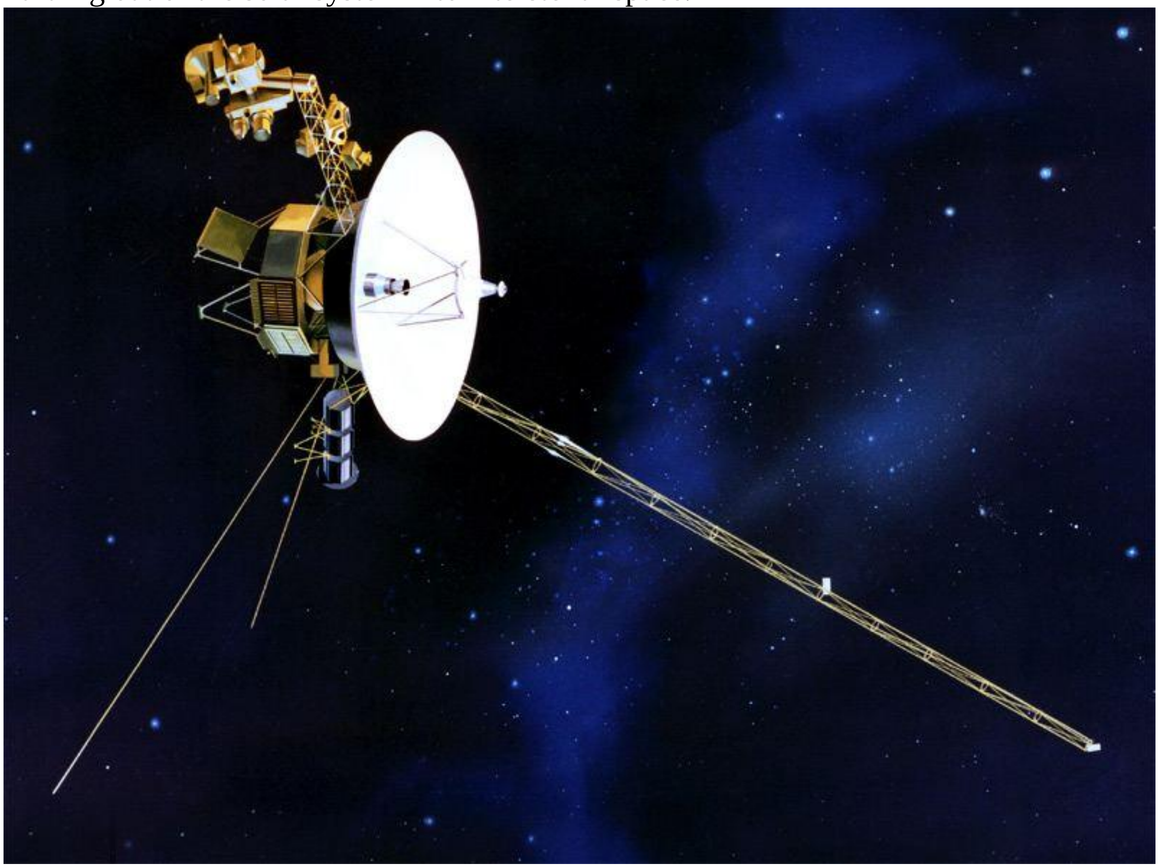
5) Draw a picture of your probe. Make sure to include power devices (solar cells), propulsion units, and scientific instruments.

Grading Rubric to evaluate student work

Students	Never (1)	Sometimes (2)	Often (3)	Always (4)	Points
Students performed preliminary research and gathered useful data about their planet of interest.					
Students used the information gathered to determine a useful science goal for their probe.					
Students showed that they understood the different components of a space probe in their design.					
The students drawings was representative of the probe that they had designed.					
Students remained on task with the assignment.					
				Total Max 20	

Voyager Space Probes:

The twin Voyager space probes (Voyager 1 and 2) are the farthest human made object in the universe. They were both launched in the summer of 1977 and were used to explore the outer solar system. Voyager 1 flew by both Jupiter and Saturn, while Voyager 2 flew past Jupiter, Saturn, Uranus, and Neptune. Both probes are currently hurtling out of the solar system into interstellar space.

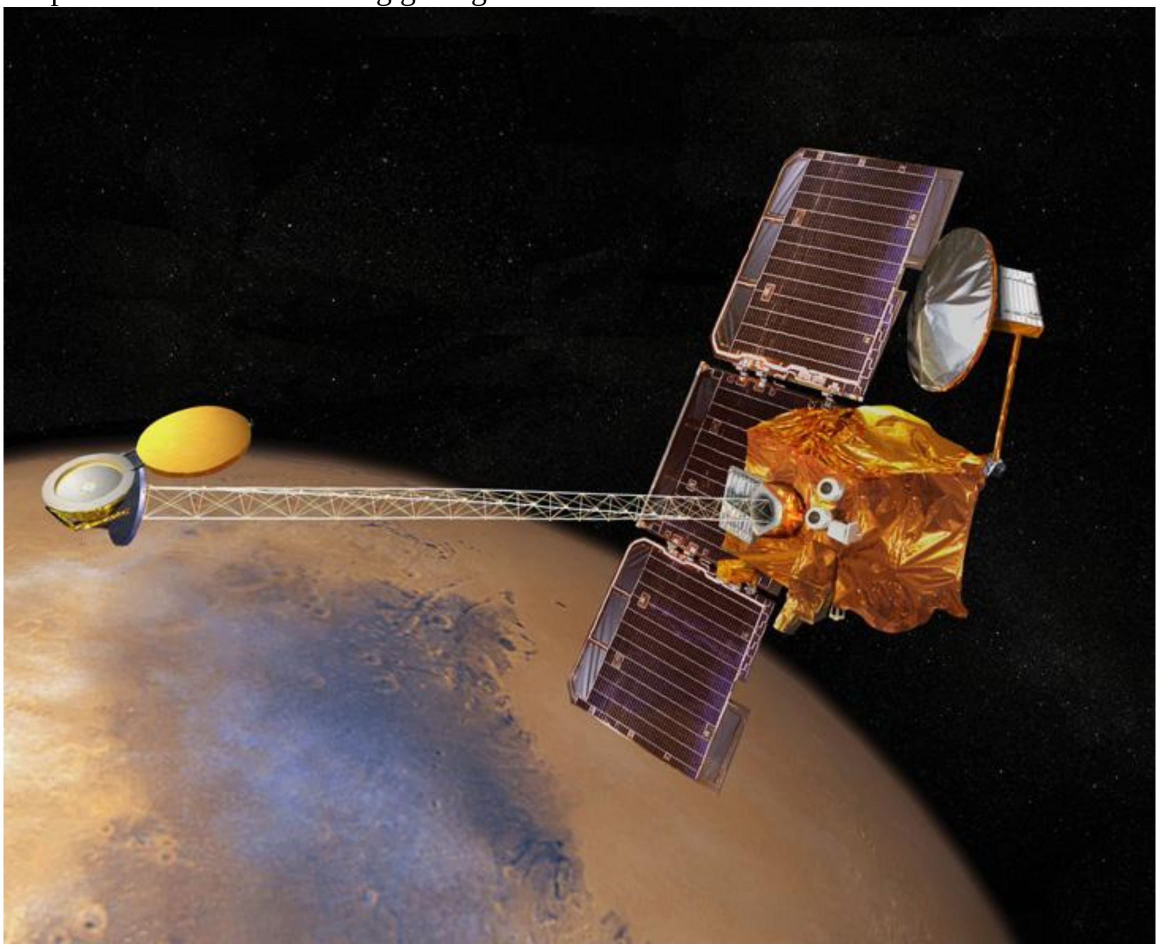


Cassini Space Probe:

The Cassini space probe is the latest success in the string of NASA space probes. Currently, the vehicle is orbiting the planet Saturn. It carried a small lander built by the ESA (European Space Agency) called Huygens. The lander detached from Cassini and entered the atmosphere of Titan, Saturn's largest moon, to conduct experiments on the atmosphere.

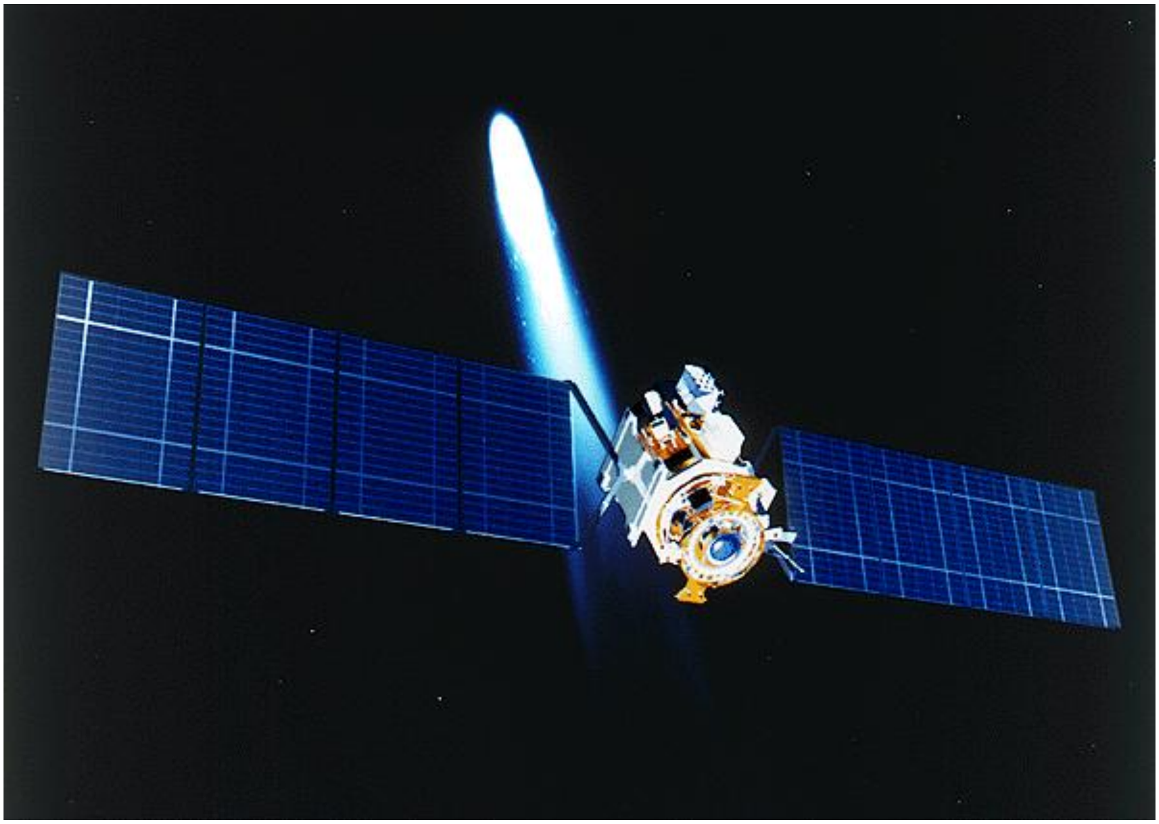
Mars Odyssey:

Launched in 2001, the Mars Odyssey space probe is currently orbiting the planet Mars. Its mission is to conduct a survey of the radiation environment along with mineral analysis of the planets surface. It's primary mission is to determine if the mineralogical data allow the possibility of life on mars at some point in its past. Currently, it is acting as a communications relay to the two Mars Exploration rovers that are currently roaming the planets surface conducting geological measurements.



Deep Space 1 Probe:

The Deep Space Probe 1 was an experimental probe which was used to test new space probe hardware. It tested a new mode of propulsion (the ion engine), along with other science tools and computer software. It flew by both a comet and an asteroid which were close to earth at the time.



Appendix A.5: Structures Lesson Plan

Lesson Title -- Destination Imagination

Grade Level – 5th Grade

Lesson Time – 2, 1 hour periods (1st hour for brainstorming and make rough structure, second hour to make finalized structure. A one week break between sessions will be needed). If time permits a few adjustment to the schedule can beneficial.

1. Allow for time to test prototype/final structure (10 minutes day after to allow glue to dry)
2. Allow for time to brainstorm final design (5 min a day)

Instructional Mode -- small groups (4-6 students)

Team/Group Size – 4-6 students per team with 3-5 groups (depending on number of students)

Summary – Groups will compete to see who can make a structure made of nothing more than glue, and wood. The object is to create a structure that is able to hold a decent amount of weight. The object will be to create the smallest structure to hold the most amount of weight. A ratio will be taken to find the highest. Bonus points will be awarded to the team with the closest guess of what their structure will actually hold without breaking.

Learning Objectives – After completion students will have a better understanding of how everyday structures are built and how different engineering designs can be effective in holding up weight. The can then take these principles and relate them to everyday structures that they can see in the real world. Also you can discuss the importance of Civil Engineering and how they start with ideas like these that end up producing some of the magnificent structures we see today.

Essential Questions -- subset from unit plan

Introduction/Motivation – Show how simple structures like a stepping stool can be the start of other more complex engineering designs such as bridges and skyscrapers. Have students name simple structures that hold weight. Let the students know the importance of structural safety and importance of civil engineering and the engineering process as a whole.

Procedure –

The Problem –

Skyscrapers are one of many magnificent man made structures we see today. Mr. Gramzow is the CEO of Gramco, a new up and coming Videogame Company. He has a lot of heavy equipment needed to help create fun and entertaining videogames. Now he is looking to build a skyscraper in Worcester to set up his headquarters. Here’s the problem, though, Gramco’s equipment is extremely heavy so he needs a group of engineers to design for him the frame of a floor structure strong enough to hold the company's equipment.

The Task –

Using the $100 that your group has for a budget come buy materials (wood and glue) to build a small model of what your floor frame would look and act like. The structure you make as a group will be tested by Mr. Gramzow himself to see if he could use the structure for his skyscraper. GOOD LUCK!!!!

1 Have the groups assign the different jobs*.
2 Lay out all the wood and glue materials at the store **. Have students purchase materials needed.
3 Brainstorm on how to make the structure (about 5 min).
4 Get a few different ideas and choose one as a group.
5 Draw the prototype design on the worksheet.
6 Build the prototype and take dimensions.
7 Test and take observations of the prototype.
8 Deliberate with group over possible flaws and improvement.
9 Take a week to brainstorm with your group on how to improve the design and make a final solution.
10 Once all the final structures are built do the contest.
11 Before the final test take the groups guesstimate.
12 Do the finish testing, and have the groups finish up the worksheet/

* Jobs are as follows:

1) Head Engineer – polls the group to decide on final and prototype designs.
2) Financial Advisor – take care of groups finances and buys materials as directed by group.
3) Secretary – Fills out worksheet and takes down important data.
4) Material Handler – responsible for safety of structure and all extra materials the group has.

** Store Prices:

1) Wood = $5 an oz.
2) Wood Glue = $25 a bottle
3) Elmers Glue = $10 a bottle

Materials List –

1 Popcicle sticks, various sizes (donation)
2 Glue

Vocabulary and Definitions – (to come later with revising with teacher)

Assessment and Evaluation – Points will be awarded as follows for the specific criteria:

The Three Criteria:

1) Structure built to guidelines (75 pts total)
2) Worksheet (25 pts total)
3) **BONUS** (up to 15 bonus pts)

Structure Guidelines:

1) Weight * (up to 25 pts)
2) Size ** (up to 25 pts)
3) Originality and Creativity*** (up to 25 pts)

* Check weight scale below
** Check size scale below
*** Check contest below

<u>1) Weight Scale:</u>

Pts.	Weight (oz)
25	7 >
20	7-10
15	10-13
10	13-15
5	16
0	16+

<u>2) Size Scale :</u>

Rank the structures from smallest to largest in total area. From here the lowest three get the top point prizes and the rest of the groups get runner-up pts.

1st – 25 pts
2nd – 20 pts
3rd – 15 pts
Runners-up – 10 pts

<u>3) Originality and Creativity Contest :</u>

Have the class at the beginning of the second part of the lesson show off their final structures. Then have the class vote on which one looks the most original. The top two groups get 25 pts. The rest of the teams will receive 20 pts.

<u>Worksheet</u>:

Grade worksheet on whether or not all the questions were completed. (To be completed with teacher)

<u>BONUS</u>:

Top three closest guesses to the actual weight receive special bonus points as follows:

Closest – 15 bonus pts

2nd Closest – 10 bonus pts
3rd Closest – 5 bonus pts

Lesson Extensions – A suggestion might be to include a short essay on the importance of the engineering process and how the steps that they took helped them in the end to achieve their goal.

Attachments – Worksheet

Trouble Shooting tips- after first experiments

Safety Issues – Careful of splinters and only teacher or aid should handle weights.

Redirect URL – www.destinationimagination.org

Key words – go over with teacher.

Appendix A.6: HotWheels Lesson Plan

Lesson Title – HotWheels

Grade Level – 5th Grade

Lesson Time – 1 hour period

Instructional Mode -- small groups (4-6 students)

Team/Group Size – 4-6 students per group with 3-5 groups (depending on number of students)

Summary – Use hotwheels tracks to show how force is used on a plane (or incline). How weight will relate to speed depending on how much a toy car weighs.

Learning Objectives – After completion students will have a better understanding of how the weight of an object

Essential Questions -- subset from unit plan

Introduction/Motivation – Show how people use hills for momentum, like in box car racing or street luge.

Procedure –

1.) Get three cars of different weights
2.) Make a ramp for each group of equal height
3.) Guess which car will go down fastest and travel a foot the fastest
4.) Shoot all three cars down the ramp and take stats.

Materials List –

Hotwheels cars of different weights, ramps

Vocabulary and Definitions – (to come later with revising with teacher)

Assessment and Evaluation – Each student must write a summary what their guess was and why.

Lesson Extensions – NA

Attachments – NA

Trouble Shooting tips- after first experiments

Safety Issues – none

Redirect URL – none

Key words – go over with teacher.

Appendix A.7: Where Colors Come From and How Mirrors Work Lesson Plan

Lesson title: Where Colors Come From and How Mirrors Work
Grade Level: 5th
Lesson Time: 1 hour
Instructional Mode: Individual work

Summary: Students will learn about how light reflects and refracts off objects depending upon certain characteristics. They will gain a simple understanding of the dispersion of light through the use of prisms as well as a basic understanding as to why mirrors and lenses work the way they do.

Learning objectives: 2002 Worcester Public Schools Benchmarks for 5th grade

- 05.SC.PS.07 – Recognize that light travels in a straight line until it strikes an object or travels from one medium to another, and that light can be reflected, refracted, and absorbed.
- 05.SC.PS.08 – Use a flashlight, mirrors, and water to demonstrate reflection and refraction.

Essential questions: Many young students will often ask such questions as "Why is the sky blue?" We hope to answer this question by showing them the process in which light is divided into its separate components when passing through a medium. We also hope to answer questions they have as to where colors come from and how mirrors work.

Introduction: The lesson will start by learning what the average level of students' understanding of light the class has. This will be done by merely asking introductory questions. At the same time, I will introduce what it is I want the students to do during the lesson.

Procedure: First, the students will get an introduction to light movement through diagrams drawn on the board. I will explain to them how light reflects at the same angle to the center line of the reflections off of mirrors. This will be done by having the students view how objects can be seen around a barrier when at an equal distance from the "Normal" line at different measurements for each distance. Next, the students will be given prisms and if need be, flashlights. Using these materials, they will view how the light that enters the prism is "refracted" into its components of light. Lastly, I will finish the lesson by explaining to them how the colors we see are made because most of the components of light is absorbed while the colors we see are reflected off the things we look at. I will also give them a brief oral introduction to lenses.

Materials: Mirrors, Flashlights, Prisms

Appendix A.8: How Gears Make Things Move Lesson Plan

Lesson title – How gears make things move
Grade Level – Fifth
Lesson Time – 1 Hour
Instructional mode – groups
Group size – 4 to 5 students

Summary – Students will be given plastic Lego gears. They will observe how the number of gears, size and teeth affect the movement of the last gear.

Learning objectives – 2002 Worcester Public Schools Benchmarks for 5th grade:

- 05.SC.TE.03 - Identify and explain the difference between simple and complex machines, i.e., hand can opener that includes multiple gears, wheel, wedge gear, and lever.

Essential Questions – Most students know how to use machines which have gears in them. However, most students do not know how gears work and how they are used to change the direction of work as well as make work easier.

Introduction – To introduce the subject of gears, I will start by learning what the students know about them, showing them examples of ways we use them every day, and introduce the procedure I want them to follow for the lesson.

Procedure – I will start by separating the kids into groups of 4 or 5 students. When that is done I will start the exercise. The exercise is meant to introduce the students to the movements of gears. I will give the groups sets of 5 gears; all of the gears will have markings on them so the students have reference points of movement. This will enable the students to have physical examples of movement to base their observations on. Using these gears, I will have them trace how adding or removing gears as well as the size of the gears affects the movement of the last gear in the series. The groups will start by having two gears in decreasing size order next to each other. They will continue this adding a gear each time. At the end, I will ask them questions about what they observed and what it means for the people using them every day.

Materials:

- Lego’s sets
- Pieces of paper
- Tape
- Pencils

Appendix B: Science and Engineering Curriculum Map

September	October	November	December	January	February	March	April	May
Design Process- Completed	Moon Solar System Review	**Erosion (LAB)-** Lesson devel. last year	Intro – **Biomes** Design a biome for a living thing	Biomes	**Simple & Complex Machines** IQPs	Waves Intro	Magnetism	Space Day (1st Thursday)
Earth Revolution / Rotation (Day / Night)	Water Cycle	**How does light affect Plant Systems?** Crystal- Design Plant System	Biomes	**Design a weather instrum-ent for your biome**	**Light & Color Reflection & Refraction** IQPs	**Sound Waves** IQPs	**Space Day Activities**	**Structures** Crystal and Leena
Shadows & Seasons Crystal- Wristwatch Sundial, Classroom Sundial	**Weather Atmosphere, & Climate**	Animal Behaviors, Habitats & Survival	Vacation	**Simple & Complex Machines** IQPs	Light & Color	Water Waves	Vacation	**Structures** Crystal and Leena
Observing the Night Sky	Weather and Climate	Food chain Predator, Prey	Vacation	Simple & Complex Machines	Vacation	**Magnetism** Mag-Lev used last year	Space Day Activities	**Structures** Crystal and Leena

Appendix C: Massachusetts Frameworks and Worcester Benchmarks

Appendix D: Members of the Project

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) Jon Scobo (UG-B,C,D terms)	Calvin Chu Christopher Donoghue Amanda Hines Michael Raimondi
Third Grade Team (Faculty Advisor Goulet)		
Jen Lahue (Flagg)	Heather Blackwell (G)	Jeanne Shaffer Lindsay Strum
Nancy Mattus (Midland)	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

Appendix E: PIEE Timeline

Appendix F: October PowerPoint Presentation

Appendix G: Original Sound Waves Lesson Plan

Lesson Title- Make a Sonar Box

Grade Level- 5th Grade

Lesson Time- ?

Instructional Mode- Whole Class

Team/Group Size- 2-3? Students

Summary –

Students will build a sonar box about the size of shoe boxes to take measurements of the surface of the box bottom. The students will then create a model of the box bottom using card to see how close they were to the actual shape. Students will learn that this is the basis for sonar, and ultra sound devices.

Learning Objectives

2002 Worcester Public Schools Benchmarks for 5th grade:

Physical Science

05.SC.PS.05- Recognize that sound is produced by vibrating objects and requires a medium through which to travel. Relate the rate of vibration to the pitch of the sound.

05.SC.TE.07- Compare natural systems with mechanical systems that are designed to serve similar purposes, i.e., a bird's wings as compared to an airplane's wings.

Essential Questions-

Introduction/Motivation-

Fill a long tank with about an inch of water. At the center of one of the long sides, tap the water so to make ripples that reflect out towards the other long edge. Tell the students to observe what the ripples look like after they bounced off the opposite side. Next, place a rectangular object (a brick?) against the reflected wall. Ask the students what they think the ripples will look like with the brick there. When the water is calm, tap the water again to form ripples like before. Ask the students how the ripples changed from the first time. Ask the students how the ripples would change if a circular object were placed on the reflection edge. Ask them how the ripples would change if there were multiple objects in the tank. Have the students think about how engineers can use this phenomenon to design machines that can detect information about the reflected side. Explain to the students that machines can detect the reflected ripples which can give them a picture of what it looks like, like sonar or ultra sound. Have the students understand that scientists discovered this phenomenon, but engineers made the machine to make measurements from it.

Procedure-

1. Have the students bring in from home an empty shoe box (one per group). On the bottom of the box, have students glue pieces of dry pasta such as lasagna, large shells, and manicotti. Make sure that the pasta is glued such that there is some depth and texture to it.
2. While the pasta is drying, have the students take the top of the boxes and measure out a grid. Each grid box should be about an inch wide and an inch long. At each intersection, have the students punch holes through the box top large enough for the measuring rod. Make sure that each row is numbered. (Perhaps these two could be done in advance by the teacher to cut down on class time.)
3. With the box cover on each box, have each student team insert the measuring rod into each hole. Have the students measure how far into the box the rod goes before being stopped by the bottom of the box, or an object within the box. Have them start measuring row by row with all measurements being written down.
4. For each measurement in each row, have the students plot the measured value on the card stock associated with the row being measured. For each row, a new piece of card stock will be used and thus, a new graph.
5. On each card with measured data, have the students connect the dots on the graph and then cut it out. Then, folding the bottom over, mount the card to the box top for the row which the card represents.
6. Have the students do this with each row for which they measured.
7. Ask the students how close their models look like compared to the actual surface of the box. Explain to students that this is how sonar and ultrasound works. Ask students how the model would look different if the grid had twice the number of boxes.
8. Ask students if they know of any animals that can do this (Bats, Dolphins)

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

Vocabulary with Definition-

Assessment/Evaluation of Students-

Troubleshooting Tips-

Safety Issues-

References-

1. "Sonar, a way of seeing with sound" Cornell Center of Materials Research, http://www.ccmr.cornell.edu/education/ask/?quid=260 Retrieved 10-13-04
2. "How does Ultrasound scanning work?" Singapore Science Centre, http://www.science.edu.sg/ssc/detailed.jsp?artid=2901&type=6&root=5&parent=5&cat=58 Retrieved 10-13-04