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Engineering Education in Worcester Fourth Grades

An Interactive Qualifying Project Report
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science
by

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Part I: Project Overview

In today's society, it has become increasingly important that children are accustomed to science and technology. Even in the past decade, the amount of technology used by young people has increased exponentially. The people in this world are becoming more reliant on technology every day and because of this they need to be prepared to live with it. It is evident nowadays that even very young children can use and be comfortable with technological devices such as computers, so it makes sense that these children would be adept to learning subject areas such as science and engineering at school, even at the elementary school level. It is our responsibility to pass down our knowledge of technical matters to children, and give them a good head start so that they can succeed in this technologically dependent society. Engineering is a discipline based on using technological skill and knowledge of science to benefit the world. A field this vital to the prosperity of our planet needs well prepared and enthusiastic members, so it is an important task for us to build the competence and passion in our future engineers. The Massachusetts Department of Education recognizes this and has decided to include educational standards for engineering in the state's curriculum. The difficulty in including engineering in the new curriculum is that young children have never been exposed to this type of subject in school before and educators do not have the technical experience necessary to teach this material. Worcester Polytechnic Institute in collaboration with the National Science Foundation have decided to help out with this transition in the local community and boost the quality of engineering and science education with their "K-6 Gets a Piece of the PIEE" (Partnerships Implementing Engineering Education) project.

The transition for the new engineering curriculum is especially difficult for the Worcester Public Schools (WPS). Minority groups and women are marginally represented in engineering and they happen to comprise a large part of the Worcester Public Schools' population. In this urban environment, many students have not had much exposure to technology and engineering related fields, which puts an additional strain on Worcester's educators and only makes the job of learning how to teach engineering subjects more overwhelming. By teaming up with WPI, the Worcester Public Schools are able to use engineering students as resources for teacher training and curriculum development, while the engineering students get a taste for the education profession.

The expected outcome of this project has been summarized in three main goals. One of these goals involves the creation of an alliance between WPS teachers, WPS students, WPI faculty, and WPI graduate and undergraduate students. Together, this group has set out to accomplish the second goal, which involves the collaboration of WPI and WPS personnel in order to come up with fresh ideas and valuable techniques that can be used to help teachers implement the brand new science and engineering/technology learning standards. The final goal of the project is for the group to determine the effectiveness of the teacher training and the amount that the students profited from the new curriculum changes, as well as promote the new findings of the group and contribute to the growing emphasis on engineering education abroad.[1]

The anticipated output of this project would be self-propelled and constantly growing. As teachers are trained in their new engineering education techniques, they can pass their knowledge and skills onto other teachers who may need some help teaching to the new standards. As the WPI fellows and WPS faculty work together to come up with lesson plans and activities, they can be archived and utilized as resources for other classrooms and schools.[2] By the end of this project, there should be a good foundation for the development of engineering education in Worcester and in Massachusetts as a whole.

Our role here is defined by our Interactive Qualifying Project (IQP). Of the three required projects an undergraduate at WPI completes (the other two being a Sufficiency which is related to the humanities and the other being a Major Qualifying Project which is based on the student's major) the IQP is the one that is based on relating the benefits of technology and science to social or world problems. In our case, we have taken the role of assistants to the graduate fellows involved in the PIEE project as part of our IQP. Our job involved creating lesson plans that can be used by teachers to meet engineering and science learning standards (specifically the Massachusetts Curriculum Framework and Worcester Benchmarks which will be elaborated upon below) and also involved helping out our graduate fellows in the classroom. Over the course of the next two years as the project continues, there will be different IQP opportunities and the project itself will be changed to include more participating teachers and schools.

During this first year there were two schools that participated in the project,

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[1] Nicoletti, D. and Miller, J. E. K-6 Gets a Piece of the PIEE Project Proposal, p. 2.
[2] Nicoletti, D and Miller, J.E. p.2.

Midland St. School and Elm Park Community School (both of which will be described in detail later). Three teachers in each school, one of each from the fourth, fifth, and sixth grades, participated in the project. Two IQP students and one graduate fellow worked with a teacher, and helped to produce lesson plans and techniques for integrating technology and engineering content into everyday curriculum.

The next year will have an expanded base of participants, with smaller teams working with fourth, fifth, and sixth grades at additional schools and new teams working with second and third grades at new schools. The teams that are working with the fourth, fifth, and sixth grades will be known as "adaptation teams", and will be there to take the lessons created in the first year and help implement them in new classrooms. The teams working with second and third grades will be called "initiation teams", and will play the role of the first year teams by creating brand new lessons. In the third year, initiation teams will be started for kindergarten and first grade classes while the adaptation teams will implement the previous year's lessons for second and third grades. Also, "sustainability teams" will take the first year's lessons and utilize them for new fourth, fifth, and sixth grade classrooms. Following the third year, NSF funding will have ended, but there will still be plans for WPI to take an active roll in helping to implement engineering lesson plans in the Worcester Public Schools.[3] A separate team was created at the beginning of this year that was not included in the original plan. This team's focus was design a Virtual Education Space type system (otherwise known as VES see below) so that we could store all of the lessons we created in an online database that would be accessible for teachers everywhere. Over the course of the three year project, there would be a large accumulation of lessons and there would be a great benefit in having an

[3] Nicoletti, D and Miller, J.E. p.6.

online storage facility.

For our project specifically, we were divided into groups by the grades we worked with. Professors Joseph Rencis and Judith Miller advised the sixth and fifth grades respectively. We belonged to the fourth grade group, which was advised by Professor John Goulet. Our fourth grade group was subdivided into two smaller groups (one for each school) that each consisted of one fellow, two IQP students, and one fourth grade teacher. The group members for each school are displayed in the following table.

	ELM PARK COMMUNITY SCHOOL	MIDLAND ST. ELEMENTARY SCHOOL
Fellow 1	Amanda Tucker	Rick Bara
Teacher	Michael Dunphy	Sue Bercume
IQP Student 1	Ermelinda Shahu	Dan Abramovich
IQP Student 2	Michael Schenck	Jason Ernst

The advisors assigned for each grade level held weekly meetings with the students and fellows where our assigned tasks were explained to us. During those meetings we shared classroom experiences, and also shared thoughts on how things should be done in order to attain the optimum classroom situation. In addition to this, our graduate fellows described to us certain examples of things that would either work well or fail in the classroom, and even provided us with insight as to what would work well with our own lessons. In the classroom, we assisted our graduate fellows in conducting their lessons, and we were scheduled to conduct our own lesson plans that we had created. Prior to our visits in the classrooms, the fellows gave us background information on each class including important characteristics of some of the students, including individual difficulties and interests that they would have. By doing this, the fellows helped us to predict what types of lessons would work well with the students. The fellows showed us some of the lesson plans they had written and they made comments on what had worked out well when implementing them in the classroom in addition to what could have been done differently. The fellows also evaluated us on the work we did for this project based our participation and the help we provided during the science and engineering periods spent in the classroom. We were also evaluated on how well our lesson plans were written, how appropriate they were for the grade level, and how well we would be able to communicate some of those lessons to the students when implementing them in the classroom.

Age appropriateness was not the only specification that had to be met by our lessons. In addition to this, our lessons were to be suitable for the learning style of a student, appealing to diverse group of students, and applicable to the state's engineering/technology and science standards.[4] In order to achieve this, we would have to come up with very creative ways to integrate technical matter into enjoyable activities in which these children would be able to relate. By creating entertaining, hands-on lessons that make students feel confident about their abilities in engineering and science, we would be helping to turn on a whole new group of children to the world of technology, and hopefully give them a head start on their way to success in technical fields.

By writing stimulating lesson plans and activities that meet the specifications listed above, the fellows and IQP students in this project would be able to not only

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[4] Nicoletti, D and Miller, J.E. p.9.

expose children to the wonders of technology, but also expose teachers to great ways they can conduct lessons on these subjects. With the work done in this project, engineering education in Worcester should see a significant development over the course of the next few years.

Part II: Benchmarks and Frameworks

The Massachusetts Curriculum Framework for the curriculum of Science and Technology/Engineering provides guidelines for what the state believes are appropriate topics to be taught to Pre K-High School for the designated subjects. [5] In addition to this, these learning standards provide suggestions on how to go about teaching the topics and also give ways to integrate the necessary skills of experimentation and open ended thinking into an everyday lesson.

The Framework begins by giving definitions of and explaining the necessity of Science and Technology/Engineering in education. In this way the Framework has provided an overall concept that our work should be based upon. Science is described to be "attempts to give good accounts of the patterns in nature", which is crucial in the development of a child's mind as it not only familiarizes the child with key knowledge about this world, but helps a child learn how to decode the world's mysteries. Engineering is described as the attempt to create and design things that will add to society and increase quality of life for everyone, and the education of Engineering can help children learn how to solve problems and learn appropriate methods to go about designing new things to improve their daily lives. There is a great deal more emphasis placed on Engineering in education nowadays than there was a few years back, and this

[5] Massachusetts Science and Technology/Engineering Curriculum Framework, May 2001

could be a large step in helping students in Massachusetts to be better thinkers for years to come.

Science and Engineering/Technology go hand in hand. The Framework states how many things developed in Engineering are used to assist workers in the fields of Science, and how scientific principles are used in Engineering to help design new products. It is this relationship between the two subjects that this Framework stresses as an important concept to be taught in the schools.

Part of the importance in teaching these subjects is having the students take part in experimentation and discussion. Lifetime thinking skills are developed from asking questions and actively participating in the lesson from an early age. For grades 3-5, the Framework makes suggestions such as asking questions and forming hypotheses that the students can research and experiment themselves and such as using appropriate lab practices in order to help the students become more independent thinkers and problem solvers.

The Framework then goes on to set down some guiding principles as the basis for Science and Engineering/Technology education in this state. Some of the key points that the Framework include how this subject matter should be taught all the way from PreK-Grade 12 and how relationships and integration of the different topics of Science and Engineering/Technology are key to the understanding of the subject matter. As well as this, the Framework states how experimentation and exploration are crucial for learning about these topics and how it is extremely important for any misconceptions the students may have about a subject area to be cleared up so that they do not build upon the misconceptions. Finally, the Framework underscores that in order for an

Engineering/Technology and Science curriculum to be successful, the community needs to take an active role in assisting with both resources and people. Basically with these beliefs stressed, the state thinks that a curriculum in these subjects can be taught successfully and students can end up with better minds for solving problems and contributing to the world.

Here is where the learning standards of the Framework come into play. The Framework covers four main subject areas and divides them up as how they are meant to be taught for the different grade levels. Earth and Space Science, Life Science, Physical Science, and Technology/Engineering are the designated subjects. The Framework provides a very comprehensive and well organized description of each key point to be learned and methods of teaching it, in addition to an explanation of the purpose of teaching each of the four main subjects.

The Earth and Space Science curriculum is designed so that students can learn about subjects such as geology, meteorology, oceanography, and astronomy. Grades 3-5 specifically look at different substances on this planet and discover certain properties about the substances and the ways they can become different. The standards are broken down even further into topics such as soil, weather, the water cycle, the Earth's history, and the Earth in the Solar System. At this age, a large importance is placed on students being able to describe how things occur and the students being able to make some of these discoveries on their own.

Children are logically drawn to the Life Sciences, as things that are alive and animated can spark interest in any student. Students in grades 3-5 have begun to go past simple sensory observations and begin to find things on their own. For this reason, experimentation and exploration is stressed during these years. Students will encounter the Life Science subjects of characteristics of plants and animals, plant structures and functions, adaptations of living things, and energy and living things. At this point they will be able to use proper lab techniques and some helpful lab instruments to help them make discoveries on their own, and to begin to expand their knowledge past initial curiosities.

The Physical Sciences are where these students will begin to learn about the properties of matter and how it functions in the world we live in. This subject specifically is best taught with a great deal of hands-on learning, as the Framework states how Physical Sciences are understood better when children are able to see it for themselves. Standards for grades 3-5 include properties of objects and materials, states of matter, forms of energy, electrical energy, magnetic energy, sound energy, and light energy. This is where a great deal of materials and examples of certain matter will come into play so that the students may see for themselves how things work and why they do.

The Engineering/Technology strand is organized very well within this Framework, as a large deal of importance is placed upon its relationship with Science, and it gives a very comprehensive process chain as to how a problem is analyzed and solved. The Framework states that the steps of the engineering design process are identifying the need or problem, researching the problem, developing possible solutions, selecting the best possible solutions, constructing a prototype, testing and evaluating the solution, communicating the solution, and redesigning. This process is broken down even further into other steps, and gives a good outline as to how to go about designing a product. Grades 3-5 specifically deal with the different tools and materials that assist engineers in their problem solving, and how to use these tools when they need to perform a task. Standards for these grades include materials and tools and engineering design. This strand is particularly important for the sole reason that it really stresses team work, discussion, and creative thinking, which are skills that not only apply to this subject area, but also to life in general.

Overall this Framework provides a comprehensive guideline to how the subjects of Science and Engineering/Technology should be approached and taught in Massachusetts schools, and the suggestions given on methods of teaching and the reasons given for the importance of these subjects are more than adequate.

The Worcester Benchmarks are an adaptation of the Massachusetts Framework which is specifically applied to the Worcester Public Schools. This set of learning standards were developed by a committee in Worcester, and they are basically the state standards with specific emphases on different points. The Science and Engineering/Technology Benchmarks are broken up into the same categories as the corresponding Massachusetts Framework. The main difference between these two standards stems from the Skills of Inquiry section in the benchmarks, which specifies certain investigative skills and experimentation proficiencies that the students are required to develop. Overall, these benchmarks are city specific versions of the Framework that emphasize specific aspects of the learning standards that the city feels are worth focus. We used the Worcester Benchmarks for our lesson plans because we believed that by using them as our standards we would cover everything that would need to be covered. By taking something that conforms to the Framework and also accounts for city specific details, we can be sure that our lessons are appropriate to what the students need to learn.[6]

Part III: School Profiles

The Worcester School District is composed of 47 schools and serves 25,712 students. Each school belongs to one of four quadrants: North, South, Burncoat, and Doherty. There is an average of 12 schools in each quadrant. Of these 47 schools, 36 of them are elementary schools with grades ranging from pre-kindergarten up to sixth grade.

Elm Park Community School is in the Doherty Quadrant. With 437 students in the (2002 – 2003) school year, Elm Park isn't a large school. Of the 437 students 240 were male and 197 were female. It is, however, a very diverse school. If you refer to *Figure 1* you'll see that Elm Park not only has a larger minority population, in some cases, take the Hispanic population for example, there is little difference in number of students when compared to the white population.

[6] WPS Student Benchmarks, http://www.wpsweb.com/benchmark/default.htm

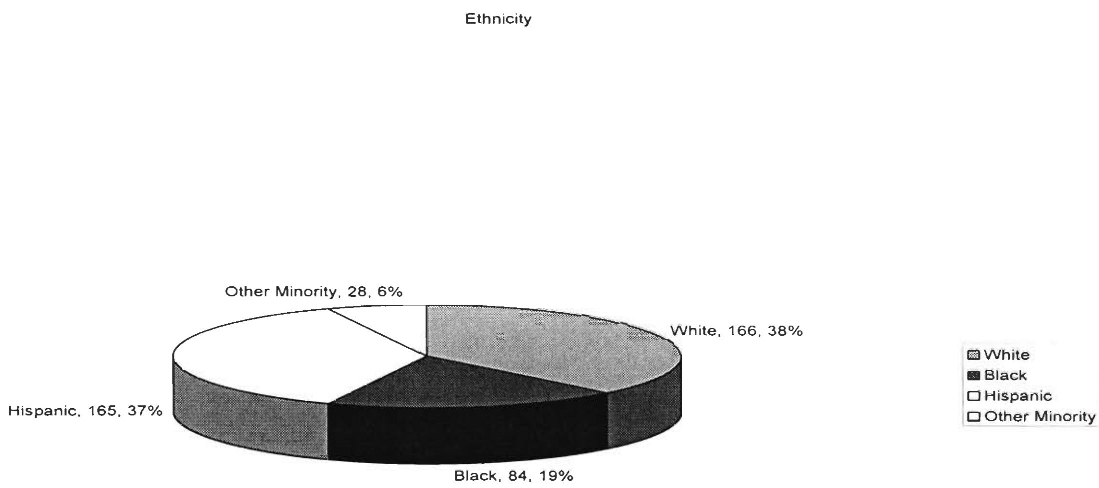


Figure 1: Ethnicity at Elm Park

Midland Street Elementary School is also in the Doherty Quadrant and had 247 students total in the (2002 – 2003) school year. There were 109 male students and 138 female students. The average percentage of different minority students in the Worcester Public School System is 51%.

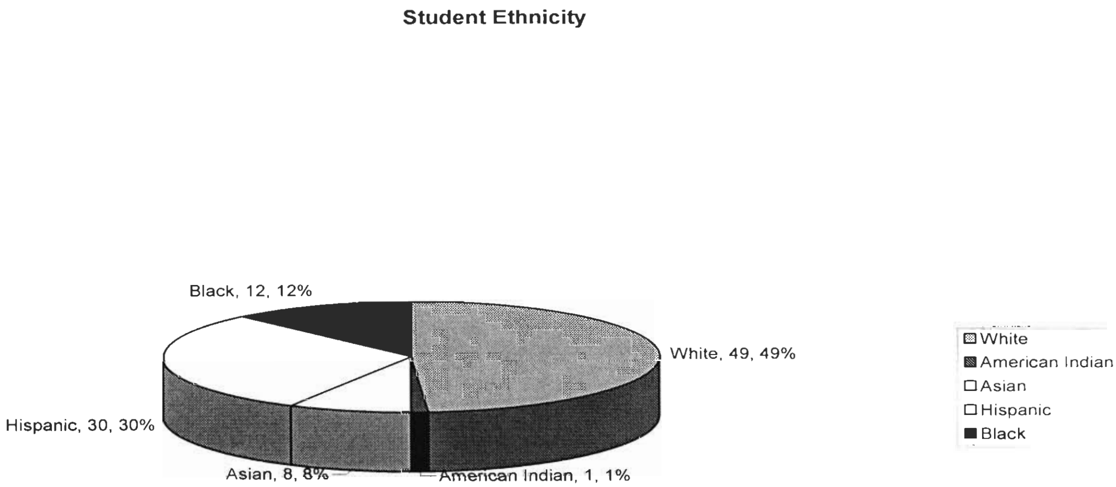


Figure 2: Ethnicity at Midland St. 3rd, 4th, and 5th Grade

The fact that Midland Street Elementary School has only a 40% minority may be a distinction of the economic status of the students' parents. While many schools in the Worcester area are not located in a very secluded section of the city, Midland St. is found tucked in a middle class neighborhood. It is shown that 50% of the students in the Worcester Public School System come from a low income home.

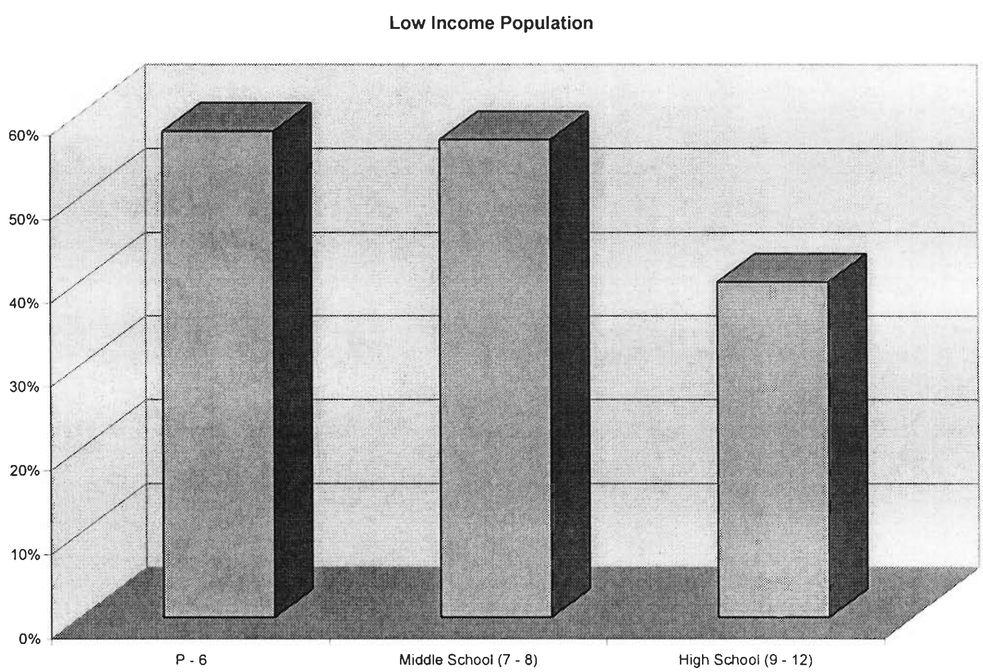


Figure 3: Worcester Low Income Population

The middle class appearance of the neighborhood surrounding Midland Street Elementary School could be an indication of why its minority level is lower than the city's average.

Grade 3	**34 students**	**29.4% minority**
Grade 4	**36 students**	**44.4% minority**
Grade 5	**36 students**	**55.6% minority**
Grade 6	**33 students**	**39.4% minority**

Table 1: Midland St. Percent Minority

Elm Park on the other hand is located in a densely populated residential area. The sights and sounds of Worcester completely surround the school, as does a maze of apartment buildings. Elm Park has a minority ratio of 62%, a sharp contrast to Midland Street Elementary School.

The fact that Midland Street Elementary School has a low amount of students in each class is also a sign of it's better than average status. Most classrooms in the Worcester Public Schools are overcrowded whereas in the Midland Street Elementary each grade has about 35 students, with two teachers for each grade. This student to teacher ratio gives the teachers a large advantage in controlling the classroom environment, and handling the students. It is much easier for students to slip through the cracks and miss out on learning when there are a large number of kids in a classroom. It is much harder for a teacher to control a larger number of children in a classroom.

Elm Park has up to 26 students in one class room. This can definitely restrict the amount of attention each child receives. Despite the fact that there are always a few students out of the room, a large class can be a strain on resources. Most classrooms at Elm Park have one or two computers and allowing enough time for each student to use them, even in groups of two, can take up a large portion of the day. For that reason some kids may only get to use the computers once a week. This is only one example of the issues related to class size.

After entering the schools and discarding any statistics, surroundings, or the rest of the Worcester Public School System, one can get a feeling for the learning atmosphere. Almost every person seems to be carrying on with a smile on their face, happy to help anyone with a question. Although there are not many people on the administration level, they all seem to keep everything under control. If one person does not show up to school for the day, such as the nurse, there is always another staff member happy to step in. The teachers all seem excited about teaching the students and more than anything the students seem excited to learn.

While observing a classroom it becomes obvious that each student in there wants to learn. They are all well behaved for the most part and willing to listen to the teacher. It is understood throughout the classroom that the teacher is in charge, nobody ever goes against what she says, and they are all affected by the emotion that she shows. By simply frowning at the class when they are getting a little out of hand, they all seem to recognize her change in mood and immediately try to follow her directions. When the teacher begins an activity, each and every student is paying attention and eager to learn how to do the activity. Sometimes when a teacher tells the class that this will be the last math question for the lesson, the entire class room begins yelling and pleading with her not to stop. This observation may be one of the most important observations because it shows that the students are all really willing to learn and enjoy the lesson. The desire of all of them is almost overwhelming considering the fact that they are doing math lessons.

Any minorities in the classrooms are hardly thought of as minorities at all. They are all just children and there is no apparent distinction between any of them when in the classroom. Each student treats the other with respect and there is no discrimination. When participating in class almost all of the students seem to answer the questions asked by the teacher equally with the exception of a couple of advanced students who seem to always know the answer.

Overall the Midland Street Elementary School appears to be an upper-middle class school, meaning that most of its students come from an economically sound background, the school is not overcrowded, and the desire to teach and learn are both high.

One place where there is a definite distinction between the two schools lies in the results of the MCAS. The Massachusetts Comprehensive Assessment System (MCAS) is the Commonwealth's assessment program developed in response to the Education Reform Law of 1993. Although the Education Reform Act proposed different ways to assess the students, the DOE (the Massachusetts Department of Education) chose to only support the MCAS. The MCAS tests all public school students, including students with disabilities and with limited knowledge of the English language. Only students who are enrolled after October 1st in U.S. schools may be considered as an exception.

The main purpose of the MCAS tests are as follows:

1) To measure students' and teachers' performance based on the state standards outlined in the Massachusetts Frameworks
2) To improve student's achievements
3) To improve the process of teaching

The MCAS tests were first taken by students in May of 1998. The system has been strongly criticized for its length and difficulty level. It also has failed to meet the needs of the disabled students and students with limited English proficiency. Test results support this criticism. After the first testing, the DOE has revised Massachusetts Curriculum Frameworks. The length of the fourth grade tests has been reduced and help is now offered to students with disabilities and limited proficiency in English in order to improve their performance on the MCAS. The DOE also offers many MCAS resources and sample test questions that might help students prepare.

According to the 1993 Education Reform Law, all students of the Massachusetts public schools must participate in the MCAS. The students are tested in the areas of:

- English Language Art (ELA)
- Mathematics
- Science and Technology/Engineering
- History and Social Science

MCAS tests are grade and area specific. They include four types of questions:

1- *Multiple choice questions*. These are used on all MCAS tests except ELA Composition. The student has to select the correct answer out of a choice of four answers.

2- *Open-response questions*. These also are excluded only from the ELA Composition tests. A student's answer might be in the form of a written sentence, chart, or graph.

3- *Short-answer questions* are included only in Mathematics tests. The answer has to be in the form of a numerical solution or a statement.

The tests are scored as *advanced*, *proficient*, *needs improvement*, or *failing*. The MCAS reports on the performance of individual students, schools, and districts. The results are then used by parents, teachers, and students to follow students academic progress, to recognize the strength or weaknesses within the curriculum, and to identify students who might need any additional support. Worcester as a district has not performed as well on these tests as the rest of the state, and more specifically Elm Park has produced results that lie far below the state average.

The following data illustrates how fourth graders around the state have performed better on these tests than those in Worcester. It also shows how factors such as English language deficiency have typically made for worse output in MCAS testing. Perhaps the large amount of students in Worcester that speak English as a second language have contributed to the city's lower scores.

1998-2003 Statewide MCAS Results:

Grade 4
Percentage of students at each performance level

		Advanced	Proficient	Needs Improvement	Warning
English Language Arts					
	2003	10	46	34	9
	2002	**8**	**46**	**37**	**10**
	2001	**7**	**44**	**38**	**11**
	2000	**6**	**43**	**35**	**16**
Mathematics					
	2003	12	28	44	16
	2002	**12**	**27**	**42**	**19**
	2001	**10**	**24**	**46**	**19**
	2000	**12**	**28**	**42**	**18**
	1999	**12**	**24**	**44**	**19**
	1998	**11**	**23**	**44**	**23**

Data Sheet of Worcester MCAS Performance

MCAS Tests of Spring 2003

Percentage of Students at each Performance Level

ALL STUDENTS	Advanced	Proficient	Needs Improvement	Warning/ Failing (Tested)	Warning/ Failing (Absent)	Proficiency Index	Number of Students
Grade4							
English	5	39	42	14		74.2	**2.01**
Language Arts	6	22	51	21		64.1	**2.044**

REGULAR EDUCATION STUDENTS	Advanced	Proficient	Needs Improvement	Warning/ Failing (Tested)	Warning/ Failing (Absent)	Proficiency Index	Number of Students
Grade4							
English	6	45	40	8		79.0	**1.464**
Language Arts	7	22	51	16		68.1	**1.471**

STUDENT WITH DISABILITIES	Advanced	Proficient	Needs Improvement	Warning/ Failing (Tested)	Warning/ Failing (Absent)	Proficiency Index	Number of Students
Grade4							
English	1	26	46	26		63.9	**427**
Language Arts	1	14	53	33		55.0	**432**

LIMITED ENGLISH PROFICIENT STUDENTS	Advanced	Proficient	Needs Improvement	Warning/ Failing (Tested)	Warning/ Failing (Absent)	Proficiency Index	Number of Students
Grade4							
English		15	44	40	1	50.6	**427**
Language Arts	1	12	48	39	1	48.8	**432**

As well as this, it can be seen that the students of Elm Park have performed sufficiently worse than those at Midland St. School. The following data illustrates the difference between the scores of these schools.

MCAS 2002-2003 School Results

Grade 4 -English Language Arts

School	Year	#incl	%Adv	%Prof	%NI	%Ftested	%Absent

Elm Park Community	2003	42	0	14	50	36	0
	2002	48	0	8	50	40	0
Midland Street	2003	35	3	49	46	3	0
	2002	34	3	38	41	18	0

Grade 4 -Mathematics

School	Year	#incl	%Adv	%Prof	%NI	%Ftested	%Absent
Elm Park Community	2003	43	0	0	56	44	0
	2002	50	0	4	30	66	0
Midland Street	2003	35	6	11	60	23	0
	2002	34	9	15	44	32	0

From the evidence presented, it is apparent that there is an issue with the performance of Worcester's students on the MCAS tests. A parallel can be drawn to the performance of schools such as Elm Park on other levels. The prevalence of disadvantaged and non-English speaking students has caused a problem with the academic output of the school. Even Midland Street, which has a greater population of middle class and English speaking students than Elm Park but still has an adequate amount of minority and English deficient students, has performed worse on the MCAS tests than the state's average students. With Science and Engineering/Technology being tested on the MCAS, the students of Worcester need to be prepared more than ever. The PIEE project team members have set out to bridge the gap between Worcester's students and the students of greater Massachusetts by creating lessons that cater to a city's student population and to the local context of schools like Elm Park.

The students at Elm Park may be at a disadvantage when compared to Midland St, but on a personal level they rise above. The word minority doesn't apply to the students as there are more "minority" students then the supposed majority of Caucasian students. It is clear that race plays no part in the learning that takes place. The ability of the students may vary between schools and even within the classroom, but each has the capacity and more importantly the curiosity needed in a young person to learn. The involvement of Worcester Polytechnic Institute and the PIEE program can only help these schools progress towards providing a better education and atmosphere for their students.

Part IV: Summary

Engineering educational standards in Massachusetts have caused a need for teachers to bring engineering into their classrooms and give their students technical skills. Because most elementary school educators have not had adequate experience with engineering or technology it is natural to expect that they could use some training from qualified members of the engineering profession. Because of this, WPI and the National Science Foundation have decided to take part in a three year project where they will be working with the Worcester Public Schools to design engineering related lesson plans and work with the teachers and students to hone their technical abilities. The teachers at both Elm Park Community School and Midland St. Elementary will be quite skilled at teaching engineering by the end of this project, and they will then be able to go forth and train their colleagues in the subject area so that the knowledge keeps spreading and students everywhere can be impacted by these new ideas.

The standards presented by the state (Massachusetts Frameworks) and the standards supplied by the city of Worcester (Worcester benchmarks) provide the guidelines for which the students are to be taught about engineering and science. By requiring that the students are able to understand how the engineering design process works and that they are able to identify the tools necessary to complete a task, the teachers have a basis for what they need to teach and something to work their lesson plans around. With the help of WPI faculty and students, the teachers of Worcester will be able to compose lesson plans that apply to these standards and that will prepare the students for any future work in engineering.

The two schools that WPI worked with this year, Elm Park and Midland St., are both very different in character. Midland St., which is the more suburban of the two, has much smaller class sizes than Elm Park. However, both schools share the quality of heavy diversity amongst the students (Elm Park does have more minorities) and a city context that needs to be taken into consideration when planning lessons and teaching.

Overall, this project should leave a huge mark on science and technology education in Worcester, and it should be a mark that will not fade away after the project is over. With the coalition of WPS educators and WPI faculty and students, a lasting relationship will be built that will persist long after the project has ended. As well as this, the advancements made in this city should spread and increase over time and other school systems all over should be impacted by the work done here.

Chapter II: Lesson Plans

Part I: Introduction

Throughout this year, we worked together with our graduate fellows to produce engineering and science related units and lesson plans that could be implemented into a fourth grade classroom that has little or no experience with the subject matter. We attempted to design the most appealing and educational activities possible in order to grab the students' attention and get them excited about engineering while at the same time having them learn a great deal of useful skills. Our project team's long-term desire was to be able to archive our lessons into an online system so that educators everywhere would have a useful resource for teaching engineering. Together with the help of the project team's VES group we were able to make great progress in this goal.

VES:

The Virtual Education Space Group (VES) was designed to implement an online service that would allow users to upload and store lesson plans online. This would enable teachers from anywhere to access a vast database of lesson plans that my otherwise be unavailable to them. What the VES group needed from the people developing lesson plans was a clear format that all lesson plans would have. This format would include text areas where users can enter categorical information, these text areas are known as fields. These fields may or may not be used and also some must be mandatory fields. It was necessary that we had fields such as keywords and title so the VES group could implement a searching utility on their web service. The idea of creating a lesson template that would aid everyone creating lesson plans was important so that all of the groups and individuals writing lesson plans ended up with a similar final result. Having a similar final product was important so the lesson plans could be compared and contrasted. It was important for the VES group to be in tune with what the lesson plan development groups were creating so their online forms would be able to handle the format decided upon by the people writing lesson plans.

The hardest part about making a lesson plan template was ensuring that everybody involved was happy with it. It was not particularly important to the VES group what fields were defined as, but to the people writing lesson plans it was crucial. Many people had already written their lesson plans and even a few unit plans by the time the final template was finished and that meant reworking their existing plans. It took a long time to decide what should be in a lesson plan template and what should not since many different people were working on the project. It was difficult for everybody to compromise but in the end the product seemed to work for all parties involved. It was not too difficult to transfer information from an old lesson plan to the new template and it covered all of the bases.

VES took this template and used it to create their online forms which could then be accessed by teachers and students looking to upload or download lesson plans. In the future this will prove very important, not only for storing lesson plans but also those who need to write lesson plans. Teachers can find lesson plans to implement directly into the classroom or they can find plans to extract ideas from. Having the lesson plans uniformly designed may be an easy way to list them online it does however take away from the overall creativity of the design. The creativity must either somehow be portrayed in the lesson plans summary and procedure, or the teachers will have to be relied on to put their own personal touch into every lesson plan.

Chapter Overview:

The following section features an archive of the entire lesson plan output for this year's fourth grade group. Each of us has produced a complete unit with lessons and supplemental material to be used in the classroom. Some of our lessons were science based while others were engineering based. There was no intent to distribute the content of our lessons in any specific way, however, we tried to incorporate as many of the Worcester Benchmarks on science and engineering into our lessons as we could. Based on the topics we chose for our lessons, some pertained more to the science standards while some pertained more to the engineering standards. Our best lessons were those that integrated both science and engineering material because they were able to cover a larger quantity of Benchmarks. A link to the benchmarks we covered in our lessons can be found in the first chapter of this report under the sixth footnote.

Also included in this section are evaluation forms that were filled out by our graduate fellows in order to review the quality of our lesson plans. All of our lesson plans and units have since been revised and updated from the time the evaluations were done, but these forms give a good reference to what our main struggles were with the lesson planning process and show what we have done since to improve our output. The following material is organized as such:

1. Erma's Unit

2. Dan's Unit

3. Jason's Unit

4. Mike's Unit

Part II: Unit and Lesson Plans

Erma's Lessons:

Erma created two units to be used in Mr. Dunphy's classroom. The first of the units involves magnetism and the other one involves simple machines. The unit on magnetism consists of the following three lesson plans:

Lesson 1- *Is it Magnetic?* In this lesson, students learn how to identify magnetic and nonmagnetic objects by using a magnet.

Lesson 2- *Magnetic Strength* By experimenting with different types of magnets, students become aware of the relationship between the magnetic force and distance between magnetic objects. The students observe how magnetic field lines go through nonmagnetic objects.

Lesson 3- *Magnet's Poles and Magnetic Field* Through the patterns formed by iron filings, students are able to identify the poles of a magnet, the way the filings interact with each other, and the direction in which magnetic field lines run.

Erma's unit on simple machines includes the following lessons.

Lesson 1- *Introduction to Simple Machines* Here, students learn what simple machines are, how to identify them, and different examples of their usage in everyday life. Ideas for this lesson plan were taken from the following website: <http://sln.fi.edu/qa97/spotlight3/spotlight3.html>

Lesson 2- *Lever Application* Experiment 1 on this lesson plan can be found at:

<http://www.coe.uh.edu/archive/science/science_lessons/scienceles1/lever.htm>

Lesson 3- *Inclined Plane and Pulley Application* In this lesson plan, students build inclined planes using boards of various sizes and varied numbers of books. They build multiple pulley systems and identify the forces used in each of them when lifting objects.

Unit Template

Unit Title: Exploring Magnetism

Grade Level: 4

Unit Time: 150-180 min

Summary:
Students should become able to distinguish between magnetic or nonmagnetic objects. They should learn about poles and the pattern of magnetic field lines.

Subject Area(s): Physical Science

Educational Standards

MSTECF Standards:

Physical Science 9. Recognize that magnets have poles that repel and attract each other.
Physical Science 10. Identify and classify objects and materials that a magnet will attract and objects and materials that a magnet will not attract.

Essential Questions:

What are some examples of magnets usage in everyday life?
What are some examples of objects that are metallic, yet not magnetic?
Is there any relationship between the distance an object has from a magnet and its magnetic strength?
What about magnetic strength and another object staying between the magnet and the object to be tested?
What part of the magnet attracts objects better and why?
How do the magnets interact with each other when they have same poles closer together?
How do they interact when they have opposite poles closer?

Learning Objectives
Students should learn how a magnet reacts when near different types of objects. They should also learn what materials do the objects attracted by the magnet consist of.
Students should learn about factors that play a role in the strength of the magnetic force.
Students should know that each magnet has two poles and they should be able to identify them and the direction magnetic force lines run from. They should learn how poles of the same and of opposite charge interact with each other.

Pre-Requisite Knowledge: None

Lessons:

Is it Magnetic

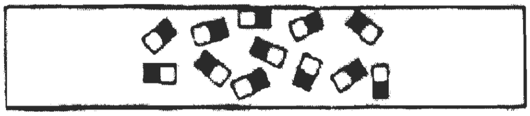
Magnet's Poles and Magnetic Field

Magnetic Strength

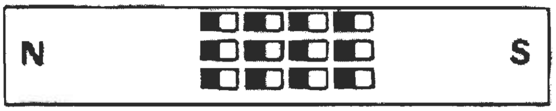
Unit Background and Concepts for Teacher:

Magnets can be made by placing a magnetic material such as iron or steel, in a strong magnetic field. Permanent, temporary and electromagnets can be made in this manner.
Magnetic materials are arranged in units called domains each of which has a particular magnetic moment orientation. In each domain, the atoms point their magnets in one particular direction.

Before magnetization



After magnetization



Magnets can be permanent or temporary. Soft iron and certain iron alloys can be very easily magnetized, but they also lose magnetism as soon as the field is removed. Temporary magnets are used in telephones and electric motors. Other kinds of alloys such as alnico (an alloy of aluminum, nickel, iron, cobalt), make excellent permanent magnets. Strong permanent magnets can also be made out of. In these materials magnetism is harder to get lost.
Metals are more likely to be magnetic than other materials, but still just being metal is not enough in order to determine for an object whether it is magnetic or not. Additional tests have to be taken.
Each magnet has North and South poles and a magnetic field that surrounds the poles. Magnetic field lines go out of the North pole and into the South pole. Magnetic force is the force exerted between magnetic poles producing magnetization. The force a magnet exerts on an object depends on the distance between them. As greater the distance, as weaker is the magnetic force.
A magnet can attract objects without even touching them because its magnetic field reaches out in space. Magnetic force is stronger at the magnet's poles

Magnetic fields can pass through nonmagnetic materials. As the distance between the magnet and the magnetic object increases, the force becomes too weak to attract the object, even though the magnetic field is still present.

For more information on magnets see the following links:

<http://www.sciencetech.technomuses.ca/english/schoolzone/Info_Magnets.cfm>
<http://school-for-champions.com/science/magnetism.htm>
<http://my.execpc.com/~rhoadley/magattr.htm>

Vocabulary list : *magnet, magnetic force, magnetic force lines, poles, electromagnet.*

Summative Assessment/Evaluation: Students will be evaluated on the understanding shown on the subject. Their answers in the notebooks and/or handouts will be reviewed.

Unit References: Information on *Unit Background and Concepts for Teacher* can be found at:
<http://www.sciencetech.technomuses.ca/english/schoolzone/Info_Magnets.cfm#whatare>
Pictures at *Unit Background and Concepts for Teacher* and pictures at *Magnet's Poles and Magnetic Field* lesson plan are taken from:
<http://www.sciencetech.technomuses.ca/english/schoolzone/Info_Magnets.cfm#whatare>

Lesson Title: Is it Magnetic

Grade Level: 4

Total Time: 45-60 minutes

Instructional Mode: Whole Class

Team/Group Size: 3-4 students

Summary: Using a magnet students should identify magnetic and nonmagnetic objects and record the results

Learning Objectives: Students should learn how a magnet reacts when near different kinds of objects.
They should also learn what materials do the objects attracted by the magnet consist of.

Materials List (per group): a magnet, different objects (plastic cup of water, paper clips, wooden ruler, cardboard, piece of fabric, glass jar, aluminum foil, cereals, chalk, wire, rubber band, pennies, drink can, iron nail).

Introduction/Motivation: Why are magnets important? Ask students to bring examples of magnets in our everyday life, and their usage.

Vocabulary/Definitions:
Magnet- an object that exerts an attraction upon particular objects without even touching them.

Attachments:

Procedure

Worksheets

Discussion Questions for students:

What are some examples of magnets usage in everyday life?
What are some examples of objects that are metallic, yet not magnetic?
Ask the students to think of other objects except the ones that are given on the spreadsheet and decide for their magnetic properties.

Assessment/Evaluation of students:

Students were able to…	**Yes**	**No**
Know what objects does a magnet attract		
Give appropriate examples of objects attracted or not		

Safety Issues: Students should be told not to come near a computer or a TV (if there is any) with the magnet.

Procedure:

Students should be provided with different objects.
Ask students "What material is each object made of?"
For each object the students should write down in their notebooks the material they think the object consists of.
Show a magnet to the students and ask them "What is a magnet?"
Ask them to bring examples of magnets in our everyday life, and their usage.
Then ask them whether they think the objects given to them are magnetic or not?
After having the students write in their notebooks for each object whether it is magnetic or not, ask them how they think they might be able to show whether an object is magnetic or not?
Tell the students that by coming close to an object with a magnet they can determine if the object is magnetic or non-magnetic. If the objects gets attracted to the magnet it is magnetic, otherwise it is non-magnetic.
Then let them precede using the magnet. What objects got attracted by the magnet?
Let the students fill out the spreadsheets given to them.
Let the students explore other magnetic properties of other objects in the class using the magnet.

Worksheet

Object	**Material**	**Magnetic/nonmagnetic**
Plastic cup of water		
Paper clips		
Wooden ruler		
Cardboard		
Glass Jar		
Aluminum foil		
Chalk		
Wire		
Rubber band		
Penny		
Drink can		
Iron nail		

List also other objects whose magnetic properties you observed by coming with the magnet near different objects in the classroom.

Lesson Title: **Magnetic Strength**

Grade Level: 4

Total Time: 45-60 minutes

Instructional Mode: Whole Class

Team/Group Size: 3-4

Summary: Experimenting with a magnet from different distances students should become aware of the relationship between the magnetic force and distance. They should observe that magnetic field lines go through nonmagnetic objects.

Learning Objectives: Students should learn about factors that play a role in the strength of the magnetic force.

Materials List (per group): Horseshoe magnet, bar magnet, staples, metal bar

Introduction/Motivation: What might be some of the ways for a magnet to best attracts an object?

Vocabulary/Definitions: Magnetic force- The strength with which a magnet attracts an object.

Attachments

Procedure

Discussion Questions for students:

1. *What can you say about the relationship between the distance an object has from a magnet and its magnetic strength?*
Explain to the students that there is a certain distance from which a magnet can exert his magnetic force toward an object.

2. *What about magnetic strength and another object staying between the magnet and the object to be tested?*
Explain to the students that non-magnetic object being placed between a magnetic object and a magnet do not affect magnet's reaction toward the object, as long as there is a certain distance between the object and the magnet. In our case by adding more cloth, the distance between the magnet and the object is greater, which is the reason the can lid gets not any more attracted by the magnet.
Explain to them that as the metal bar has magnetic properties it gets attracted by the magnet. All the force the magnet has, has gone toward attracting the metal bar being this way unable to attract the can lid also.

Assessment/Evaluation of students

Student could…	**Yes**	**No**
Perform the experiments		
Understand the conclusions drawn		

Safety Issues: It is important that the teacher makes sure the can lid has smooth edges.

Procedure

Experiment1:

Divide the students into groups of 4-5.
Pass out materials to each group.
Have the students place a pile of staples on the desk.
Have them place a horseshoe magnet a good distance away from the pile.
Have students slowly move the magnet towards the pile until the staples jump to the magnet.
Discuss with them why they think this happened.

Experiment2:

After having asked the students what they think would be the best position to keep the magnet toward an object so that it best attracts it let them experiment with a bar magnet and staples.
Tell the students to record their results for each position of the magnet.

Experiment3:

Have students place a can lid on the desk.
Have them hold the horseshoe magnet above the lid and move it closer until the lid "jumps" to the magnet.
Repeat this after replacing some cloth between the lid and the magnet.
Continue adding cloth until the magnet no longer attracts the lid.
Ask the students why they think it no longer works. Was it the cloth or simply the distance of the lid from the magnet?
Ask the students what magnetic properties does a cloth have. Is it attracted by a magnet? Knowing the cloth has non-magnetic properties should its existence affect the attraction of the lid by the magnet?
Repeat the experiment after replacing the cloth with a metal bar.
Ask the students why the lid was not attracted at all.
Ask them what magnetic properties does a metal bar have. Explain to them that as the distance between the magnet and the can lid is small, the reason should have been something other than the distance.

Lesson Title: **Magnet's Poles and Magnetic Field**

Grade Level: 4

Total Time: 60 minutes

Instructional Mode: Whole Class

Team/Group Size: 4-5 students

Summary: Through the pattern of iron filings students should become able to identify the poles of a magnet and the direction that magnetic force lines run from. They should learn how poles of the same and opposite charge interact with each other.

Learning Objectives: Students should learn how a magnet reacts when near different types of objects.
They should also learn what materials do the objects attracted by the magnet consist of.

Materials List (per group): bar magnets, iron filings, cardboard.

Introduction/Motivation: Students should be introduced with the vocabulary. After becoming familiar with the new terms they should be asked on the problem from the "*Magnetic Strength"* lesson plan: Why do they think the magnet attracts more staples with its ends than its middle part? It should be explained to them that in the center between the poles of a magnet, there is very little magnetic field outside the magnet. All of the magnetic field is inside the magnet itself. Because of this, there will be no staples or quite a few of them attracted to the middle of the magnet. While at the end or pole of a magnet staples will stick easily.

Vocabulary/Definitions:

Magnetic force lines- The area around a magnet where magnetic force can attract on other objects.
Poles- The opposite ends of a magnet which we call the North and South.
Magnetic Field- Magnetized region of space

Attachments

Procedure

Worksheets

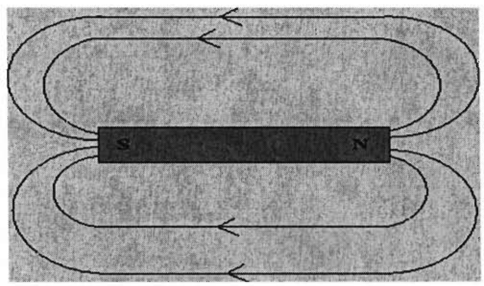
Assessment/Evaluation of students: Student will be evaluated according to the answers given on the handout.

Students could…	Yes	No
Draw the right pattern of magnetic field		
Understand how magnets interact with each other		
Explain why a magnet attracts an object with its pole		

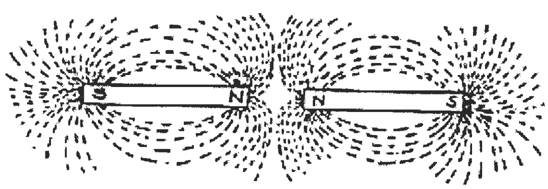
Troubleshooting Tips: The teacher should better place the iron filings in the zip bag by himself/herself for each students-group. It is really important that students do not open the zip bag, otherwise all iron fillings would get stuck and then it would be really hard to get them separated from the magnet.

Procedure

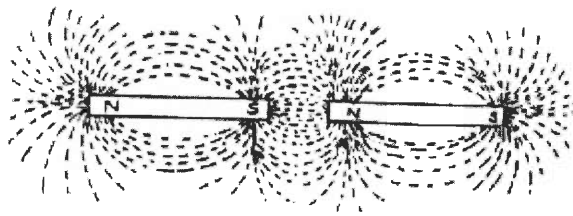
Introduce the students with the new vocabulary.
Divide the class into groups of 4-5 students. Pass out materials to each group except for the iron filings.
The teacher should place some iron filings in a plate-form cardboard and then place it in a zip-bag.
Students can place the magnet underneath the iron filings and observe their pattern.
Ask them what can they say about the direction of the pattern relative to the poles of the magnet.
Explain it to the students that the direction of the pattern, which is also the direction of the force lines, is from North to South. The force lines go out from the North pole and get into the South pole.



After explaining to the students that unlike poles attract each other ask them to predict the pattern when two bar magnets would be used, with their North poles closer together.
Then let them follow the same procedure and show them the pattern, explaining in the meanwhile that like poles repel each other.



Ask them to predict what might happen if instead of the North they would have the South poles closer together.
Let the student repeat the procedure, now using two bar magnets with their South poles closer together.
After explaining to the students that unlike poles attract each other ask them to predict the pattern when two bar magnets would be used, with their South and North poles closer together.
Let the students repeat the experiments with two bar magnets which have the North and South poles close and discuss how the pattern has changed.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Worksheet

Draw the pattern of iron filings after magnetization for each of the following cases:

a. Bar magnet

b. Two bar magnets with South poles closer together

c. Two bar magnets with North poles closer together

d. Two bar magnets with North and South poles closer together.

Answer the following questions:

1.What part of the magnet attracts objects better and why?

2.How do the magnets interact with each other when they have same poles closer together?

3.How do they interact when they have opposite poles closer?

Unit Template

Unit Title: Experimenting with simple machines

Grade Level: 4

Unit Time: 180 minutes

Summary: Through experiments in class, students will learn how we apply different kinds of simple machines in our lives and how they might help us better. Using the three kinds of levers students will explore the easiest way to lift a book. Students will build inclined planes and pulley systems and explore the force used in each of them

Subject Area(s): Technology and Engineering

Educational Standards

WPS Benchmarks: 04.SC.TE.03 Identify and explain the difference between simple and complex machines.

Essential Questions:

1. What are the six kinds of simple machines and some of their functions?
2. How is the force used to lift an object through an inclined plane in relationship with its length and height?
3. Where do the three classes of levers differ from and how is the force applied to lift an object in each case?
4. What is the relationship between the effort and the load in a fixed, a movable, and a combination of pulleys?

Learning Objectives

Students should learn to recognize simple machines from each other and how they help us do work.
Students will learn the three classes of levers and how they work.
They should also learn how different kinds of pulleys help us make our work easier.

Pre-Requisite Knowledge: None

Lessons:

Introduction to Simple Machines

Lever Application

Inclined Plane and Pulley Application

Unit Background and Concepts for Teacher:

There are two types of pulleys: fixed and movable. A fixed pulley does not move. This kind of pulley uses more effort than the load to lift the load from the ground. When attached to an unmovable object the fixed pulley acts as a first class lever. When using this pulley you don't have to use any force to move it. The effort to be applied is more than the load.
The second type of pulley is the movable pulley.
A movable pulley is used in combination with a fixed pulley. It moves along the rope which increases the amount of force placed on the rope, using less effort than the load to do work. It acts as a second class lever.
A combined pulley makes life easier as the effort needed to lift the load is less than half the weight of the load. The main disadvantage is it travels a very long distance.
There are three classes of levers.
Class 1 levers have the fulcrum between the effort and the resistance as in a seesaw, a crowbar, scissors, or pliers. In this class of levers the effort used will be less than the load as the load is nearer the fulcrum than the effort.
In Class 2 levers the load is between the fulcrum and the effort applied. A wheelbarrow, a screwdriver, a catapult, a nutcracker, and a stapler are examples of 2nd class lever. When the load is nearer the fulcrum, the force used to lift the load will be less.
In Class 3 levers the effort applied is in the middle of the fulcrum and the load. Wherever the load is placed in relationship with the fulcrum, the effort will be greater than the load when using this class of lever. A fishing pole is a class-3 lever where our hand at the end of the pole is the fulcrum and the fish caught, at the other end is the load. The effort is applied by the hand placed between the fulcrum and the fish. A tweezers, our forearm are also examples of third class levers.

For more information on levers see:
<http://www.science.sjsu.edu/CSP-PISE/levers.html>
For more information on pulleys see:
<http://exemplars.ysiste.com/pencil-paper/gr4_sm_content_connections.pdf>
For more information on simple machines see:
<http://www.coe.uh.edu/archive/science/science_lessons/scienceles1/finalhome.htm>
<http://sln.fi.edu/qa97/spotlight3/spotlight3.html>
<http://www.fi.edu/pieces/knox/automaton/simple.htm>

Vocabulary list (w/out definitions):

Simple Machine, Inclined plane, Lever, Pulley, Work, Fulcrum, Lever, Load, Effort arm.

Unit References:

Information on Unit background and concepts for teachers can be found at:
<http://www.smartown.com/sp2000/machines2000/main.htm>
<http://www.science.sjsu.edu/CSP-PISE/levers.html>
Experiment 1 on *Lever Applications* lesson plan can be found at:

<http://www.coe.uh.edu/archive/science/science_lessons/scienceles1/lever.htm>
The source of procedure in the *Introduction to Simple Machines* lesson plan is <http://sln.fi.edu/qa97/spotlight3/spotlight3.html>
Pictures on pulleys in the *Inclined Plane and Pulley Applications* lesson plans are taken from <http://www.smartown.com/sp2000/machines2000/main.htm>
Pictures on *Introduction to Simple Machines* lesson plan are taken from <http://sln.fi.edu/qa97/spotlight3/spotlight3.html>

Owner ID: Ermelinda Shahu

Key Words: simple machines, wheel, axle, inclined plane, wedge, screw, lever, pulley, fixed pulley, movable pulley, pulley system.

Lesson Title: Introduction to simple machines

Grade Level: 4

Total Time: 60 minutes

Instructional Mode: Whole Class

Team/Group Size: 3-4 students

Summary: Students should be able to recognize simple machines usage in our lives and distinguish between them.

Learning Objectives: Students should learn what the six kinds of simple machines are and differentiate between them.

Introduction/Motivation: Ask the students what they think a simple machine is? Introduce the with the term simple machine and explain to them the relationship between simple and compound machines.
Ask them to name some simple machines.
Ask students to give examples of different machines and why they are used. For each example ask them whether they think it might be a simple or a compound machine.

Vocabulary/Definitions:
Work -- A force acting on an object to move it across a distance.
Simple Machine--A tool used to make our work easier

Attachments

Procedure

Worksheet

Discussion Questions for students: Students will take the quiz at <http://edheads.org/activities/simple-machines/index.htm>.

Assessment/Evaluation of students: Students will be evaluated on the handouts they fill and on the quiz taken.

Object	Simple machine
Flag pole	
Broom	
Car's windshield	
Saw	
Clock	
Pin	
Light switch	
Jar lid	
Staircase	
Skates	
Bathtub	
Scissors	
Garage gate	
Crane	

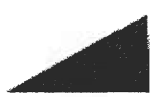
Simple machine	Helps us to ….
Lever	
Pulley	
Wheel and Axle	
Wedge	
Screw	
Inclined Plane	

Key Words: simple machines, wheel, axle, inclined plane, wedge, screw, lever, pulley.

Procedure:

Ask students what they think a simple machine is?
Ask them to name some simple machines.
Explain it to them what work is by giving its definition.
Ask the students of examples of work done by them.
Explain to the students that a machine is a tool used to make work easy and simple machines are simple tools used to make work easier.
Tell the students that there are 6 kinds of simple machines which are:
Inclined plane, Wedge, Screw, Lever, Wheel and Axle, Pulley.
Ask the students to say for each simple machine what they think it might be useful for.
Then tell them what these simple machines help to do and give examples of their applications after having asked the students first to do so.
At the end students should be able to take the quiz at the following address:
<http://edheads.org/activities/simple-machines/index.htm>.

Inclined Plane



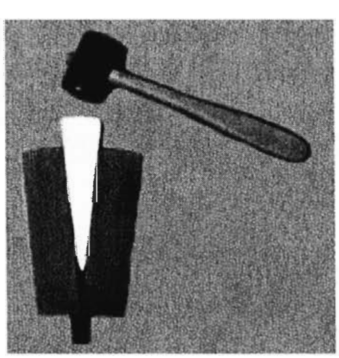
An inclined plane is a flat surface that is higher on one end. You can use this machine to move an object to a lower or higher place. Inclined planes make the work of moving things easier. You would need less energy and force to move objects with an inclined plane.

An inclined plane is a ramp, sloping road, plow, bottom of a sink, staircase, a roof.

Staircases help us move up or down.

A roof helps keeping rain or snow from collecting.

Wedge



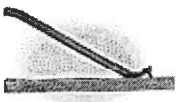
A wedge is a kind of an inclined plane where the pointed edges are used to do some kind of work like tightening, securing or holding, or splitting things apart.

An axe blade, a kitchen knife, a push pin, a nail, a fork, a saw are examples of a wedge.
A nail secures thing. A wedge under a door keeps the door from moving. An ax splits things.

Screw

A screw can raise weights or it can press or fasten objects! A bolt or a jar lid is a screw. The jar lid tightens onto the jar with a screw. Screws can be found on Jar Lids, light bulbs, key rings, spiral staircase.

Lever



A lever is an arm that "pivots" (turns) against a "fulcrum" (point). The “fulcrum” is the resting or balancing point upon which a lever turns. Someone or something has to push or pull on a lever to make it work A light switch, scissors, garage gate, broom, toaster handle, oven or refrigerator door are examples of a lever.
In the case of the light switch, the switch pivots in a fulcrum, turning light on and off.

Wheel and Axle

The wheel and axle is a kind of lever that moves objects across distances. The axle is a rod that goes through the wheel. This lets the wheel turn. The wheels of a car or bicycle are wheels and axels, which allow the car or bicycle to move easily although it is a heavy object. Roller skates, gears in clocks or watches are also examples of wheels and axles

Pulley

This simple machine is made up of a wheel and a rope. The rope fits on the groove of the wheel. One part of the rope is attached to the load. When you pull on one side of the pulley, the wheel turns and the load will move. Pulleys let us move loads up, down, or sideways. Pulleys are good for moving objects to hard to reach places. It also makes the work of moving heavy loads a lot easier.
A flag pole uses a pulley to raise or lower a flag.
When the rope of the pulley is pulled down the flag is raised.

Shoe laces, sailboats, blinds, a crane, cloth lines are also examples of a pulley.

Worksheet

Object	Simple Machine
Flag pole	
Broom	
Car's Windshield	
Saw	
Clock	
Pin	
Light Switch	
Jar Lid	
Staircase	
Skates	
Bathtub	
Scissors	
Garage Gate	
Crane	

Simple Machine	**Help us to…**
Inclined plane	
Lever	
Wedge	
Pulley	
Wheel and axle	
Screw	

Lesson Title: **Lever Applications**

Grade Level: 4

Total Time: 60 minutes

Instructional Mode: Whole Class

Team/Group Size: 3-4

Summary: Using the three kinds of levers students will explore the easiest way to lift a book.

Learning Objectives: Students will learn the differences between the three kinds of levers. They will learn how to use levers best in order to make the job easier for them.

Materials List (per group): 1 yardstick, ruler, string, toy car, metal ring, soda bottle, scale.

Introduction/Motivation: Students will introduced with the new vocabulary. A discussion should be held on examples of lever usage. Students should be asked if there is any difference in the way different levers help us do work. It should be explained to them that there are three kinds of lever, and what the difference between them is.

Vocabulary/Definitions:

Lever- A simple machine consisting of a bar that moves about a fixed point
fulcrum- Point about which a lever turns or pivots.
load- The object being moved.
effort arm- The distance from the fulcrum to the point where the force is applied.
load arm- The distance from the fulcrum to the load.

Attachments

Procedure

Discussion Questions for students:

Ask the students to give examples for each of the three kinds of levers.
Discuss with the students the easiest way for a light person to lift a heavy person up through a see-saw.
Discuss how a fishing pole is a lever of class-3 where our hand at the end of the

pole is the fulcrum and the fish caught, at the other end is the load. The effort is applied by the hand placed between the fulcrum and the fish.

Assessment/Evaluation of students: How well could the students perform the experiments? Students may be evaluated on the answers written on their science notebooks on each of the experiments

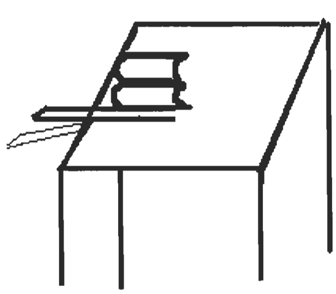
Redirect URL: http://wow.osu.edu/SimpleMachines/levers.htm

Key Words: lever, lift, ruler, simple machines.

Procedure

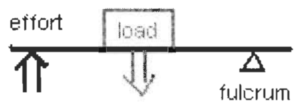
Experiment1:
Class 1 levers have the fulcrum between the effort and the resistance as in a seesaw, a crowbar, scissors, and pliers.

Put a ruler on the desk such that a part of it goes out of the table's edge. Place a textbook on the other end of the ruler in such a way that the book is completely over the ruler, and try to lift it by pressing the other end of the ruler down.
Try the same experiment by moving the book closer to the edge. Continue until the book is at the edge of the table.
Ask the students what they think was the kind of machine implemented to lift the book.
Show them that the ruler is the lever and the edge of the table is the fulcrum.
Ask the students when they think it was easier to lift the book.
Tell them that when using a lever to lift an object it is easier to move an object when the fulcrum is closer to the load.

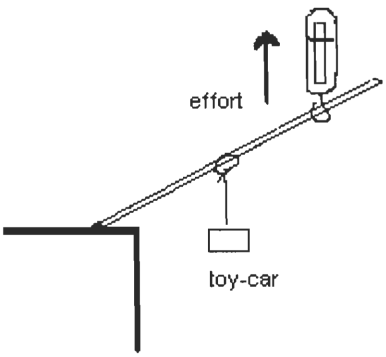


Experiment2:
In Class 2 levers the fulcrum is at one end of the lever and the load is in the middle. The input is applied at the opposite end. A wheelbarrow is an example of this kind of lever. In a wheelbarrow, the fulcrum is on the axis of the wheel, the weight is in the center of the load being lifted, and the effort is that exerted on the

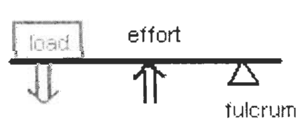
handles by the hands of the operator. A screwdriver, a catapult, a nutcracker, and a stapler are also examples of 2nd class lever.



Cut a 1 meter piece of string. Tie the toy-car around one end of the string and place it on the floor.
Lift the car at different distances from the floor and record the effort required for each case using a scale.
Place one end of the yardstick (about 5 cm) on the table and tape it well.
Tie the end of the string around the middle point of the stick.
Lift the free end of the stick at the distances you lifted it before without using the yardstick.
Students should compare the effort used for each case and record the results in their science notebooks.



Experiment3:
In Class 3 levers the fulcrum is at one end of the lever and the load is at the other end. The input force is applied in the middle.



Cut a 1m long piece of string. Tie one end of the string to the end of the yardstick.
The free end of the string should be tied to the metal ring.
Put a soda bottle on the floor.

With one hand grip near the bottom of the stick and the other hand come closer to the string.
Find the appropriate position so that the metal ring swings above the top of the bottle.
Moving the stick just with the hand on top try to hook the ring over the mouth of the soda bottle.
Ask the students how they think the effort was in this case. Explain to them why using a third class lever requires more effort.

Lesson Title: **Inclined Plane and Pulley Application**

Grade Level: 4

Total Time: 60 minutes

Instructional Mode: Whole Class

Team/Group Size: 3-4

Summary: Using different sized boards and different number of books students will build inclined planes. Students will build different pulley systems and explore the force used in each of them.

Learning Objectives: Students will learn how an inclined plane and pulley might help us to make the job easier. They will learn the best effective way to build an inclined plane and the most appropriate kind of pulley to help us in doing our job.

Materials List (per group): some books, boards of different lengths, toy car, rubber band, spring scale, fixed pulley, movable pulley, long string, rubber band.

Introduction/Motivation: Students will be asked to give examples of inclined planes and pulleys. For each of these simple machines they should explain how they think those simple machines help us in the process of lifting different objects.

Vocabulary/Definitions:

pulley-- a simple machine made of a rope and a wheel
inclined plane-- a sloping surface that connects two points together

Attachments

Procedure

Worksheets

Discussion Questions for students:

1. When did you have to use less force when using an inclined plane or no inclined plane at all?
2. How was the force used in relationship with the length and height of the inclined plane?
3. What can you say about the length of the rubber band in each case?

4. What is the relationship between the effort and the load in a fixed and in a movable pulley?
5. In which case do you have to use less effort to push or pull the load?
6. When using a combination of pulley how was the effort to lift an object when using more pulleys?
7. What about it when using less pulleys?

Assessment/Evaluation of students:

Students should write the answers to the discussion questions in their science notebooks. They should be evaluated by these answers.

Key Words: inclined plane, pulley, pulley system, fixed pulley, movable pulley, combined pulley system

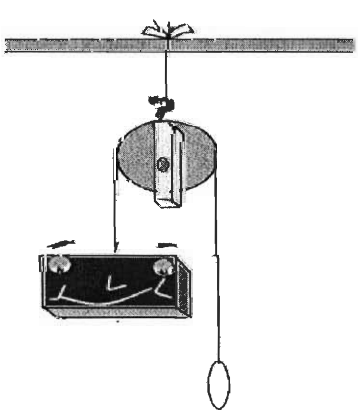
Procedure

Experiment1

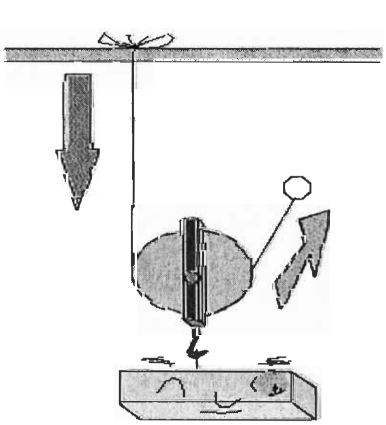
Put a pile of books on the table. Try to rest the board on top of the pile of books. Tie a toy car well with a rubber band. Attach it to a spring scale and lift the car keeping it vertically till it goes at the same height as the top of the books.
Tell the students to record their reading at the spring scale at their spreadsheets.
Then tell the students to pull the car up the incline and record the reading again.
Ask the students in which case did they have to use less force in order to lift the car.
Repeat the experiment this time using a board of greater length, and recording the reading at the spring scale.
Then add some more books to the pile and repeat the experiment using the first board recording the readings of the spring scale.
Students should also measure the height of the inclined plane which should be the height of the books.
Ask the students to write down their conclusions on the science notebooks as they will need those for the discussion.
What can they say about the relationship of the height and length of the inclined plane and the force used.

Experiment2

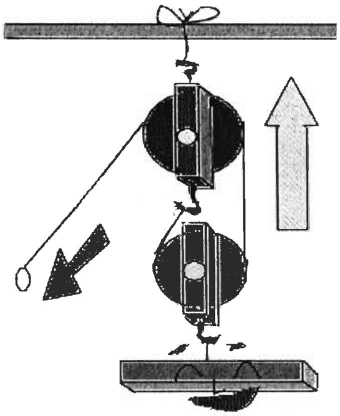
Lift the toy car attached to fixed pulley. Using a spring scale measure and record the force required. Also measure the distance the car was lifted.
Lift the toy car again this time by attaching it to a movable pulley. Lift it at the same distance it was lifted using a fixed pulley. Measure the force again. Lift it again but this time at a distance twice as big as the first one. Record the force used.
Lift the toy car using a combination of pulleys. Repeat the lifting process changing the number of pulleys in the pulley system. For each case tell the students to record the force used filling out the spreadsheets in the meantime.



a) a fixed pulley



b) a movable pulley



c) a combined pulley

Worksheet

Name________________________ Date__________________

Force recorded when no inclined plane was used

Length of inclined plane	**Height of the inclined plane**	**Force used**	**Length of rubber band**

Type of pulley	**Number of pulleys**	**Force used**	**Length of rubber band**

Dan's Lessons:

The following material contains a unit and its subsequent lessons that Dan developed for Mrs. Bercume's class. The unit is entitled "Bicycle Physics" and it deals with using science concepts to explain how the simple machines on a bicycle work. The students are then able to relate the types of simple machines to different components and systems on a bicycle and identify what makes each of these simple machines work well. From their understanding of how simple machines work well, the students are then able to use the engineering design process to suggest improvements that can be made to a bicycle in order to enhance its performance or function.

Dan's first lesson deals with the forces of friction and how they relate to the brakes on a bicycle. By teaching the students what factors need to be present for friction to occur, they are able to figure out the most effective way to make a braking system dependant on frictional forces. In this lesson, the students use the engineering design process extensively and hone their brainstorming skills.

The next lesson deals with gear ratios and their related concepts. By using homemade "gear boards" that replicate the mechanical advantage of two gears of different sizes, the students get an idea of how the gears on a bicycle work to make it easier for the rider. In the second part of the lesson, the students work with a computer spreadsheet to determine how gear ratio, wheel size, and speed of pedaling contribute to the overall speed of a bicycle. They then are required to use their engineering skills design a bike with certain characteristics based upon the spreadsheet data that will allow them to go a certain speed. Along with the engineering design process, the students also become familiarized with measuring in metric units during this lesson. Amanda Tucker assisted Dan with this lesson by giving him the idea for the replica gear board and discussing with him how she conducted a similar lesson. Dan adapted her ideas to be appropriate for Mrs. Bercume's class and add a larger engineering dimension to the lesson.

The third lesson in the unit discusses how levers are incorporated into bicycles to make handlebars and pedals work. By discussing mechanical advantage and having the students experiment to see what gives the bigger advantage when using a system of levers, they are able to design a set of handlebars that can be used by someone with low strength. This lesson puts simple machines into real life context and allows them to use the engineering design process.

The final lesson in the unit is centralized on math rather than science. The students compare the geometries of bicycle frames on different bicycles and make measurements of different angles and lengths. Along with honing their measuring skills and knowledge of the metric system, this lesson allows students to make connections between certain shapes and functions of bicycles. Their knowledge is then tested by seeing if they can determine what the relative size and shape of a frame would have to be for a specific bicycle. The original idea of having students measure angles and lengths of bicycle frame components and was taken from the Mathline website (http://www.pbs.org/teachersource/mathline/concepts/designandmath/activity1.shtm) but the given lesson was adapted to suit the purposes of Mrs. Bercume's fourth grade classroom and was made more age appropriate.

Unit Title: Bicycle Physics

Grade Level: 4th

Unit Time: Four Lessons (approximately 1-2 hours each)

Summary: Students will be learning about the simple machines and different systems that compose a bicycle. They will be learning about the physics and math that makes these parts, and after they reach an understanding about the subject they will proceed to design a part of a bike that performs a designated task.

Subject Area(s): Engineering, Science, Mathematics

Educational Standards:

MSTECF Standards (ID and text)

Physical Sciences

-The students will differentiate between properties of objects and properties of materials

-The students will give examples of how energy can be transferred from one form to another

Technology/Engineering

-The students will identify materials used to accomplish a design task based on a specific property

-The students will identify and explain the difference between simple and complex machines

-The students will identify a problem that reflects the need for shelter, storage, or convenience

-The students will describe different ways in which a problem can be represented

-The students will identify relevant design features for building a prototype of a solution to a given problem

-The students will compare natural systems with mechanical systems that are designed to serve similar purposes

WPS Benchmarks (ID and text)

Worcester Public Schools 4th Grade Benchmarks

Engineering Strand

-The students will identify materials based on properties

-The students will differentiate between simple and complex machines

-The students will utilize various representations

-The students will identify a problem that reflects the need for shelter, storage, or convenience

-The students will describe different ways in which a problem can be represented

-The students will identify relevant design features for building a prototype of a solution to a given problem

-The students will compare natural systems with mechanical systems

-The students will apply the metric system in design projects and experiments

Skills of Inquiry

-The students will ask questions and make hypothesis

-The students will use tools and technology

-The students will record data and results

-The students will recognize trends, draw conclusions

-The students will use charts and graphs

Additional Learning Objectives:

-The students will be able to understand how simple machines compose a system on a larger machine.

-The students will have better understanding of the concepts of friction, levers, gears, and simple geometry.

-The students will be able to brainstorm and use charts and tables to record data.

Essential Questions: What different designs suit different purposes for bikes? What are some systems on a bike? How do simple machines help make bikes work? How do forces like friction help simple machines work?

Pre-Requisite Knowledge: Children are able to measure with a ruler

Lessons:

1) **Gear Ratios**
2) **Friction And Brakes**
3) **Brakes and Levers**
4) **Bicycle Geometry**

Unit Background and Concepts for Teacher: Gears and Gear Ratios, Friction, Levers

Vocabulary list (w/out definitions): Drive System, Gear, Sprocket, Gear Ratio, Derailleur, Chainring, Crank, Braking System, Brake Cables, Brake Pad, Steering System, Top Tube, Structural System, Hub, Stem, Headset, Spokes, Shock Absorber, Lever, Fulcrum, Friction

Summative Assessment/Evaluation: Homeworks (pass/fail), Engineering Design Reports (pass/fail), Science Lab Reports (pass/fail)

Unit References: see lessons

Comments

Redirect URL

Owner ID

Contributors

Attachments: Vocabulary list with definitions

Key Words: Bicycles, Physics, Science, Math, Engineering, Friction, Gears, Levers, Geometry

Vocabulary with Definitions:

Bicycle Definitions

Drive System – A system of parts on a bike that allow you to move yourself along. This system is made up of the gears, wheels, chain, pedals, shifter, cables, derailleur, derailleur gears, hub gears.

Gear – A wheel with teeth on it that can mesh with other gears so that when one gear turns the other does as well.

Sprocket – A gear that is part of a chain of gears.

Gear Ratio – Ratio of the number of teeth on the larger gear to the number of teeth on the smaller gear (number of big/number of small). This helps determine how far your bike can go per pedal.

Derailleur – Moves the chain from one gear to another. Most bikes have two of these.

Chainring – The ring that the chain is guided along. It has teeth to keep the chain on it.

Crank – Connected to the pedals. This turns the motion of your pedaling into power on the chainring.

Braking System A system of parts on a bike that allow you to stop yourself when you are riding. This is made up of the brake lever, cables, caliper arms, brake pads, and wheels.

Brake Cables – These attach the brake levers to the brake mechanism.

Brake Pad – Pad that is pressed against wheel by pressure from the brake mechanism to slow down the wheel.

Steering System – This system allows you to steer. It is made up of the handlebars, stem, wheels, and frame system.

Top Tube – The upper bar on the bicycle frame.

Structural System – This holds the bike together and holds you up. It is made up of the frame, handlebars, wheels, shock absorber.

Hub – The center of the wheel where the spokes extend from.

Stem – This is the piece that connects the handlebars to the steering tube that allows you to turn the handlebars.

Headset – This connects the front of the frame to the steering tube and the handlebars.

Spokes – Metal rods that extend from the hub to the rim of the wheel. They support the wheel so it does not collapse.

Shock Absorber – Made up of a spring. This allows you to ride over bumps smoothly.

Lever – A type of simple machine that is used to make lifting or moving something easier by pushing the lever from the tip. An example of a lever is a see saw.

Friction – A special force that prevents slipping and sliding.

Lesson Title: Friction and Brakes

Grade Level: 4th

Total Time: One to Two Hours

Instructional Mode: Entire class for demonstration, Small groups for brainstorming

Team/Group Size: 3-4 Students

Summary:

This lesson provides a good background on frictional forces and relates friction to a brake mechanism on a bicycle. By taking a systematic approach to testing the factors that do and do not cause friction by using everyday objects, the students should be able to draw conclusions about what causes friction. In part 2 of the lesson, they will have the chance to design their own braking system which allows them to apply the knowledge they gained about friction and will give them some flavor about what engineering design really is.

Learning Objectives:

Worcester Public Schools 4th Grade Benchmarks

Engineering Strand

-The students will identify a problem that reflects the need for shelter, storage, or convenience

- The students will differentiate between simple and complex machines

-The students will identify relevant design features for building a prototype of a solution to a given problem

-The students will utilize various representations

-The students will identify materials based on properties

Skills of Inquiry

-The students will ask questions, make hypothesis

-The students will record data, results

-The students will recognize trends, draw conclusions

Additional Objectives:

-The students will understand what friction is, and what factors do and do not affect friction.

Procedure for Teacher:

PART 1:

1) Gather the class around front of the room where everyone can see you.
2) Give an introductory question to gauge the classes knowledge about friction. (allow 4 min for answers)
3) Explain to class what the word friction means (see definitions) and explain that there are certain factors that affect how much friction there is.
4) Break class into teams of 4 or 5 and place them at stations where materials are ready to go.
5) Hand out procedure and data table.
6) Explain the first step (sliding book by itself, see station 1 sketch) and have each student attempt this and write down observations about difficulty. (3 min)
7) Explain the next step (book with "squeeze force", see station 2 sketch) and have students try it. (5 min)
8) Repeat step 7 for texture, flatness, and shape experiments in the student procedure (see sketches for stations 3-5). (5 min each)
9) Call on a member of each group to give an observation out loud for you to write onto the copied table on the blackboard.
10) Take a show of hands vote about whether a category affects friction and write results on the board. (End Part 1)

PART 2:

11) Explain the problem about needing a break system to stop a wheel from spinning. Tell the class that they will be engineering a solution to this problem.*

12) Begin a brainstorming session. (30 min) Last 15 minutes should be used to either fill a decision matrix** or have students discuss the practicality of their ideas.

13) Pass out engineering lab reports to each student (or one for each group if appropriate).

14) Have the students fill out the engineering lab report given to them. This report should be explained at a previous time much like the decision matrix. (30 min)

15) When the students have filled out the report they will have completed their assignment, and you can tell them they have engineered a solution to the problem!

16) If a real bicycle is accessible, have one ready to bring out at the end of class and show the students the real brake system and how it works.

17) Hand out homework puzzles to each student and explain what they must do.

*At this point offer a hint to any group that wants to see it (go around to each group and demonstrate how a top can stop from spinning by squeezing the sides with your fingers). See top demonstration diagram after student procedure.

** The matrix is used by placing an idea in the table and rating it based on how good it is for a certain category. Make sure this matrix was explained to students in a previous lesson or at some point prior to this lesson, as it can be a bit complicated to be used for the first time when thrown into a lesson.

Materials List:

For Class:

Any type of bicycle for demonstration (not imperative if unavailable)
Desktop
A Sneaker
Textbook
Jar and box of similar weight and surface area
Pencil with an eraser
Large eraser

Spinning top

For Each Student:

Pencil and paper

Introduction/Motivation: Initial question to class (see procedure step 2)

Vocabulary/Definitions:

Braking System - A system of parts on a bike that allow you to stop yourself when you are riding. This is made up of the brake lever, cables, caliper arms, brake pads, and wheels.

Brake Cables – These attach the brake levers to the brake mechanism.

Brake Pad – Pad that is pressed against wheel by pressure from the brake mechanism to slow down the wheel.

Friction – A special force that prevents slipping and sliding.

Discussion Questions for students:

How does squeeze force, texture, flatness, and shape affect friction?

Assessment/Evaluation of students:

Homework Assignment (pass/fail), Engineering Lab Report

Lesson Extensions:

Troubleshooting Tips:

Safety Issues:

Redirect URL

Attachments:

Procedure (for possible distribution to students)

Data Table for Students

Diagrams of Setup and Top Demonstration

Engineering Lab Report and Decision Matrix

Homework Puzzle

References: Richard Bara

Key Words: Bicycles, Friction, Simple Machines, Science, Engineering, Physics

Procedure for Students:

Procedure for Friction and Brakes Project

1) **Slide the book across the desktop. Write down your observations in the table under "book by itself" about the difficulty of sliding the book.**

2) **Now slide the book while a partner presses down on the top of the book. Write down your observations in your table under "squeeze force"**

3) **Now slide the sneaker across the table. Write down observations in your table under "texture".**

4) **Try sliding both erasers. Write down what your observations are in your table under "flatness".**

5) **Now slide the jar and the box. Write down observations in your table under "shape".**

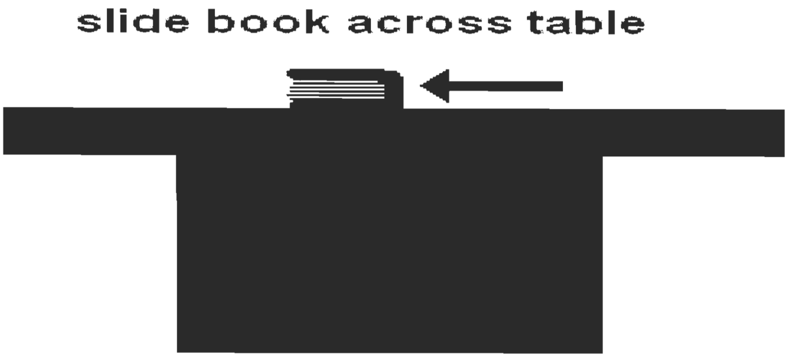
Friction Observations

Friction Factor	Observations About How Friction Factor Affects Friction for Sliding
Book By Itself (no factor)	
Squeeze Force (book pressed down)	
Texture (sneaker)	
Flatness (erasers)	
Shape (box and jar)	

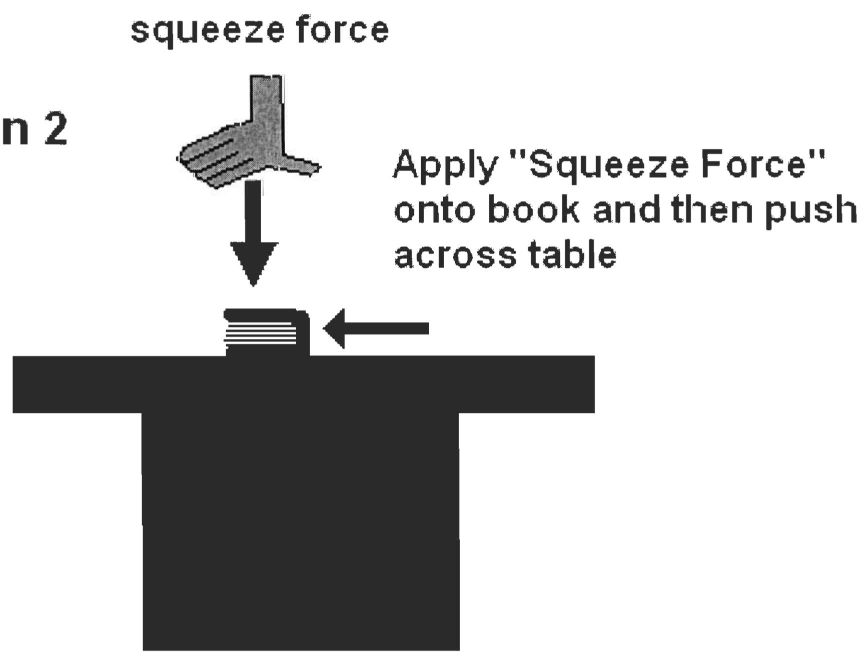
Friction Observations (sample answers)

Friction Factor	Observations About How Friction Factor Affects Friction for Sliding
Book By Itself (no factor)	The book by itself slides easily. There is not much friction.
Squeeze Force (book pressed down)	The Book does not slide as easily now. The squeeze force causes friction.
Texture (sneaker)	The sneaker is harder to slide than the book by itself. Texture causes friction.
Flatness (erasers)	The flat eraser is harder to slide than the small eraser. Flatness causes friction.
Shape (box and jar)	The box and jar slide about the same. Shape does not cause friction.

Station 1

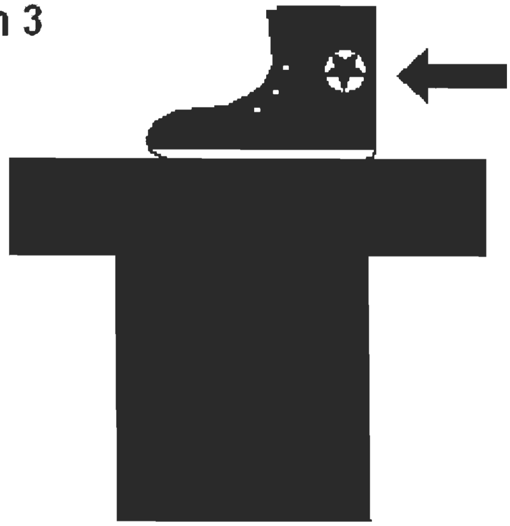


Station 2



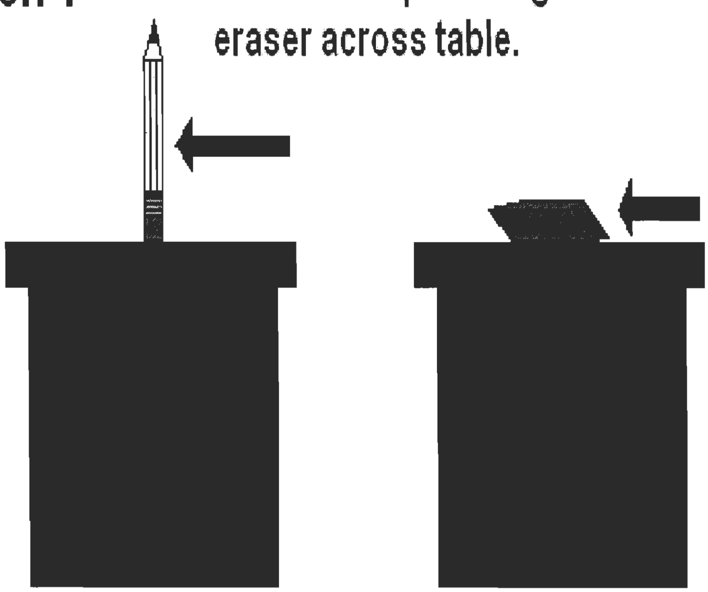
Slide sneaker across table

Station 3



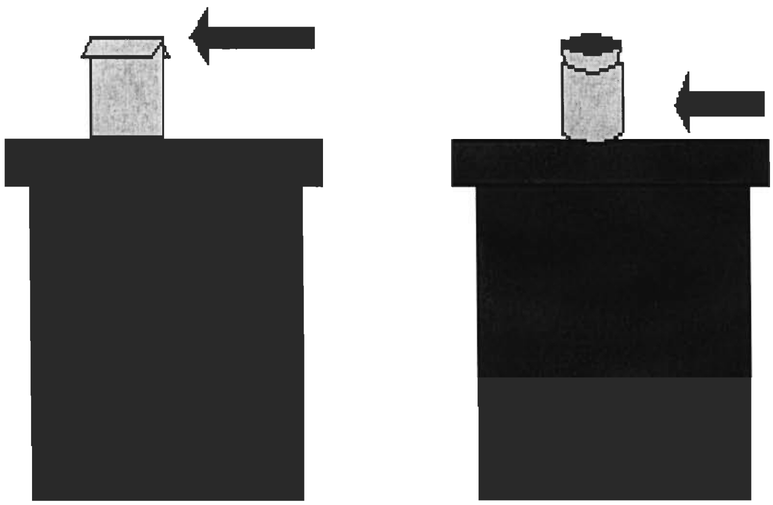
Station 4

Push pencil eraser across table. Then push large eraser across table.

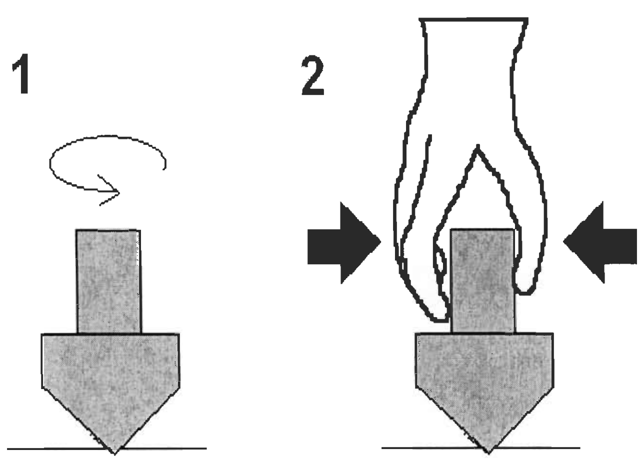


Station 5

Slide the box across the table and then slide the jar.

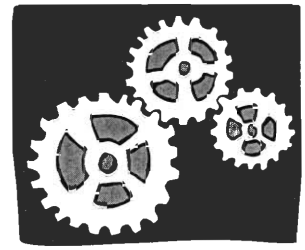


TOP DEMONSTRATION



Engineering Design Report

Project Name: ______________________



Group Members:

Date:

Grade:

What is the problem?

What is the goal of your solution?

How did you research the problem? Summarize your findings.

How did you develop and select your solution?

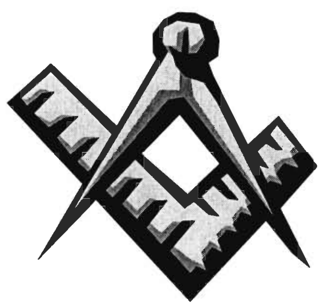
Draw a sketch of your solution

Explain your solution.

Explain why you were or were not successful in solving the problem.
Describe any difficulties encountered.

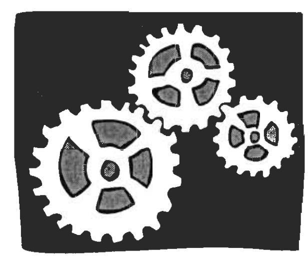
Explain how you would improve on your solution or how you could modify your design.

Teacher comments



SAMPLE

ANSWERS



Project Name:
Friction And Brakes

Group Members:	Date: **x/xx/xx** Grade: **4**

What is the problem?

There is a bike that cannot stop because it has no brakes to stop it from moving.

What is the goal of your solution?

Our goal is to create a brake system that can slow down and eventually stop the wheels from turning so that the bike stops. Our design must meet the requirements we came up with in our decision matrix.

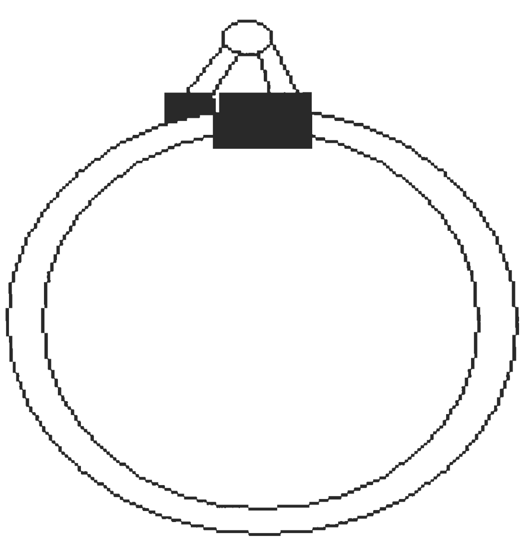
How did you research the problem? Summarize your findings.

We experimented with different objects to see what things affect friction. We tested squeeze force, flatness, texture, and shape to see what causes friction. We found that squeeze forces, rough textures, and very wide flat surfaces help provide friction.

How did you develop and select your solution?

We used the decision matrix to select among some ideas we came up with during brainstorming. Our solution met the three requirements of squeeze force, flatness, and texture.

Draw a sketch of your solution



Explain your solution.
We have a flat plate on the side of the wheel that squeezes with great force against the rim. The plate is very flat and is made of a rough material. Because it meets the three requirements of squeeze force, flatness, and texture, we feel that this brake will do a good job of slowing down the wheel and stopping the bike from moving.

Explain why you were or were not successful in solving the problem.
Describe any difficulties encountered.
The plate slowed the wheel down but did not stop it. We were not successful in stopping the bike, so we decided that the single plate was not the best solution to the problem.

Explain how you would improve on your solution or how you could modify your design.

Using a plate on either side of the rim would make the squeeze force and combined flatness (two plates has double the flatness of one plate) larger.

Teacher comments

Decision Matrix

Project Name:	Matrix Number:
What is this Matrix Deciding?	

Scale: 0 (worst), 1 (ok), 2 (best)

Requirement					

Requirement Worth

Possible Choices							**Totals**

Notes:

Project Name: Friction	Matrix Number:
What is this Matrix Deciding? Best Brake Idea	

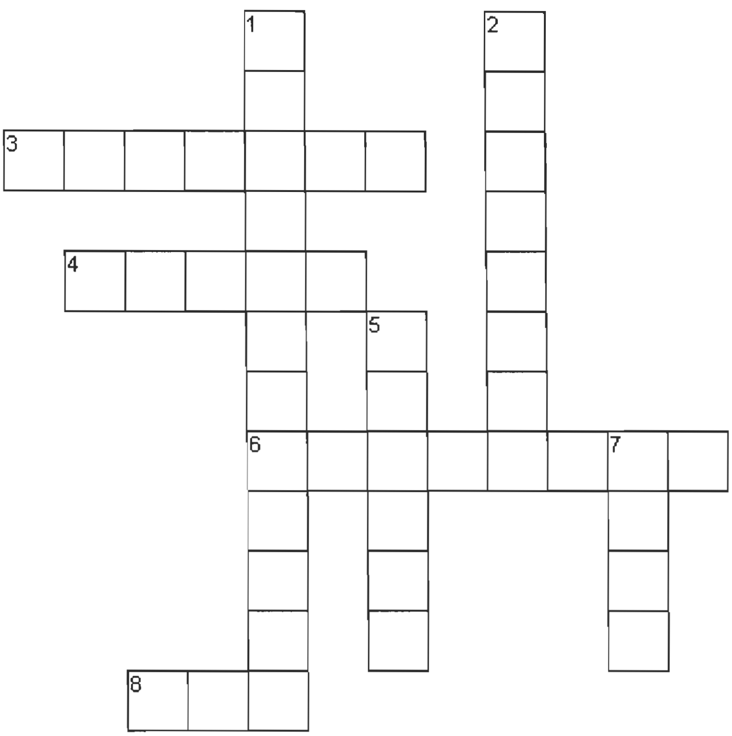
Decision Matrix (Sample Answers)

Scale: 0 (worst), 1 (ok), 2 (best)

Possible Choices	squeeze force	flatness	texture				**Totals**	
Requirement Worth	1	1	1					
push pad one side	0.5	0.5	1				2	
push pad both sides	1	1	1				**3**	<-----
flap on front of tire	0	1	1				2	
back pedal	?	?	?				?	
pressured pins	1	0	1				2	

Notes: The push pad both sides were the best for all three categories. This will be our choice of brake.

Friction Criss Cross



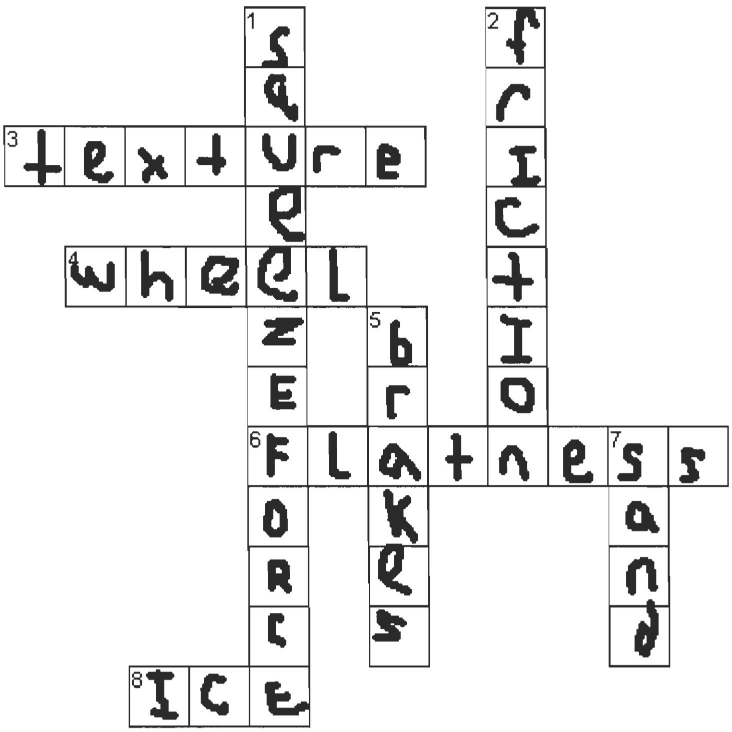
Across
3. How sandpaper causes friction.
4. Stop this from spinning to stop a bike.
6. How a flat box causes friction.
8. Low friction stuff on the road in winter.

Down
1. How heavy things cause friction.
2. A force that makes moving hard.
5. Friction helps this bike part work.
7. High friction stuff on the beach.

Word list: texture, flatness, squeeze force, friction, sand, ice, wheel, brakes

Friction Criss Cross

(sample answers)



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Word list: texture, flatness, squeeze force, friction, sand, ice, wheel, brakes

Lesson Title: Gear Ratios

Grade Level: 4th

Total Time: Two Days (approx. two hours)

Instructional Mode: Entire class for demonstration, Small groups for brainstorming

Team/Group Size: 3-4 Students

Summary:

In this lesson the students will be working in groups and learning about how gears work and how the sizes of the gears on a bike relate to each other and allow the bike to travel farther in a shorter amount of time.

This lesson will give the students a taste of engineering, as well as give them experience using a program such as excel and making accurate measurements. They will also see the relationship between certain quantities and how they can form an equation to determine an unknown.

Learning Objectives:

Worcester Public Schools 4th Grade Benchmarks

Engineering Strand

-The students will identify a problem that reflects the need for shelter, storage, or convenience

-The students will differentiate between simple vs. complex machines

-The students will identify relevant design features for building a prototype of a solution to a given problem

-The students will apply the metric system in design projects and experiments

Skills of Inquiry

-The students will use tools and technology

-The students will record data, results

-The students will recognize trends, draw conclusions

-The students will use charts and graphs

Additional Objectives:

The students will understand what how gear ratios work, and how they combine with properties such as cadence and wheel distance to determine the speed of a bicycle.

Procedure for Teacher:

PART 1:

13) Gather the class around front of the room where everyone can see you.
14) Give an introductory question to gauge how much the students know about gears. Ask them if they can think of any things they know that use gears to work. (allow 4 min for answers)
15) Demonstrate to class how the replica gear boards work, and show them how to line up markings so they can measure how many times the gears move around.
16) Break class into 3 teams and place them at stations where boards are ready to go.
17) Hand out data table.
18) Have the teams measure the diameters of the two gears on their respective board by lining up their ruler with the diameter line across the gear, and then explain to them how to calculate the gear ratio. (2 min)
19) Have one team member spin the crank gear around ten times while their partners count how many times the other gear turns around and then have them record their data into the table. (3 min)
20) Have the groups calculate the gear ratio for the station and record it. (1 min)
21) Rotate the students between the three gear stations, and then call for their attention.
22) Have the students offer their data so you can write it on the board. If the groups values differ then repeat the trial in front of the class and show them how many times the gear turns.

23) Ask questions to make sure the students understand the relationship between gears of different sizes. For instance, ask them how many times a gear will spin if a gear half the size of it is meshed with it and spins four times.

24) Tell them that in the next class they will be using their engineering skills to design a gear system on a bicycle that can make the bicycle go specific speeds.

PART 2:

a. Do a quick review to make sure the class remembers how gears of different sizes relate to each other.
b. Explain to the class what cadence means by demonstrating different speeds of turning the crank. Ask them to think about whether a higher cadence will make the bicycle go faster or slower
c. Ask the class what wheel diameter has to do with the speed of the bicycle. Use two marked cardboard circles (see attached) of different sizes to illustrate how a larger wheel can be turned as many times as a smaller wheel and go farther.
d. Ask them to recall the gear ratios they calculated, and explain to them that having a gear ratio of 2 or 5 is like saying that a gear is half or a fifth of the size as the one it is meshed with.
e. *Have each group go to a computer and enter in different values for the gear sizes, wheel diameters, and cadences in the excel spreadsheet. Have them complete about 8 trials and write down the results in their tables. (5-10 min) Tell them to ignore the "too high/low" column for now.
f. Call for their attention and see if the class can tell you whether increasing or decreasing the gear ratios, wheel diameters, and cadences will make the bicycle go faster.
g. Tell them you want a bicycle that will go 50 km/h and have them go to the computers again and try and enter in the numbers that will get that speed. Have them rank their past trials based on whether they were too high or low for that speed, and have them rank their new trials as well until they reach their goal. (10 min)

h. Tell them they are now engineers and have done a great job designing a gear system!
i. Explain the homework and describe to them what the words on the matching sheet mean if you have not already explained them.
j. Once they have the background necessary, pass out homework sheets to the students.

*If there are not enough computers available, you can use a computer to demonstrate the program to the students. Have them raise their hands offer you the values to input until a solution is obtained. This way they can discuss the problem as a class and figure out what needs to be changed in order to obtain a correct answer.

Materials List:

For Class:

Three cardboard gear replicas (pre-assembled)
Two marked cardboard disks of different sizes for demonstration
3 computers with Microsoft Excel installed

For Each Student:

Pencil and paper

Introduction/Motivation: Initial question to class (see procedure step 2)

Vocabulary/Definitions:

Gear – A wheel with teeth on it that can mesh with other gears so that when one gear turns the other does as well.

Sprocket – A gear that is part of a chain of gears.

Gear Ratio – Ratio of the number of teeth on the larger gear to the number of teeth on the smaller gear (number of big/number of small). This helps determine how far your bike can go per pedal.

Derailleur – Moves the chain from one gear to another. Most bikes have two of these.

Chainring – The ring that the chain is guided along. It has teeth to keep the chain on it.

Crank – Connected to the pedals. This turns the motion of your pedaling into power on the chainring.

Discussion Questions for students:

How can different sized gears be combined to make a bike go faster?

Assessment/Evaluation of students: Homework Assignment (pass/fail)

Lesson Extensions

Troubleshooting Tips: see *

Safety Issues:

Redirect URL

Attachments:

Gear Board Assembly Instructions (with diagrams)

Gear Data Tables

Circles Diagram

Homework Sheet

References: Mandy Tucker, www.howstuffworks.com

Key Words: Bicycles, Gears, Simple Machines, Science, Engineering

Instructions for Assembly of Gear Board

Materials needed:
- scrap corrugated cardboard (in big sheets)

- a drawing compass with pencil
- a permanent marker
- an x-acto knife (or anything similar)
- super glue for layering cardboard
- a ruler or meter stick
- various nuts, bolts, and washers
- a drill or a hammer and nails that can be used to make pilot holes

1) Lay out a flat sheet of cardboard.

2) Determine the sizes of the "gears" that you want, and draw them on another sheet of cardboard by using the compass to make neat circles.

3)Cut these out neatly with the x-acto knife. (if you wish to reinforce them, make extra circles and layer them with the super glue to make thicker "gears") Make sure to clearly mark the centers of the circles with the point of the compass (FIGURE 1)

4) Draw a horizontal line with a pencil across the center of the first sheet of cardboard

5) Take the radii of each of the gears and add them together. On the horizontal line you drew, mark two points that are at a distance from each other equal to the sum of the radii. (For example, if you're gears have radii of 3 and 5 inches respectively, mark two points on the line that are 3+5 = 8 inches apart) (FIGURE 1)

6) Make small pilot holes through the centers of the gears and the points marked on the cardboard sheet.

7) Assemble the gear board by inserting bolts through the gear centers into the points on the cardboard sheet. Include washers in between the cardboard surfaces and the nuts on the ends of the bolts. Make sure there are no sharp edges sticking out that the students can hurt themselves with. (FIGURE 2 + 3)

8) Take a ruler and line it up across the center line you drew on the cardboard sheet. Make markings on the left edges of each gear to correspond to the line so that the students will be able to see when each gear has made a revolution (FIGURE 4)

9) Optional: Decorate the board to make it look like a real bicycle

FIGURE 1

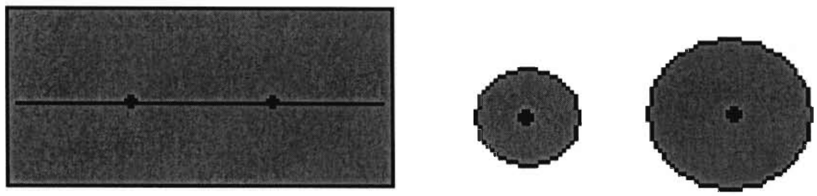


FIGURE 2

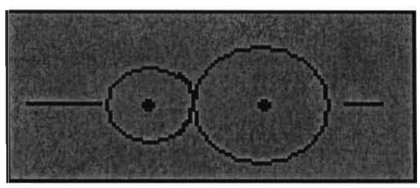


FIGURE 3

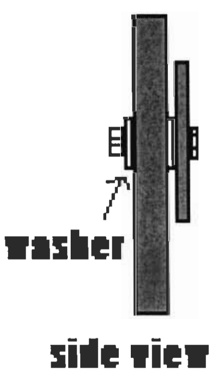
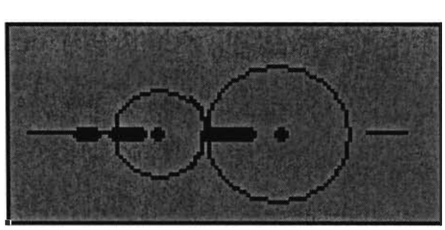


FIGURE 4



GEAR TO SPEED CALCULATOR

Number of Teeth		Gear Ratio	Wheel Diameter (cm)	Wheel Distance (cm)	Cadence (rpm)	Speed (km/h mph)	
small gear	large gear			cm	rpm	km/h	mph
10.00	3.00	3.33	30.00	94.25	25.00	47.12	29.29

shaded regions can have numbers entered

How Good Are Your Gears?

Trials	Teeth Small	Teeth Large	Wheel Diameter (cm)	Cadence (rpm)	Final Speed (km/h)	Too High?Low?
1						
2						
3						
4						
5						
6						
7						
8						

How Good Are Your Gears? (sample answers)

Trials	Teeth Small	Teeth Large	Wheel Diameter (cm)	Cadence (rpm)	Final Speed (km/h)	Too High?Low?
1	3	6	4	20	0.75	too low
2	6	3	4	100	15.08	too low
3	10	3	4	100	25.13	too low
4	15	3	4	100	37.70	too low
5	15	3	4	200	75.40	too high
6	10	3	4	200	50.27	good!
7	10	3	30	25	47.12	good!
8	10	3	15	54	50.89	good!

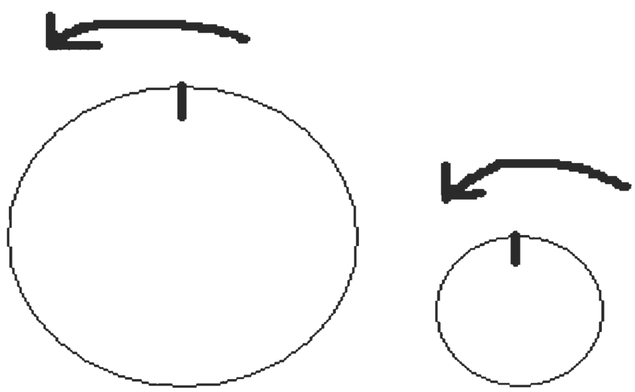
Gear Ratio Chart

Stations	Crank Gear Size	Driven Gear Size	Gear Ratio
1			
2			
3			

Gear Ratio Chart (Sample Answers)

Stations	Crank Gear Size	Driven Gear Size	Gear Ratio
1	4	1	4
2	10	5	2
3	15	10	1.50

Marked Circles: Use the markings to count a set number of turns that each circle makes. Compare the distances each travels for the set amount of rotations.



Bicycle Part Matching

Name:__________________

Match the words in the first column to the best available answer in the second column.

_____ Gear Ratio	1) Connected to the pedals. This turns the motion of your pedaling into power on the chainring.
_____ Cadence	2) Describes how fast something is going.
_____ Wheel Distance	3) The ring that the chain is guided along. It has teeth to keep the chain on it.
_____ Wheel Diameter	4) How many times the wheel spins around all the way in a period of time
_____ Drive System	5) You measure across a wheel to get this.
_____ Gear	6) Ratio of the number of teeth on the larger gear to the number of teeth on the smaller gear. This helps determine how far your bike can go per pedal.
_____ Crank	7) You measure around the wheel to get this.
_____ Chainring	8) System on a bike that includes gears
_____ Derailleur	9) Moves the chain from one gear to another.
_____ Speed	10) a round part with teeth on it

Bicycle Part Matching

Name:_________________

Match the words in the first column to the best available answer in the second column.

SAMPLE ANSWERS

__6___	Gear Ratio	1) Connected to the pedals. This turns the motion of your pedaling into power on the chainring.
__4__	Cadence	2) Describes how fast something is going.
__7_	Wheel Distance	3) The ring that the chain is guided along. It has teeth to keep the chain on it.
__5_	Wheel Diameter	4) How many times the wheel spins around all the way in a period of time
__8___	Drive System	5) You measure across a wheel to get this.
__10___	Gear	6) Ratio of the number of teeth on the larger gear to the number of teeth on the smaller gear. This helps determine how far your bike can go per pedal.
___1__	Crank	7) You measure around the wheel to get this.
___3__	Chainring	8) System on a bike that includes gears
___9__	Derailleur	9) Moves the chain from one gear to another.
___2__	Speed	10) a round part with teeth on it

Lesson Title: Brakes and Levers

Grade Level: 4th

Total Time: Two Hours

Instructional Mode: Whole class for demonstration, small groups for brainstorm session

Team/Group Size: 3-4 Students

Summary:

Here the students will discover how levers work and how levers are incorporated into the design of brake handles and pedals. Group brainstorming and sketches will be required from the students. In this activity the students will learn more about the simple machines that compose a bicycle and figure out how to put their knowledge into practical use.

Learning Objectives:

Worcester Public Schools 4th Grade Benchmarks

Engineering Strand

-The students will identify a problem that reflects the need for shelter, storage, or convenience

-The students will differentiate between simple vs. complex machines

-The students will identify relevant design features for building a prototype of a solution to a given problem

-The students will compare natural to mechanical systems

-The students will utilize various representations

Skills of Inquiry

-The students will ask questions, make hypothesis

-The students will record data, results

Additional Objectives:

-The students will gain knowledge about levers (examples of levers, how levers work, how a lever makes work easier)

Procedure for Teacher:

1) Gather the class around front of the room where everyone can see you.
2) Announce that the class will be finding a way to make pedaling a bicycle and pressing brake levers easier for someone who is not very strong by using a special machine called a lever.
3) Ask the class to tell you what they know about levers. (2 min) Follow up by giving background on levers.
4) Break class into groups of about five and send them to stations where materials are ready to go.
5) Hand out attached procedures and observation tables.
6) Explain the book and meterstick experiment and have each person in each group try the experiment and write down their observations in their tables.* See Figure 1. (10-15 min)
7) Call on one spokesperson from each group to state what observations they came up with for each category and write onto a replica of the table on the blackboard.
8) Have students think to themselves about the relationship between distance and applied force on a lever.
9) Now put them back in groups solving the engineering challenge of children that cannot operate the brake handles or pedals on a bicycle.
10) Begin a brainstorming session. (30 min) Last 15 minutes should be used to either fill a decision matrix** or have students discuss the practicality of their ideas.
11) Have each group announce their ideas to the rest of the class while you list each idea on the board. Go through and discuss each idea as a class by talking about the pros and cons. After this announce that they have engineered great solutions to this problem!
12) Pass out the attached homework assignments.

* If there is downtime with the students have them write down on paper all of the different levers they can find in the classroom.

** The matrix is used by placing an idea in the table and rating it based on how good it is for a certain category. Make sure this matrix was explained to students in a previous lesson or at some point prior to this lesson, as it can be a bit complicated to be used for the first time when thrown into a lesson.

Materials List:

For Class:

Meterstick (x number of groups)
Desktop (x number of groups)
Textbook (x number of groups)

For Each Student:

Pencil and paper

Introduction/Motivation: Initial questioning (see procedure step 2)

Vocabulary/Definitions:

Lever – A type of simple machine that is used to make lifting or moving something easier by pushing the lever from the tip. An example of a lever is a see saw.

Fulcrum - The point on a lever that pivots.

Discussion Questions for students:

If you are not very strong is it better to push a lever closer to the fulcrum or further from the fulcrum?

If you can't push long distances is it better to push a lever closer to the fulcrum or further from the fulcrum?

Assessment/Evaluation of students: Homework Assignment (pass/fail),

Lesson Extensions

Troubleshooting Tips:

Safety Issues:

Redirect URL

Attachments:

- **-Book Experiment Diagram**
- **-Student Data Table**
- **-Student Procedure**
- **-Homework Assignment**
- **-Decision Matrix**

References: Richard Bara

Key Words: Bicycles, Levers, Science, Engineering, Physics

When are Levers Hard or Easy?

Push Trial	Push Next to Fulcrum or at Tip	Easy or Hard
Push 1		
Push 2		

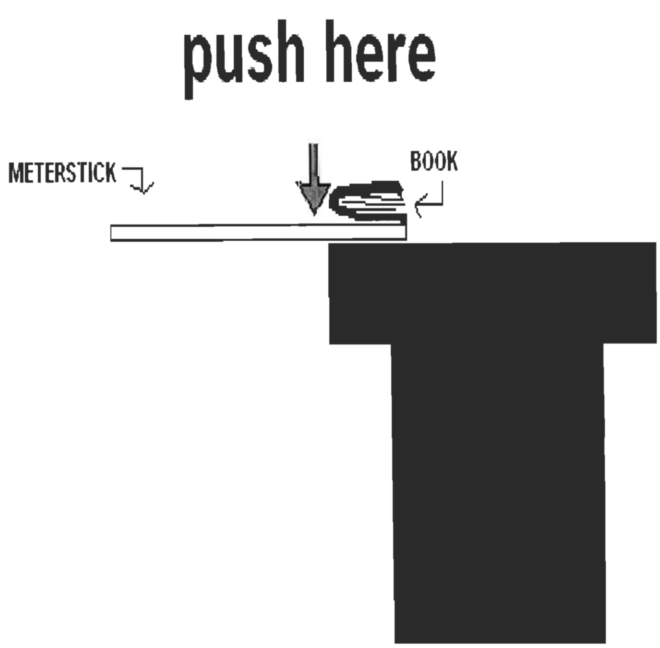
When are Levers Hard or Easy? (Sample Answers)

Push Next to Fulcrum or at Tip	Easy or Hard
We pushed the lever next to the fulcrum.	This was hard to do.
We pushed the lever at the tip.	This was much easier to do.

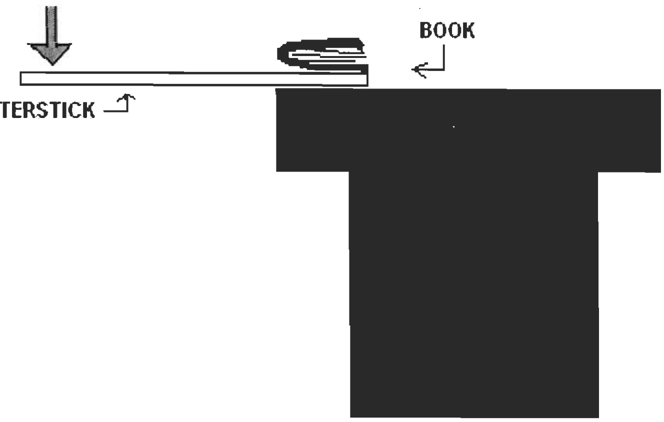
Student Procedure for Levers

1) Go to the station with the book and meterstick
2) For Push #1, try pushing down (not hard…the object here is not to flip the book or break the stick) on the meterstick about a couple centimeters away from the book.
3) For Push #2, go to the tip of the meterstick and try pushing down.
4) Write down in the table for push 1 and 2 about how hard they were and how far you had to push them in the columns "Difficulty" and "Distance".
5) Let your partners have a turn.

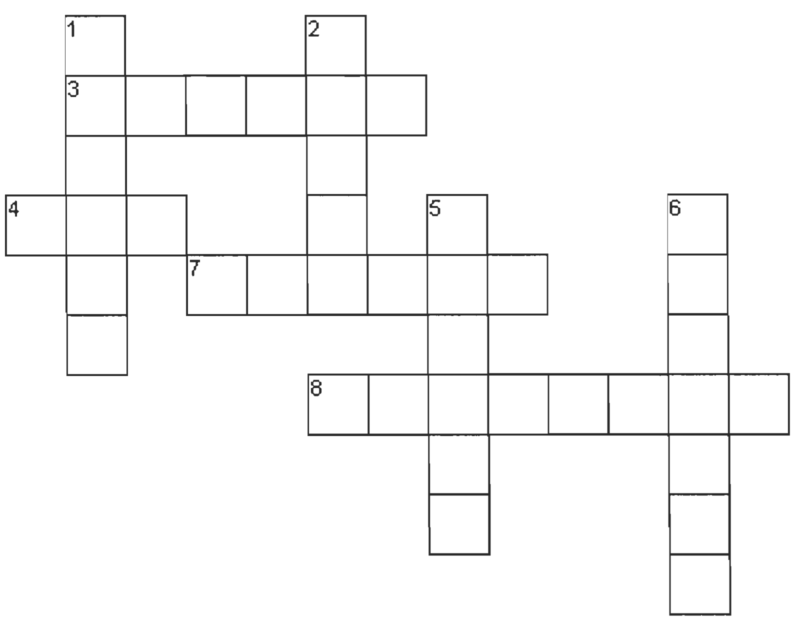
Figure 1



then push here



Levers and Bikes Criss-Cross



Across
3. Its __ to push when farther away from fulcrum
4. Use this lever when playing baseball
7. Its __ to push when closer to fulcrum

8. Make this big to make pushforce less

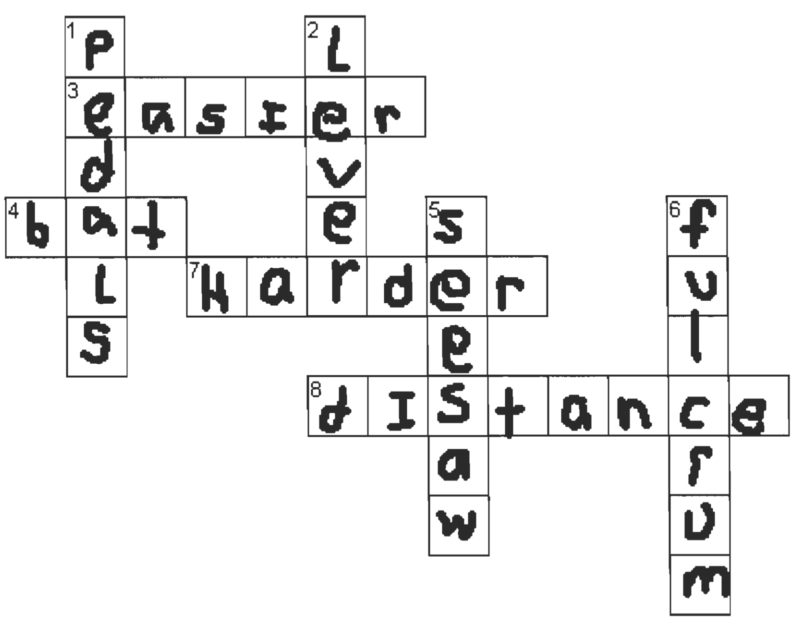
Down

1. This bike part is a lever for feet
2. Bike handles are this kind of simple machine
5. You can ride this lever on playgrounds
6. Pivot point of a lever

word list: bat, easier, distance, fulcrum, seesaw, harder, lever, pedals

Levers and Bikes Criss-Cross

(Sample Answers)



Across

3. Its __ to push when farther away from fulcrum

4. Use this lever when playing baseball
7. Its __ to push when closer to fulcrum
8. Make this big to make pushforce less

Down

1. This bike part is a lever for feet
2. Bike handles are this kind of simple machine
5. You can ride this lever on playgrounds
6. Pivot point of a lever

word list: bat, easier, distance, fulcrum, seesaw, harder, lever, pedals

Lesson Title: Bicycle Geometry

Grade Level: 4th

Total Time: One to Two Hours

Instructional Mode: small groups

Team/Group Size: 3-4 Students

Summary:

The students will be honing their measuring skills in this lesson where they examine bicycles with similar shapes and try to determine the subtle differences. This lesson can help a student to distinguish between different shapes that can appear similar but do in fact have differences. Here the students will be discovering how geometry affects the design of a bicycle, why different bicycles have different shapes, have their first small experience in engineering design, and practice good data collecting and recording skills.

Learning Objectives:

Worcester Public Schools 4th Grade Benchmarks

Engineering Strand

-The students will identify a problem that reflects the need for shelter, storage, or convenience

-The students will describe different ways in which a problem can be represented

-The students will identify relevant design features for building a prototype of a solution to a given problem

-The students will compare natural systems with mechanical systems

-The students will apply the metric system in design projects and experiments

Skills of Inquiry

-The students will use tools and technology

-The students will record data, results

-The students will recognize trends, draw conclusions

-The students will use charts and graphs

Procedure for Teacher:

1) Bring out the three bicycles.
2) Gather the class around front of the room where everyone can see you.
3) See what knowledge the students have about different bicycle types. (3 min) Follow up by describing each bike
4) Tell the students that they will be doing an experiment where they see what the differences in shapes of the bicycle frames are for different types of bicycles.
5) Pass out measurement diagrams (see attached) to each student and by showing each angle and size on the actual bicycle describe to the students what each measurement is.
6) Take a sample measurement of one angle and one size using a ruler and a protractor so the students can see how to do it.
7) Pass a table out to each student and break the class into three groups.
8) Place each group at one station (where one of the three bikes is).
9) Specify the units they are going to be measuring in and show them the side of the ruler to use.
10) Assign responsibilities to all of the members in each group (size measurer, angle measurer, and recorders to write in the table).
11) Start each group at a station and rotate groups when done (10 min).
12) After completion, call for their attention and explain how to calculate the chain stay/frame size ratio.
13) Have each student calculate the ratios for each of their measurements and have them record the values in their table. * (10-15 min)
14) Have a spokesperson from each group supply you with values to enter in the table that you copied onto the board.
15) Discuss with the groups how certain values compare on different types of bicycles and have them figure out which bicycle has the smallest and largest value for each measurement (use attached chart if needed).

16) If time is provided, have each group pick a type of bicycle and sketch a picture of a bicycle frame and label on the sketch where the sizes and angles are located. (10-15 minutes)
17) Have the groups write down next to each label "smallest", "largest", or "medium" based on how they think their measurement should rank out of the 3 bicycle types. (5-10 min)
18) Announce that they have successfully designed a bicycle frame and congratulate them on their engineering skills!
19) Pass out homework assignments.
20) As an optional precursor to this lesson, you can pass out the diagrams of the bicycle parts and go over with the class what the different parts of a bicycle are and what they do.

* The ones that finish more quickly can begin writing down on paper the different shapes contained in each bicycle frame. Have them write down which bikes have the smallest and largest values for each category.

Materials List:

For Class:

3 Bicycles (BMX, Mountain, and Racing, or whatever is availiable) that students, teachers, or classroom aids bring into class

Protractors and rulers (4 or 5 for each group)

For Each Student:

Pencil and paper

Introduction/Motivation: Initial Questions (see procedure)

Vocabulary/Definitions:

Seat Angle- refer to diagram

Head Angle- refer to diagram

Back Angle- refer to diagram

Frame Size- refer to diagram

Chain Stay- refer to diagram

For definitions of bicycle parts to use in optional step, see unit plan

Discussion Questions for students: If you were to design a BMX bike, would its seat and back angles be as big as the seat and back angles of a mountain bike? (vary the same question for different bike types)

Assessment/Evaluation of students: Homework Assignment (pass/fail)

Lesson Extensions

Troubleshooting Tips:

Safety Issues:

Redirect URL

Attachments: **Procedure (for possible distribution to students)**

Data Table for Students

Diagrams of Bike Measurements and Parts

Homework Puzzle

References: Mathline, a part of PBS Teacher Source

http://www.pbs.org/teachersource/mathline/concepts/designandmath/activity1.shtm

Key Words: Bicycles, Geometry, Math, Science, Engineering, Physics

Procedure for Student:

Procedure for Bicycle Geometry

1) At the first station, the measurers will measure the different angles and sizes while the recorders will write the answers down in the table.

2) Do step 2 for each bike.

3) Divide your frame size number by your chain stay number for each bike.

4) Write these answers down in the table under "ratio".

Bike Geometry Table

Bike Number	Seat Angle	Back Angle	Head Angle	Frame Size (cm)	Chain Stay (cm)	Ratio
Bike 1						
Bike 2						
Bike 3						

Enter a Bike Number Under Each Category for Whichever Bike is the Largest, Medium, or Smallest

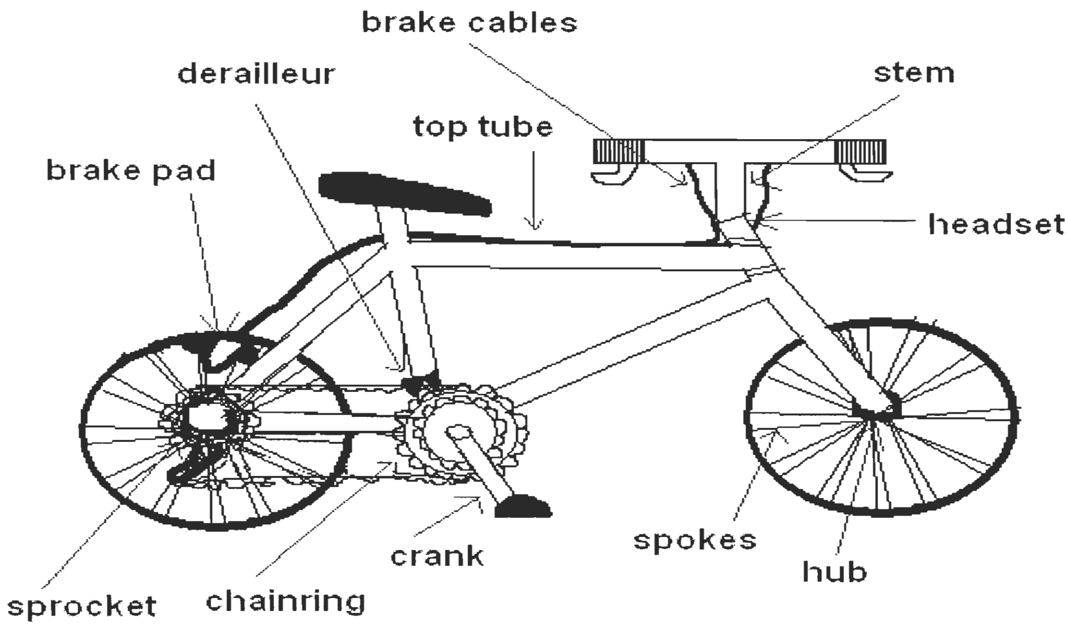
Rank	Seat Angle	Back Angle	Head Angle	Frame Size (cm)	Chain Stay (cm)	Ratio
Largest						
Medium						
Smallest						

Bike Geometry Table (Sample Answers)

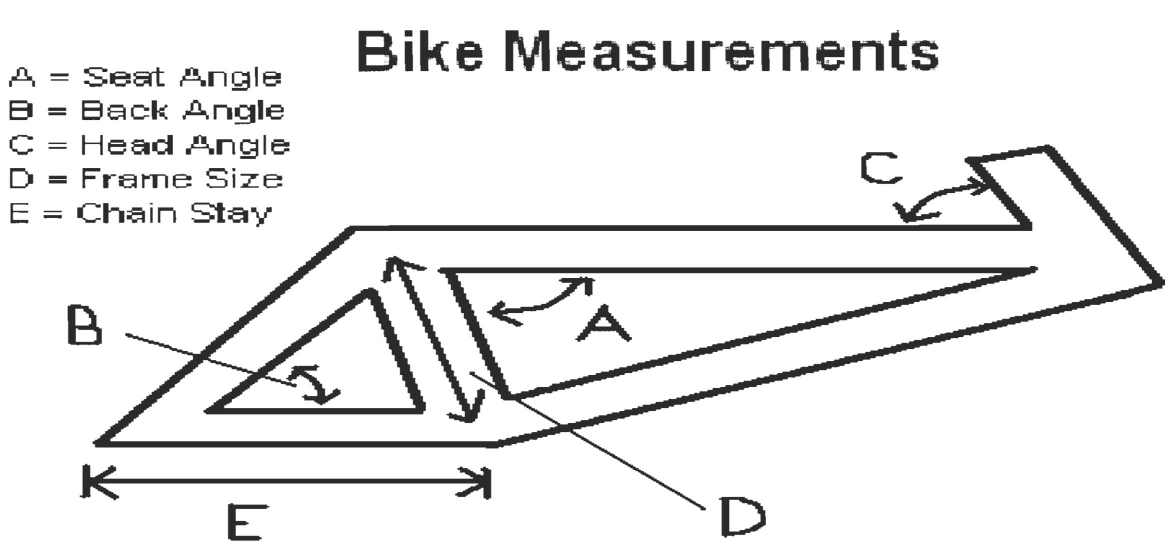
Bike Number	Seat Angle	Back Angle	Head Angle	Frame Size (cm)	Chain Stay (cm)	Ratio
Bike 1	70 degrees	20 degrees	80 degrees	28 cm	67 cm	0.418
Bike 2	75 degrees	38 degrees	79 degrees	72 cm	78 cm	0.923
Bike 3	81 degrees	73 degrees	65 degrees	112 cm	89 cm	1.26

Enter a Bike Number Under Each Category for Whichever Bike is the Largest, Medium, or Smallest

Rank	Seat Angle	Back Angle	Head Angle	Frame Size (cm)	Chain Stay (cm)	Ratio
Largest	Bike 3	Bike 3	Bike 1	Bike 3	Bike 3	Bike 3
Medium	Bike 2	Bike 2	Bike 2	Bike 2	Bike 2	Bike 2
Smallest	Bike 1	Bike 1	Bike 3	Bike 1	Bike 1	Bike 1



BICYCLE PARTS



Geometry Search

R	E	L	U	R	A	Z	Z	E	C
E	L	V	I	O	Y	M	L	Z	H
O	G	L	W	T	V	G	I	I	A
A	N	T	W	C	N	K	L	S	I
B	A	C	K	A	N	G	L	E	N
Z	T	Z	D	R	C	Q	S	M	S
F	A	A	L	T	S	I	Y	A	T
Q	E	E	G	O	I	T	A	R	A
H	S	O	Y	R	C	Y	Z	F	Y
X	B	K	Y	P	Z	G	Y	I	X

BACKANGLE
HEADANGLE
RULER
CHAINSTAY
PROTRACTOR
SEATANGLE
FRAMESIZE
RATIO

GEOMETRY SEARCH SAMPLE ANSWERS

```
R E L U R + + + E C
+ L + + O + + L Z H
+ G + + T + G + I A
+ N + + C N + + S I
B A C K A N G L E N
+ T + D R + + + M S
+ A A + T + + + A T
+ E + + O I T A R A
H S + + R + + + F Y
+ + + + P + + + + +
```

(Over,Down,Direction)
BACKANGLE(1,5,E)
CHAINSTAY(10,1,S)
FRAMESIZE(9,9,N)
HEADANGLE(1,9,NE)
PROTRACTOR(5,10,N)
RATIO(9,8,W)
RULER(5,1,W)
SEATANGLE(2,9,N)

Jason's Lessons:

The following is a description of what Jason's unit on projectile motion contains. There are short descriptions of what the lesson plans accomplish and what the main ideas of the lessons are.

Lesson 1: SPRING INTRODUCTION - This lesson is an introduction to springs and potential energy. The students should be familiar with the basic ideas of potential energy and how springs work after this lesson. The main goal is to get the students interested in springs and how they work.

The following resources were accessed to help design this lesson:

Simple catapult - www.cosi.org/ossw/2001/experiments/catapult.htm

Experiment where there is a target –

www.sciencebyjones.com/marshmallow_projectile.htm

Lab report format that will give lab experience for the students –

www.usoe.k12.ut.us/curr/science/core/plans/int/grape.html

Site to help students design their own catapult/launcher -

www.usoe.k12.ut.us/curr/science/sciber00/8th/machines/sciber/cat.htm

Link to a lesson on gravity and acceleration –

http://hcs.harvard.edu/~xmentors/pages/resources/lessons/physics/fourth/10.html

Lesson 2: TOOL INTRODUCTION AND BUILDING – This lesson should teach the children about common tools and they should understand the danger of misusing them.

The students will get a chance to see each tool and in the building part of the lesson where they will get to use some of the tools. They should have a good understanding of what tools are used for and be able to determine if a certain tool will be appropriate for a specific job. This website was accessed supply some visual data on tools.

Amazon.com Tools and Hardware - http://www.amazon.com/exec/obidos/tg/browse/-/228013/ref=sd_str_hi/103-9980193-4767806

Lesson 3: DESIGN AND HYPOTHESIS – The third lesson will introduce the students to designing their own projectile launcher. They will have the opportunity to create a unique rendering of their idea and hypothesize about what their model will do. A question about lesson four will be posed to the students so they can hypothesize what will happen in lesson four.

Lesson 4: LAUNCHING BALLOONS AND RECORDING DATA – The final lesson will involve launching water balloons and having the students collect accurate data. Their results will be put into graphs and the students will draw conclusions from their data. It is important for the students to understand how to graph their results in a clear manner.

Unit Title: Projectiles

Grade: 4th

Unit Time: 4 - 5 hours

Summary:
The unit will cover springs, potential energy, projectile motion, design, hypothesis, recording data, and conclusions. The unit will end with an activity of launching water balloons and recording the data.

Essential Questions:

How does projectile motion work?
How does storing energy work?
What different types of tools serve what purposes?
How can one build a creative water balloon launcher?
How can one form a hypothesis that will be accurate?
What makes an experiment valid?
How can one collect better data?
What different types of graphs will better show the results?

Benchmarks:
04.SC.IS.01 – Ask questions and make predictions that can be tested.
04.SC.IS.03 – Keep accurate records while conducting simple investigations or experiments.
04.SC.IS.04 – Conduct multiple trials to test a prediction.
04.SC.IS.05 – Recognize simple patterns in data and use data to create a reasonable explanation for the results of an investigation or experiment
04.SC.IS.06 – Record data and communicate findings to others using graphs.
04.SC.TE.02 – Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, etc…)
04.SC.TE.06 – Identify relevant desing features for building a prototype.
04.SC.TE.08 - Apply the metric system.
04.SC.PS.03 – Give examples of how energy can be transferred from one form to another.
04.PE.SP.9.1 – Discuss major causes of accidents.

Learning Objectives:
Introduce students to the concept of storing and releasing energy through projectile motion.

Familiarize students with common hand tools needed to construct a simple projectile launcher. Introduce students to the engineering design process by brainstorming ideas for a prototype of a water balloon launcher.

Students will learn to use tools to build parts of a water balloon launcher. During this process they can begin to form hypotheses about projectile motion and record their hypotheses

Experiment with a water balloon launcher testing student's hypotheses and recording data and results. Students will learn how to conduct an experiment that will result in good data.

Unit Background and Concepts for Teacher:
Basic physics of a projectile, spring knowledge, potential energy, tools overview.

Lessons:
Introduction
Tool Introduction and Building
Design Process and Hypothesis
Launching Balloons and Recording Data

Vocabulary:
Projectile, Capacity, Force, Angle, Arc, Spring, Tool, Hammer, Screwdriver, Flathead, Screwdriver, Philips screwdriver, Wrench, Adjustable wrench, Pliers, Needle-nose pliers, Allen, Wrench, Ratchet, Screwdriver bits, Hack saw, Chop saw, Drill, Drill press

Research:
The below sites should be looked over for background information regarding the upcoming lessons. There is quite a bit of information contained and plenty of ideas that could be incorporated into the lessons in this unit.

Simple catapult - www.cosi.org/ossw/2001/experiments/catapult.htm
Experiment where there is a target – www.sciencebyjones.com/marshmallow_projectile.htm
Lab report format that will give lab experience for the students – www.usoe.k12.ut.us/curr/science/core/plans/int/grape.html
Site to help students design their own catapult/launcher - www.usoe.k12.ut.us/curr/science/sciber00/8th/machines/sciber/cat.htm
Link to a lesson on gravity and acceleration – http://hcs.harvard.edu/~xmentors/pages/resources/lessons/physics/fourth/10.html

Assessment: Record book along with graphs and conclusions.

Key Words:
Spring, projectile, launch, record, data, graph, hypothesis, design, build, potential, energy.

Lesson Title: Spring Introduction

Grade Level: 4th

Total Time: 1 hour

Instructional Mode: Whole Class

Summary:
Introduce students to the concepts of projectile motion and storing energy, using springs and a handkerchief.

Benchmarks:
04.SC.PS.03 – Give examples of how energy can be transferred from one form to another.

Learning Objectives:
The student will differentiate between springs with different characteristics.
The student will explain potential energy and its applications.

Materials:
5 small springs
1 handkerchief
2 – 3 Small Baskets

Vocabulary:
Projectile: A fired, thrown, or otherwise propelled object, such as a bullet.

Capacity: The ability to receive, hold, or absorb.

Force: The capacity to do work or cause physical change; energy, strength, or active power.

Angle: The figure made by. two lines which meet.

Arc: Something shaped like a curve or arch.

Spring: An elastic device, such as a coil of wire, that regains its original shape after being compressed or extended.

Gravity: The constant pull towards the Earth.

Attachments:
Procedure
Overheads

Discussion Questions for students:
What is a projectile?
Why do projectiles not fly into space?
In what ways can you make a projectile travel a further distance?
What types of devices create projectiles?

Safety Issues:
Springs can be dangerous.

Resources:
Energy overview - http://phun.physics.virginia.edu/topics/energy.html

Assessment:
N/A

Key Words:
Spring, projectile, motion, potential, energy, introduction.

Spring Introduction
PROCEDURE:

1. Give the students many different springs for them to use for several minutes to get a feel for them.

2. Explain how different springs have different flexibility and some are harder to stretch than others.

3. Have the children split up into groups and give each some springs. Have the students choose which spring they think will stretch the most when a basket with a book is attached to it.

4. Have the students now choose which spring will stretch the least. Discuss why there is a difference.

5. Attach one end of the spring to the edge of a desk or something sturdy. Place a basket and the other end of the spring. Now place a book in the basket and measure how far the spring stretched. Do the same with the other spring the students chose and see how far that stretches.

6. Ask the students what type of things springs could be used for. Have them spend time writing down as many ideas as they can within a few minutes.

7. Attach 1 spring to each corner of a piece of cloth.

8. Tape a string to the center of the cloth.

9. Choose four students to hold each end of the 4 springs not attached to the cloth. Place a cotton ball in the center of the cloth.

10. Pull the string down and release, propelling the cotton ball into the air.

Lesson Title: Tool Introduction and Building

Grade Level: 4th

Total Time: 1 hour

Instructional Mode: Whole Class

Summary:
Introduce the students to the tools necessary to build a larger launcher and other similar structures. Use some of the tools they just learned about to build some structure.

Benchmarks:
04.SC.TE.02 – Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, etc…)
04.SC.TE.08 - Apply the metric system.
04.PE.SP.9.1 – Discuss major causes of accidents.

Learning Objectives:
The student will recognize and describe a tool and its use.

Materials:
Tool kit including hammer, screwdrivers, wrenches, ratchet wrenches

Vocabulary:
Tool: A device used to perform manual or mechanical work.

Hammer: A hand tool that has a handle and a head of metal that is used for striking or pounding.

Screwdriver: A tool used for turning screws.

Flathead screwdriver: A screwdriver with a flat shape on the tip of itself.

Philips screwdriver: A screwdriver with a star * shape on the tip of itself.

Wrench: A tool having fixed jaws, used for gripping, turning, or twisting objects such as nuts or bolts.

Adjustable wrench: A wrench with adjustable jaws.

Pliers: A hand tool having a pair of pivoting jaws, used for holding, bending, or cutting.

Needle-nose pliers: Small pliers with long thin jaws for fine work.

Allen wrench: A tool consisting of an L-shaped bar with a hexagonal head, used to turn screws with hexagonal sockets.

Ratchet: Mechanism that allows motion in one direction only.

Screwdriver bits (interchangeable): Small bits that can be put into on end of a holder than can be easily changed.

Hack saw: An object which holds a long skinny blade used for cutting through objects.

Chop saw: Power tool used to cut through an object.

Drill: An object with cutting edges or a pointed end for boring holes in hard material by rotating.

Drill press: A powered vertical drilling machine in which the drill is pressed to the work automatically or by a hand lever.

Attachments:
Procedure
Pictures of Tools

Discussion Questions for students:
What is the reason for having tools?
Is any tool better than other tools?
How does one decide which tool to use?

Safety Issues:
Tools require responsibility and can be dangerous if used the wrong way.

Resources:
Amazon.com Tools and Hardware - http://www.amazon.com/exec/obidos/tg/browse/-/228013/ref=sd_str_hi/103-9980193-4767806

Crossword puzzle generator - http://www.edhelper.com/crossword.htm

Assessment:
Crossword Puzzle

Key Words:
Tools, Building, Safety

Procedure for Tool Introduction and Building

Tools:
Hammer, Flathead screwdriver, Philips screwdriver, Wrenches, Adjustable wrenches, Pliers, Needle-nose pliers, Allen wrench set, Ratchet set, Screwdriver bits (interchangeable).

Tools: Dangerous might not use in school but mention::::
Hack saw, Chop saw, Drill press, Cordless drill, Cordless handsaw.

1. Explain that tools can be dangerous if used improperly and cause accidents.

2. Show the children a picture of a tool, after each picture is shown as the students if they know the name of the tool.

3. Show the actual tool that you just showed the picture of.

4. Ask the students if they know what the tool is used for.

5. Explain what the tool is used for.

6. Ask the students if they know any people or workers that would use that tool.

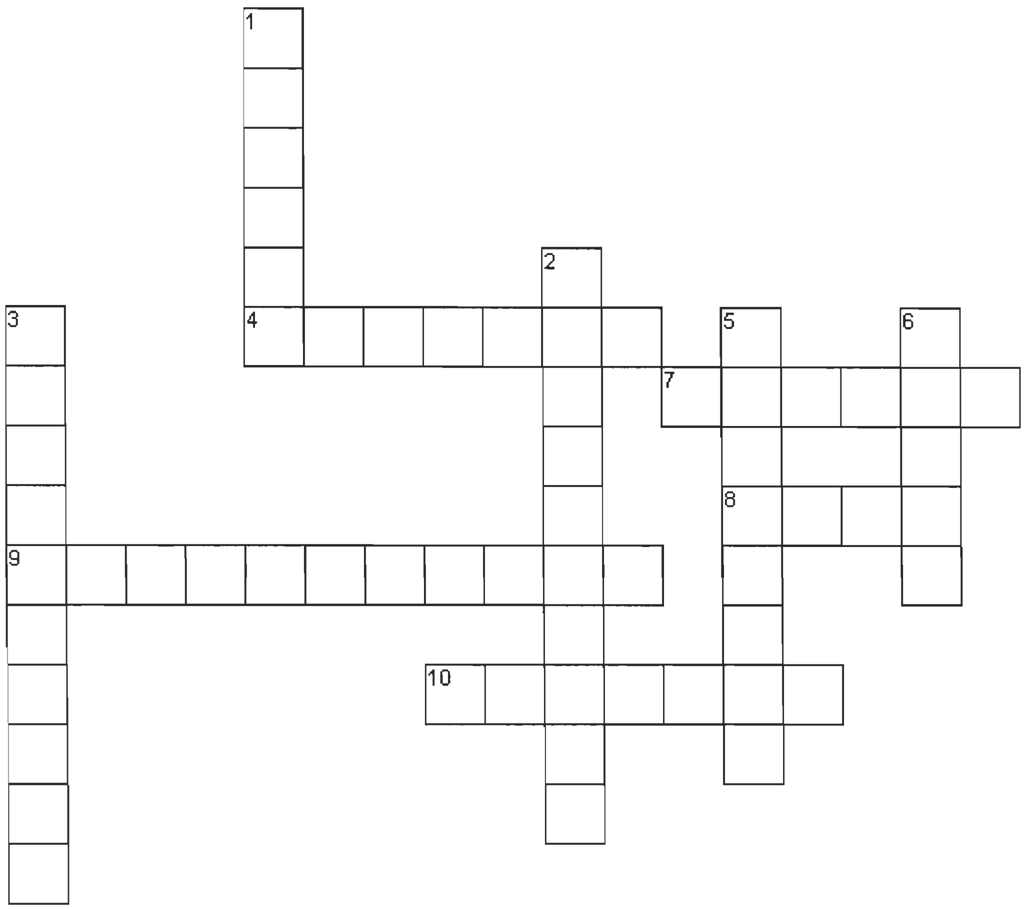
7. Explain what type of people or workers would use that tool.

8. Ask the students if any of them have *used* that tool, and for what.

9. Repeat with all tools.

10. Have students go to each station in groups and let them all get a chance to use the tools listed. Each station should be built to allow the students to use the tools easily. For example the Screwdriver station would have all types of screwdrivers in order, and the student simply uses the screwdriver to tighten a screw.

11. After students have gotten a chance to use each station have them draw their favorite tool, and describe what it is, what it is used for, and who would use it for what purpose.

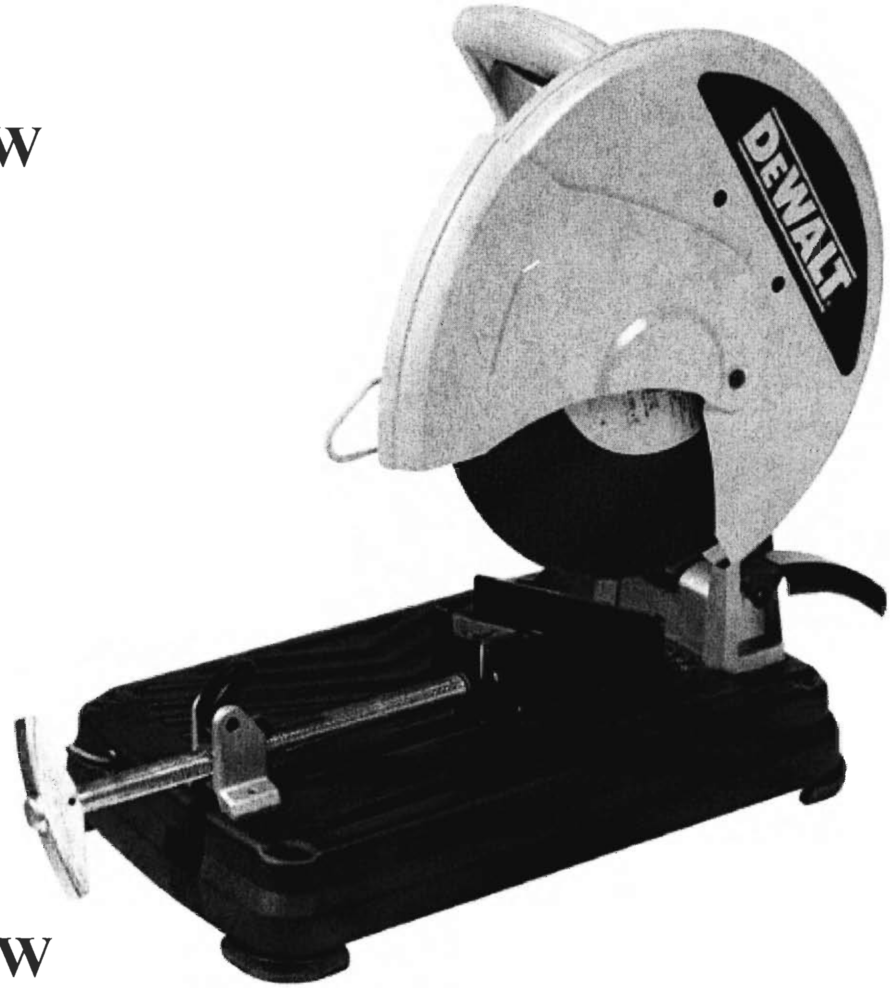


Across
4. Mechanism that allows motion in one direction only.
7. A hand tool having a pair of pivoting jaws, used for holding, bending, or cutting.
8. A device used to perform manual or mechanical work.
9. A tool used for turning screws.
10. Power tool used to cut through an object.

Down
1. A hand tool that has a handle, and a head of metal that is used for striking or pounding.
2. Small pliers with long thin jaws for fine work.
3. A wrench with adjustable jaws.
5. A screwdriver with a flat shape on the tip of itself.
6. An object with cutting edges or a pointed end for boring holes in hard material by rotating.

Tool	Adjustable	Pliers
NeedleNose	Ratchet	ChopSaw
Drill	Hammer	Screwdriver
Flathead		

CHOPSAW



HACKSAW

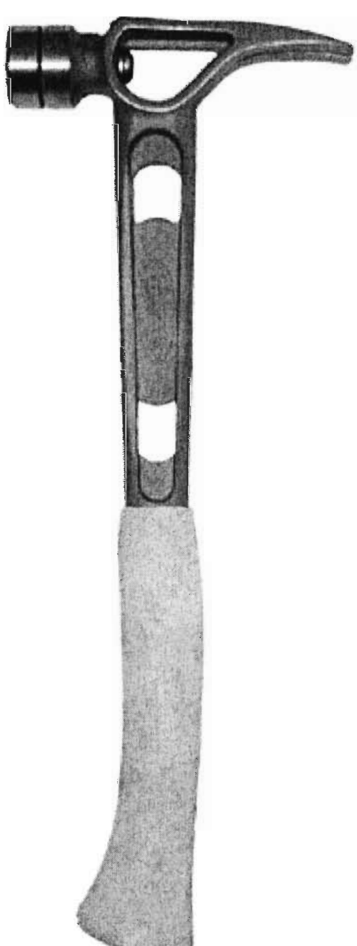
DRILL

CORDLESS DRILL

RATCHET

WRENCH

HAMMER



SCREWDRIVERS

Lesson Title: Design and Hypothesis

Grade Level: 4th

Total Time: 1 hour

Instructional Mode: Small Group -> Independent activity

Summary:
The students will design a water balloon launcher and hypothesize about how their launcher would work. They should write about why their launcher will work the way they hypothesize.

Benchmarks:
04.SC.TE.06 – Identify relevant design features for building a prototype.
04.SC.IS.01 – Ask questions and make predictions that can be tested.

Learning Objectives:
The student will design a launcher.
The student will describe which characteristics of the launcher affect the projectile, and how.

Materials:
Paper and Drawing utensils

Discussion Questions for students:
What is the *best* design for a launcher?
Does the design depend on what is being launched?

Resources:
Word Search generator - http://teachers.teach-nology.com/web_tools/word_search/

Assessment:
Word Search

Key Words:
Design, hypothesis, launcher, projectile

Procedure for Design Process and Hypothesis

1. Explain to the students what a water balloon launcher is and how it works.
2. Ask the students what things could be used to create a force that "bounces back"
3. Give three examples of a water balloon launcher… Spring loaded, See-saw… Rubber bands.
4. Have the students brainstorm ideas for a prototype of a water balloon launcher. Allow them to work in small groups. Make sure they understand that brainstorming means giving out ideas to the group and that there should be no criticism no matter what the idea.
5. Give the students constraints on their personal water balloon launcher, such as the projectile cannot go further than 100 feet and has to clear a 30 foot tall building.
6. Have the students write a description of a water balloon launcher they envision. Make sure the students change a few things from the balloon launcher their group came up with to ensure everyone's is different.
7. Have the students draw a picture of their water balloon launcher.
8. Ask the students to hypothesize which angle will make the balloon go the furthest, and which angle will make the balloon go the highest.

Projectile Word Search

A	O	K	C	T	S	V	C	K	L	D	Z	R	R	U
S	N	R	J	R	O	H	M	L	Q	S	A	P	C	N
E	A	G	E	T	C	O	I	S	C	T	X	G	A	A
A	L	I	L	N	Y	R	L	R	C	O	V	M	P	F
G	L	I	E	E	D	S	E	H	Z	H	I	P	A	N
P	Q	R	T	U	B	W	E	Q	U	W	K	F	C	P
F	W	L	H	C	D	T	N	W	I	H	J	S	I	T
F	H	F	N	R	E	S	P	R	I	N	G	H	T	D
S	E	I	I	P	Z	J	W	X	Z	S	H	D	Y	F
Z	M	V	I	G	V	H	O	Y	M	A	E	I	O	R
B	E	P	A	C	S	C	H	R	M	B	L	R	C	C
R	T	K	L	T	W	B	Y	M	P	A	C	B	T	Y
N	E	L	L	A	X	A	E	J	W	E	E	G	B	F
Z	D	S	H	P	V	R	E	T	Z	A	S	Y	P	K
T	X	P	Y	A	T	L	O	N	E	L	S	Z	I	Y

ALLEN	ANGLE	ARC
CAPACITY	DRILL	FORCE
HAMMER	PLIERS	PROJECTILE
RATCHET	SAW	SCREWDRIVER
SPRING	TOOL	WRENCH

Lesson Title: Launching Balloons and Recording Data

Grade Level: 4th

Total Time: 2 hours

Instructional Mode: Whole Class

Summary:
Experiment with a water balloon launcher testing student's hypotheses and recording data and results.

Benchmarks:
04.SC.IS.03 – Keep accurate records while conducting simple investigations or experiments.
04.SC.IS.04 – Conduct multiple trials to test a prediction.
04.SC.IS.05 – Recognize simple patterns in data and use data to create a reasonable explanation for the results of an investigation or experiment
04.SC.IS.06 – Record data and communicate findings to others using graphs.

Learning Objectives:
The student will record clear data.
The student will graph data in a organized manner.
The student will draw conclusions about projectile motion from the data and graphs.

Materials:
1 water balloon launcher.

Attachments:
Procedure

Discussion Questions for students:
What changed how far or high the balloon went?
Were all of the hypotheses true?
What could be changed to make the results more accurate?

Assessment:
Their records, hypotheses, and conclusions.

Key Words:
Spring, projectile, motion, potential, energy, launch, graph, record, data.

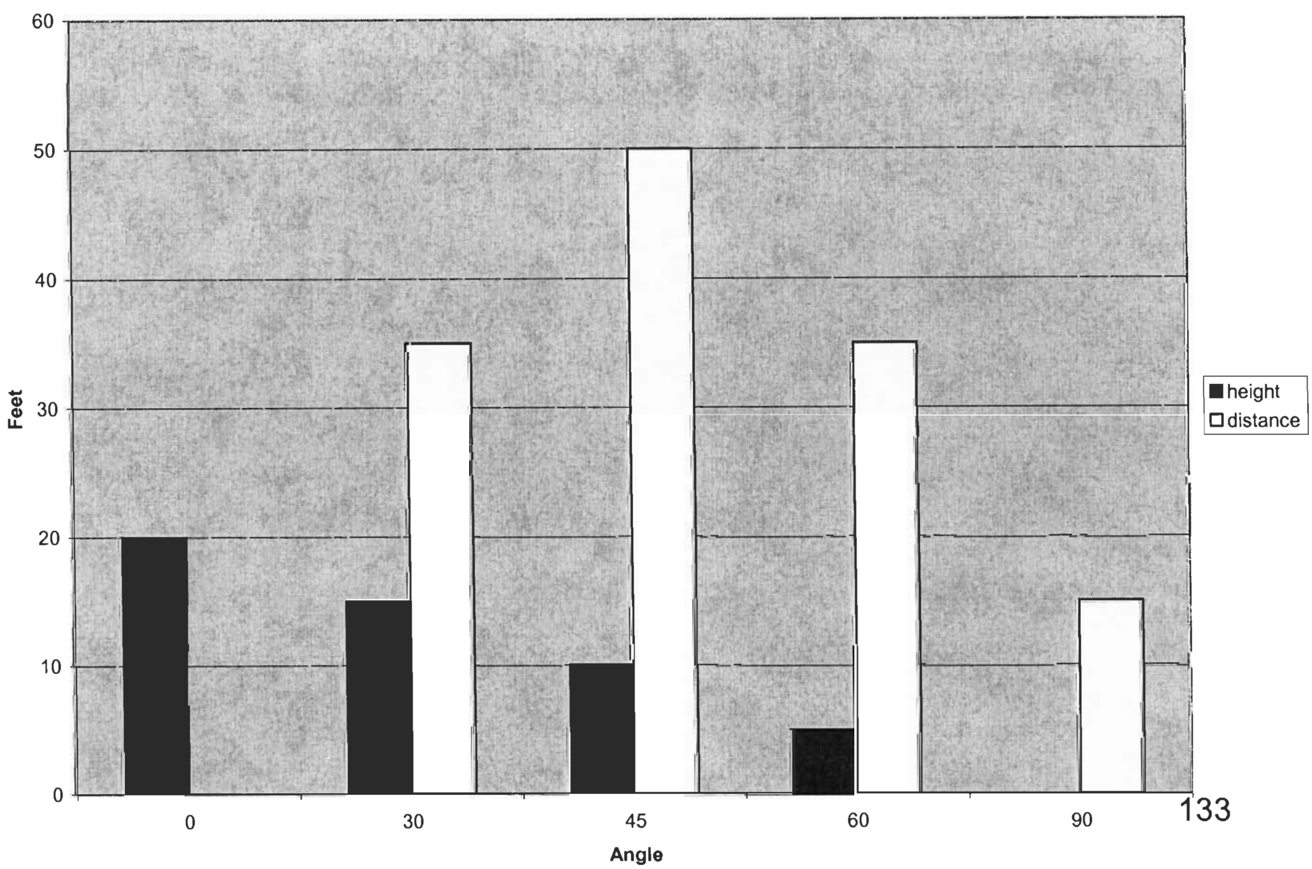
Water Balloon Launch
PROCEDURE:

1. Have the students record all data.
2. Launch one balloon from each designated angle and length.
3. After each launch have a one student measure how far the balloon went.
4. Have the students individually decide which balloon went higher.
5. Make sure the students record each balloons data. Height, distance, angle, length pulled back.
6. Have each student take his or her data and record it in a graph.
7. Compare the students graphs and show the class total.

Have the students write their conclusions and have some share with the class.

Sample data recording sheet, and graph:

Water	Balloon	Launch	Data
Trial#			
1	Angle	height	distance
	30	?	?
	45	?	?
	60	?	?
Trial#			
2	Angle	height	distance
	30	?	?
	45	?	?
	60	?	?
Trial#			
3	Angle	height	distance
	30	?	?
	45	?	?
	60	?	?



Mike's Lessons

The following are all original lessons constructed from personal knowledge of the subject of electricity.

Lesson 1: Introduction to Electricity and Energy Transfer

This lesson is meant to be a first introduction to electricity. It defines some terms for the students and give them a feel for the concept. One of the ways this is accomplished is by discussing common objects that use electricity. Energy transfer is used to show the students that electricity as it is, isn't very useful to use, but converting electricity into light, heat, motion, or sound, is.

Lesson 2: Inside Electricity

This lesson takes students down to the atomic level to show them on a very basic level what electricity is and how it moves. It includes a basic model of the atom and a diagram showing how electron moves. Again it has more terminology to help students know how to talk about electricity.

Lesson 3: Loops and Circuits.

This lesson explains the concept of a complete circuit. It takes the students from the technical science level of electricity into the practical realm of how we make electricity work for us. This lesson also teaches the students about how to make a basic circuit safe using fuses. To further illustrate the point about electron flow, and to keep the students interested in the lesson, we play the electron game which is a physical activity for the whole class.

Lesson 4: Conductors and Insulators

This lesson shows the students the electrical properties of the world around them, while also advancing the topic of electron flow with resistance. There is a lab-type activity where the students explore for themselves the conductive properties of various objects.

Author

Michael J. Schenck
February 2004

Lesson Title

1: Introduction to Electricity

Grade Level

Fourth Grade

Total Time

15 minutes.

WPS Benchmark(s)

04.SC.PS.03
04.SC.PS.05

Instructional Modes

Whole Class

Team/Group Size

N/A

Summary

Students will learn about the basics of electricity through class discussion and brainstorming.

Objectives

1. Students will learn the basic definition of electricity while dispelling common myths about electricity.
2. Students will learn about the various ways electricity is converted into more useful forms of energy like heat, light, and sound.

Materials

Items that clearly show electricity is converted to another form of energy for example:
Fan, alarm clock, portable radio, pencil sharpener, desk lamp

Introduction/Motivation

N/A

Vocabulary

- Electricity – energy from the flow of electrons

Attachments

- Procedure

Discussion Questions for students

- What is electricity?
- Where does it come from?
- What forms of energy can electricity be converted into?

Assessment / Evaluation of Students

Student should be asked to write answers to the discussion questions in a science notebook.

Lesson Extensions, Troubleshooting Tips, and Safety Issues do not apply to this lesson.

Key Words

Electricity, Introduction, Brainstorm.

Procedure

1. Ask the students, "What is electricity?" and brainstorm ideas with the class. Make sure to note the ideas on the chalk board.
2. Ask the students to name things they use, that need electricity. Again note these items on the board.
3. Using some of the items the students have suggests discuss how electricity goes into a device, and another form of energy comes out.
4. Using the devices in the materials list, demonstrate by connecting these devices to the wall and turning them on.
5. Now have a student read the definition of electricity from a dictionary.
6. Break down the definition with the students and compare it to the brain stormed ideas they had about electricity.

Author

Michael J. Schenck
February 2004

Lesson Title

2: Inside Electricity

Grade Level

Fourth Grade

Total Time

30 minutes.

Instructional Modes

Whole Class

Team/Group Size

N/A

Summary

Students will learn about the basic structure of an atom and how it related to electricity. They will also learn about the flow of electrons through a complete circuit through a hands on demonstration

Objectives

3. Students will be able to identify the three basic parts of an atom and what constitutes electricity at the atomic level.
4. Students will learn about the basic terms of electricity.

Materials

Several small objects that can easily be passed from student to student
a box to hold these objects that students can easily reach into

Introduction/Motivation

N/A

Vocabulary

- Atom – Tiny particles all objects are made from.
- Electron – Negatively charged particle that circles around and atom.
- Proton – Positively charged particle in the center of an atom.
- Current – Flow of electrons from atom to atom.
- Voltage – The potential for electrons to flow.

Attachments

- Procedure
- Simple Model of the Atom
- Simple Model of Electron Flow
- Rules for the Electron Game

Discussion Questions for students

Assessment / Evaluation of Students

Lesson Extensions

Troubleshooting Tips

Safety Issues

Key Words

Electricity, Atom, Electron, Proton, Current, Voltage

Procedure

1. Write the definitions of the vocabulary words on the board and have the students copy these words into their science notebooks.
2. Draw the Simple Model of the Atom on the board after passing out a copy to each of the students. Explain the relationship between the electrons the protons and the neutrons.
3. To demonstrate the concept of voltage call two students up to the front of the room. Place a large number of the small objects from the materials list in the hands of one student and a much smaller number of the small objects in the other students hand. Explain to the class that voltage is the potential for the small objects, electrons, to balance them selves out.
4. To demonstrate the concept of current have the students stand in large circle. Make sure they are close enough to be able to hand the small objects from the materials list to each other.
5. Pick a spot in the circle and place the "Battery" , small box, between two students. Now explain and recite the Rules of the Game with the students.
6. Play the game. At some point break two of the students apart and illustrate that once the loop is broken the electrons stop flowing because they have nowhere to go.

Electron Game Rules

(as played with pennies)

1. Every starts with <u>one</u> penny.
2. Pennies pass to the <u>left</u> only.
3. When you have passed your penny, politely ask you neighbor to the <u>right</u> for another penny.
4. If the Battery is on your <u>right</u> take a penny from it when you need one.
5. If the Battery is on you <u>left</u> place you penny in it before asking for another.

Author

Michael J. Schenck
February 2004

Lesson Title

3: Conductors and Insulators

Grade Level

Fourth Grade

Total Time

1 hour

WPS Benchmark(s)

04.SC.PS.06
04.SC.PS.07

Instructional Modes

Whole Class, Small Group

Team/Group Size

Two to Three Students

Summary

Students will learn about conductors and insulators through experimentation.

Objectives

5. Students will learn the concept conductors and insulators
6. Students will learn to classify object based on their conductivity through a hand on experiment.

Materials (per group)

insulated copper wire, aluminum foil, length of string, block of wood, narrow strips of paper. These are suggestions many other objects would be suitable.

D-Cell size battery (with holder) , small wires with clips attached, small light bulb with socket.

Introduction/Motivation

Students will learn about how well the objects around them conduct electricity.

Vocabulary

- Conductor- a material that allows the passage of electric current.
- Insulator – a material that restricts the passage of electric current.

Attachments

- Procedure
- Tester Setup

Discussion Questions for students

- What are conductors? Insulators?

Assessment / Evaluation of Students

Students will record their observations in a table in their science notebooks.

Lesson Extensions

Troubleshooting Tips

Make sure all wires are properly connected..

Safety Issues

Make sure you do not complete a circuit to the battery with out the light bulb. This will cause a short circuit, heat the battery and the wires up very quickly and could possible harm students.

Key Words

Conductors, Insulators, Experiment.

Procedure

7. Ask the class is any of them already know what an insulator was? A Conductor?
8. Explain that conductors are materials that let electricity flow through and insulators are materials that restrict electricity from flowing.
9. Break the students into groups and have them test each of the objects in the materials list using the tester setup.
10. Have the record which materials are conductive and which are not in their science notebooks.

Author

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February 2004

Lesson Title

4: Circuits and Symbols

Grade Level

Fourth Grade

Total Time

20 minutes.

WPS Benchmark(s)

04.SC.PS.05

Instructional Modes

Whole Class

Team/Group Size

N/A

Summary

Students will learn to draw electric circuits and to spot problems with circuits..

Objectives

7. Students will learn the various symbols associated with circuit diagrams
8. Students will learn basic troubleshooting skills associated with circuit diagrams

Materials

Introduction/Motivation

Students will learn about circuits and why they work, or why they don't work.

Vocabulary

- Circuit – an electrical path made up of a source and a load.
- Load – a device that consumes electricity
- Source - a device that provides electricity
- Short Circuit – A circuit with no load.

Attachments

- Procedure
- Symbol Sheet

Discussion Questions for students

Assessment / Evaluation of Students

Quizzing students using various circuit diagrams.

Lesson Extensions

Troubleshooting Tips

Safety Issues

Key Words

Circuit, Short Circuit, Load, Source, Symbols

Procedure

1. Draw the various symbols on the board under the proper category (source or load) and have the students copy this into their science notebooks.
2. Now draw several circuit diagrams with the symbols some with complete circuits and some without. Also draw some circuits with only sources and some with only loads.
3. Quiz the students on whether a given circuit is complete, whether the light will go on or not.

Part III: Lesson Evaluations

The lesson plans evaluations here were done by our graduate fellows. The lessons were evaluated on how accurately they followed the template, how closely they addressed the WPS 4th grade Benchmarks, how appropriate they were for the students' age, how effectively our ideas were communicated, how the lesson plans were organized, how well we incorporated our fellows' comments into our revisions, and how neatly our lessons were presented. As well as this, the implementation of our lesson plans was evaluated on how well the information was communicated to the fourth graders, how engaged the students were, and how much the students learned.

We felt that some things could be improved in order for this project to go further next year. It is important that the IQP students know what is expected of them as soon as they begin work on their lessons. Because this was the first year of the project, everyone was feeling their way around and the process took much longer than it would normally, but next year should be much smoother. It is of great importance that the graduate fellows make it clear to the IQP students that implementation of a lesson plan is crucial in order for it to be of a high quality. The IQP students should know the fourth graders knowledge level well enough to have their lesson plans implemented effectively. Having the fellows manage the IQP students' earlier classroom visits might help them to start earlier and write lesson plans that can be implemented more quickly.

In the next chapter, these suggestions will be elaborated upon, as well as the actual process of writing lessons and the experiences we had in the classroom that helped us to write better lessons.

Chapter III: Project Experiences

Part I: The Lesson Writing Process

Scheduling:

The process of writing lesson plans and implementing them into an actual classroom is as challenging as it is rewarding. The thing that made this project so interesting is the fact that we went into this process with no teaching experience whatsoever. After learning how to create lesson plans and translate them into active knowledge from which children could benefit, we came out with a good sense of how lesson plans should be produced and implemented as well as a streamlined method of creating them. The following is an account of the techniques used to create these lesson plans, and the knowledge gained about the overall process.

One important lesson we learned was that flexibility is an important attribute, because changes are likely to happen at any minute. The original plan was to have a unit composed of a half hour introduction lesson, two one hour supporting lessons, and a two hour long culminating activity with an assessment. We ended up deciding later on that four stand alone lessons which could be grouped into a unit would be better, simply because they would be more versatile for the specific needs of a teacher. This was especially important for our purposes, where there was a large limit on available time in the classroom, and the possibility of completing an entire unit in the given time would be next to impossible.

The best decision we made the entire year was to break up the lesson design into individual sections which would each have to be written by a certain point in time. This scheduling proved to be extremely vital because it kept everyone on task and allowed for consistent review of each completed section so that revisions could be made frequently. In addition to this, a schedule served as a reference to the progress made and allowed us to see where we were and what else needed to be done. A schedule was developed by the graduate fellows and over time it was revised to conform to each task.

Background Research:

The first part of the schedule involved performing background research to help brainstorm ideas for the lesson plans and to give a general idea of how lessons are arranged. This research would eventually be summarized and placed into a report for the classroom teacher. Performing background research was very significant if for nothing else than the sole purpose of introducing a group of novice educators to the intricacies of lesson planning. It is much harder for someone lacking experience in designing lesson plans to come up with ideas quickly, so the research served as a catalyst for the team to come up with innovative ideas. The majority of the research was comprised of internet sources. From the use of the internet, we were able to find ideas on which to base our units, as well as sample lessons and activities that related to the units. The lessons found were not necessarily employed into our units; however, they served as wonderful influences and inspirations for our lesson output. A good example of this was Dan's "Bicycle Geometry" lesson, which was inspired by a math activity from a PBS teaching website but was modified to be engineering based and to meet the needs of the classroom.[7] Not all of the lessons created by us were influenced by other lessons we

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[7] Mathline, a part of PBS Teacher Source:

http://www.pbs.org/teachersource/mathline/concepts/designandmath/activity1.shtm found, but the ones that were influenced by other lessons were modified to be appropriate for our classrooms. A large part of the brainstorming process is to take previously done lessons and adapt them to work for capabilities and requirements of a classroom. In the case of the Worcester Public Schools, some specific constraints include classroom size, academic capability of the students, rules and regulations, economic constraints, and the material that needs to be covered. Context of the specific situation is what defines how the background research is to be used, so the key to finding useful references is to look for things that will apply to as much of the essential factors as possible. It is extremely difficult to find a lesson online that will completely encompass the specifications that need to be present. Because of this, finding something that works for most of what is needed and adapting the rest to customize it for the target classroom is the most efficient way to attack this problem. For an example, refer to the "Bicycle Geometry" website listed on the previous page and then refer to Dan's "Bicycle Geometry" lesson in Chapter II. The end of the lesson on the website involves the students determining why different bicycles are shaped the way they are. Because Dan felt that this would be too much to expect from the fourth graders in such a little period of time, he modified this to have the students simply draw comparisons between the different measurements on different types of bicycles. To add an engineering aspect to this, Dan then would have the students pick a type of bicycle and "design" a frame based on what the relative sizes of the parts should be. This is the type of modification that is needed to take a lesson and make it appropriate for a certain class. Some of the lessons found online would apply to the benchmarks that needed to be covered, but the age levels would not be appropriate. This is where our engineering experience came into play. All teachers need to have the ability to solve problems in a creative way, and our engineering skills definitely helped us adapt lessons we researched to meet our needs.

Creating a Lesson:

The next step in the schedule was to create a skeleton for the unit plan and its associated lessons. This skeleton was comprised of the major aspects of the lesson template. The initial template was composed of

- **title**
- **objectives**
- **summary**
- **materials**
- **references**

At this point the lesson and unit plans that were created were in their most basic form. As the writing process continued they would be filled in with all the complimentary detail. As the process went on the lessons were analyzed to determine which benchmarks were met. Multiple drafts of the purposes and summaries were made. At the time we were not aware of the number of times the lesson plans would need to be revised. This gave us a new appreciation of the difficulty of creating lesson plans. When factors such as student teacher ratio, necessary materials, and individual school rules were taken into account there was a need to alter the lessons. This information did not come to light all at once. New problems would gradually arise and the lessons needed to be altered accordingly.

The skeleton was now to be filled in. The first addition to the unit plan was a list of general definitions relating to the unit that the students would be responsible for learning. Definitions would later be broken up and grouped into their respective lessons. Not all of the definitions were used in the end and served as additional background information.

After this the lesson procedures were developed. The procedures were initially one page in length and were made for the students to follow in the lesson. Later on it was discovered that these procedures were too difficult and detailed for the students to use (see section on reading ability below), so they had to be altered appropriately. In the end some lessons did not even include a student procedure, as it was viewed to be more of an optional item for the fourth grade level. It was more important for there to be a procedure that the teacher could use to conduct the lesson rather than one that students could follow, so this now became the main focus of creating a procedure. Once again, there needed to be many revisions due to the procedures being too complicated for the teachers to use successfully. Each successive revision was more concise and easier to follow for someone who does not necessarily have the background in engineering that the project team possessed. It was a great challenge as engineering students to produce a procedure that is comprehensive enough to be used in a classroom. We were so used to the technical writing that engineers normally produce that it was difficult to phrase a science and engineering subject matter in a different way, especially one that is geared toward fourth grade students. It was important to us that the detail of the procedures was preserved throughout the revisions. This made it extra difficult to make the procedures more concise and comprehensive. Initially we had thought that the detail would need to remain in order for the lesson to be taught successfully and for the correct information to be conveyed well to the students, but it was more important for the procedures to be meaningful in a much simpler way so it was decided that the level of detail would be somewhat sacrificed to obtain this simpler form. In retrospect, this sacrifice was not a terrible one to make because although teachers might not have experience with engineering lessons, they are professionals in teaching children and can certainly handle taking a lesson and making it work for them and their classroom. Just as we adapted the research to create our own lessons, the teachers most likely would not follow an exact procedure given to them and would alter it to suit their class' individual needs. A large part of the experience that we gained was realizing the unique skills that teachers have and working with that to come up with better lessons.

The lesson plans were closer to being completed but they needed an assessment to make sure the students gained the appropriate knowledge. To accomplish this, we produced a pass or fail homework assignment for each lesson that would meet the following specifications.

1) The homework would test the students on key concepts from the lesson, and ensure that they were able to grasp the information that was taught to them.

2) The homework would be enjoyable enough so that the students would be motivated to do well.

3) The homework would be of an appropriate length for a fourth grade student.

4) The homework would be of an appropriate difficulty level so that the student would not be discouraged from completing the assignment.

With these requirements in mind, we utilized a website to create crossword puzzles, word searches, and word matching exercises that would serve as valuable homework assignments for the students to complete.[8] An example of this can be seen in Dan's Friction and Brakes lesson. The crossword puzzle used here assessed the students on how many of the key facts about friction they could recall and on how well they understood the lesson's vocabulary. The game format of the assignments would make them enjoyable for any child to do, and it was quite simple to make them pertain to the subject matter of each lesson. The real challenge of creating these homework assignments lied in the process of making them appropriate for time and ability level. The initial drafts expected too much for a single assignment to be completed by a fourth grader, and the questions were worded in an awkward manner that would not only confuse the students, but probably their parents as well. The parents were a major consideration in these homework assignments. When a student is at home and a teacher is not around to help the responsibility to assist the child lies on the shoulders of the parents. In most cases the parents do not have background on the homework assignment their child has, so it is very important that the homework is at such a level that parents with literally no backgrounds whatsoever would still be able to help their child. Fourth graders take longer to complete things than one would initially expect (which will be discussed further later on in this report), so the time that the assignment would take to complete needed to be carefully planned. Throughout the revisions, the assignments were shortened and an answer key was added to each one in order to make them easier to complete within a limited amount of time. In addition to this, the questions and clues on the homework's were made clearer so that the students would not get confused or discouraged and their parents would be able to help and not feel like they are doing an inadequate job of assisting their child. After these specifications were met at an

[8] www.puzzlemaker.com

acceptable level, the homework assignments were ready to implement within the lesson plans.

The next step of the process was to create overheads, diagrams, and handouts to help provide visualization to both the teacher and the students for what would be occurring in the lesson. At this point we realized how important it was for the students to have a picture of what they are going to be learning about, and throughout the lesson planning process more and more diagrams were created in order to ensure that there would not be a difficult to understand part of a lesson. Many of the diagrams created were simply depictions of how the lessons were supposed to be setup. In other cases the diagrams showed illustrations of actions that would take place during the lesson. Some of the handouts included tables and charts for the students to fill with the data they obtained. Simple tables with clear headings and large spaces for the students to write in were ideal for what they had to do. Tables could be used in just about every lesson, and they teach students how to organize their data and group it into different categories that can be related to each other. Learning how to use tables at such a young age is a skill that will benefit the students years from now. Over time, the diagrams and charts were revised so that they became bigger, clearer, and easier to use. With the help of Microsoft Paint, drawings were created with a small degree of hassle, and provided a much more versatile format than sketches done on paper. With every aspect of the lesson stored electronically, it could be taken anywhere and edited any way necessary. Tables with sample expected results were developed for the use of the teacher, which helped anyone who lacked experience with the measurements taken in a specific lesson. Once all of these supplements were created, they were placed right within each lesson ready to be studied and distributed amongst the students.

Two extra components of the lesson plan which were added on specifically by Rick Bara were the decision matrix and engineering design report. The decision matrix was developed by Rick as a tool to help the students brainstorm in an organized and efficient fashion. As part of the engineering process, the students would be required to brainstorm as many solutions as possible for a specified problem. The point of this matrix was to rate each solution based on a number of criteria, and whichever solution had the greatest number of points for criteria met would be the best choice. Each category would be rated on a numeric scale where 0 means that the specification was not met at all, 1 means that it was somewhat covered and 2 means that it was covered very well. Once adding up all of the numbers for every category, each solution would have a total. This seems like a very good process to use when brainstorming, but one may wonder what place this has in a fourth grade classroom. At first we were very skeptical of how this would be received by the students. We assumed that the students would get very confused and not understand it at all, or it would completely bore them and they would not stay on task. We did not actually see this matrix implemented in the classroom, but from what was reported it seemed as if this decision matrix did indeed work. It is very easy for older people to underestimate children, and when someone is afraid to challenge students they are really hindering the children from learning. In this specific situation, we decided that the matrix could still be a bit too much for some classrooms, but we decided not to rule out the matrix completely from their lesson plans. This decision matrix was placed within the lesson plan as an optional handout to be used at a teacher's discretion. Each classroom is different, so only the teacher will be able to successfully gauge whether or not the class would be able to handle using that matrix. An example of this can be seen in Dan's Friction and Brakes lesson, where three solutions to the brake design problem were contrasted with each other to determine which design met the most specifications of the project. The winning choice had the highest point total from all of the categories being added to each other. The engineering design report that Rick designed was a way for students to record their results in an organized fashion and use a systematic approach to solving their problem. By guiding the students through the steps of the engineering process, and having them write down what they observed and what they think needs to be done, the students experience the actual process of engineering design. This report could prove to be very useful in an engineering lesson, and the expectations associated with it are definitely more reasonable than the expectations surrounding the decision matrix. This report was also attached to the lesson as an optional handout because it is still something that is only as appropriate as a teacher says it is. On one hand it could be much too complicated for a certain class while for a more capable class it could be a good tool to help them learn proper decision making skills.

At this point the entire lessons were finished and they were ready to be organized within a binder to be reviewed by the graduate fellows. The lessons were placed by order within their units, and were complete with all of the supplemental data. Once these lessons were approved, they would be potentially ready to use in a classroom or post online for other teachers to use.

Part II: Issues Encountered Throughout the Year

Because the project was brand new this year, there were some things that did not go as smoothly as they were planned. This can be expected in the first year of a project that has never been done before. Part of a successful project means trying new and different things and being willing to fail and learn from it. The following are some problems that came up this year, as well as the lessons we learned from them.

Formatting:

One major issue that had to be dealt with this year was the actual format of the unit and lesson plans. The purpose of having a lesson plan template was to streamline all of the planning and make the lesson plans easier to write. The problem here was that it took about two months to finally agree on a template that everyone would use. Initially the lesson templates that our group used consisted of the basic elements; summary, objectives, materials, and the other essential pieces. Not long after the very first plans were developed, a meeting was held and it was decided that there needed to be a single format for these lessons. A lesson planning sub-committee was organized and they held weekly meetings for the next 6 weeks where they discussed what the essential components of lesson and unit templates should be. There was much debate throughout this process, and it was tough for the group to make a distinction between the immaterial details and the crucial information that needed to come across in the plans. Like most of the other parts of a lesson plan, the optimal situation is to have a piece of information that contains everything needed for a teacher to understand what needs to be done while at the same time being as concise as possible. After discarding much of the unnecessary information from the original templates and adding a couple useful points, the subcommittee had workable templates. By this time, our group was well into the process of writing lessons and the incorporation of a new template caused a bit of a disruption. The new template was useful as a guideline as to what needed to be included in a lesson plan, but we felt that the formatting aspect almost drew more attention than the actual content of the plans. This was another time when it was important to take into consideration the fact that teachers are professionals and they know how to manipulate a lesson to make it work for their classroom. In most cases, even a few missing pieces from a lesson plan would not stop a teacher from using it. If anything the teacher would probably adapt the plan just to make it easier to use. One template would not be something that every teacher could use to its entirety. There are always variables that need to be changed depending on the classroom. Even in our case once we had our final lessons there were certain sections of the template we did not strictly follow just because they were either unnecessary or irrelevant to our purposes. With the process of creating a template taking almost four times as long as expected, the progress of the entire team was delayed. Because it is only the first year of the project, experimentation was expected and these types of delays were taken into account when scheduling the project. In fact, it was beneficial to go through the arduous process of creating a template, because it produced a precedent on how to decide what is necessary to include in lesson and unit plans. Overall, next years project will greatly benefit from the work we have done with templates, but the process of creating lessons with this year's team was definitely hindered because of it.

Material Restrictions:

One specific issue that came up with the design of our lesson plans was the presence of rules or restrictions that would hinder us in creating lessons and would force us to find alternate methods of conveying knowledge to the students. This is a problem that teachers are required to cope with every single day. When schools have their capabilities restricted by factors such as budget and liability, it forces their educators to become additionally resourceful in their lessons. After our initial lesson plan drafts, we realized that quite a few of the materials we intended to be used were unrealistic for cost and safety reasons. For example, Jason would not be able to have fourth grade students launch an expensive rocket for their projectile motion unit. It would be much too costly and much too dangerous. Specific materials could not be used within a classroom without causing a problem or posing a hazard, and if they were used outside it could potentially harm the students. Certain tools and materials were far too expensive for a school to afford, especially when most schools have a difficult time fitting all of the bare necessities into their budget. When pondering the idea of having students and their parents lend or supply certain materials, we concluded that it would not be fair to expect families to supply these materials to a classroom. Even if some families did supply materials, the children of families that would not be able to afford these supplies would feel terrible about not contributing to the classroom, and that it pretty much the last thing we would hope for a student to feel. We finally came to the decision that we would have to edit our lessons so that they did not incorporate materials or supplies that would not be feasible to have in the classroom. This was not a simple task, but it was far from impossible and it was an issue that any educator would have to handle.

Communication, Organization, and Scheduling:

It was mentioned earlier that the scheduling of this project took into account issues that would come up along the way. One of these issues was the amount of revising that had to be done. Planning lessons took much more time than we originally anticipated so it was a very important thing that we had an adequate amount of time to reach our goals. Creating the initial lessons did not take a large amount of time, but it is easy to say that our lesson plans were constantly being revised up until the end of last C-term. There is always something to amend or something to add to a lesson plan and because of this it is vital that a significant time period is allowed to the writers. One of the most positive things that can be said for the way this year's project was organized is that plenty of time was allowed for each step to be taken. At points there was a large amount of pressure to complete certain tasks, but the pressure was put on in a fashion that allowed time for us to sit and think about what we had written and allowed for us to come up with numerous ways to improve our output.

Another reason it was so important that this project was well organized is that there was such an enormous amount of people involved that meetings and deadlines needed to be set up quickly and efficiently in order to keep everyone on the same page and assure that everything that needed to get done would be done. A lack or coordination between such a large group of people could have posed a very serious issue, but luckily this was kept under control with consistent monitoring of progress and weekly meetings to bring everyone up to speed with how far the team had gotten with the project.

The main issue that was present with having a large group was the difficulty of scheduling meetings around everyone's daily routines. Even within the fourth grade division of the project, there were only one or two spots during a week where everyone would have an hour to spare. Between classes, projects, and extracurricular activities, the IQP students would have to be willing to sacrifice times when they would normally eat meals or study in order to make it to meetings. In the faculty advisors' cases especially, it would be quite a struggle to find a time that they could meet with the team members. In some cases, the problem of not being able to make it to meetings due to classes or prior engagements could not be avoided, and this had to be handled as best as it could be. It is a giant issue to keep track of where everyone is at a given time, and it is likely that when planning a meeting someone could be forgotten about. Flexibility was the answer here and it really reduced the damage caused by imperfect planning. Spur of the moment changes in plans were adjusted to accordingly and last minute cancellations were thwarted by alternate procedures. Illness, excessive homework assignments, personal emergencies, and inability to make it to Worcester for a meeting were all contributing factors to sudden cancellations and plan changes. Fortunately, our flexibility allowed us to make small adjustments in our own schedules so that we would be able to make up for any important meetings we missed. Miscommunication, which is something that all large groups deal with at times, augmented the issue of scheduling around the entire group. This was mostly due to team members not being informed directly from the advisors and the consequent third party misinformation. Electronic mailing lists helped solve this problem, although it did not always provide a solution because it put the responsibility on the receiver of the information when the receiver was not always reliable. Fortunately, this year's project team was very good to work with for the most part, and just about everyone seemed to take their responsibilities seriously. These kind of issues rely on the individual just as much as the team to be maintained, and by making sure in advance that the participants of the project are going to be dependable, the problem can be avoided.

Another place where miscommunication caused some problems was in the actual design of lessons. It took a few months before we knew exactly what the fellows were looking to see in our lessons, and during that time we were going through the writing process somewhat blindly. The feedback we received on our work was ambiguous at times, and it caused us to have to make more revisions than we would have had to make if we knew exactly what to do. In one case there was a diagram that was created for a lesson that was said to be labeled unclearly. When the IQP student went back and fixed the diagram to incorporate the fellow's suggestions, the fellow then said that the IQP student's original diagram was better and told him to change it back to its initial state. In general, problems like these would end up costing time and effort that could have been used for more productive purposes (see below about why Jason and Dan's lessons did not get implemented). This was not necessarily something that could have been avoided, however. Because it was the first year for this project, the entire team was feeling their way around and trying to determine what components of the lessons worked and what components did not work. Due to this, it was difficult for the fellows to see whether or not what we had for our lesson plans would succeed in the classroom. In some cases, suggestions were made for sections of our lesson plans and later on the suggestions were taken back and new ones were made. The course of lesson plan revising involved much trial and error. During the third term, the fellows brought forth a review that allowed us to accurately judge how our lessons were, and with their help we were able to see exactly what needed to be adjusted in order to get our lessons to the quality level we sought. The fact that we did not know exactly what was expected at first ended up being a positive turn of events. From this year's experiences, it should be much easier for next year's fellows to come up with clear expectations for lesson plan design. With the hindsight of what worked and what did not work, future project teams should hopefully have a much more efficient writing process with fewer revisions.

One specific issue that involved working with the teachers had to do with catering to their demanding schedules. Perhaps one of the most strenuous aspects of what educators do is teaching everything the students need to learn while staying within the limits of the very restricted amount of time they are provided. Because of this, every second is critical and needs to be used to its fullest extent. This is the reason why many of the lessons we created included multiple benchmarks and covered several subject areas at a time; it is necessary to fit as much information as possible into each minute with the students in order to cover everything the students are required to learn. The teachers' limited amount of flexible time put a great strain on what we were able to accomplish in the classroom. The units that Jason and Dan wrote were originally intended to be used in the classroom, but due to time restrictions they were only going to be allowed two classroom hours each to instruct their lessons. Because of this, Jason and Dan decided that they would each instruct one lesson that would spread out over two class periods. Although this became the plan, it was later decided that Jason and Dan would not have the time to teach in the classroom at all. At this point, the IQP students had not realized that Rick actually intended to teach their lessons himself. Because he did not feel comfortable with teaching the lessons as they were (the reason for this will be elaborated upon below), he decided that Mrs. Bercume could not afford to take away from the time she needed to cover her benchmarks by allowing Rick to experiment with these lessons that did not necessarily have a guarantee of success. It would have been very beneficial for Jason and Dan to see how their lesson functioned in a classroom setting and Mrs. Bercume would have been willing to give them a chance, but it was much more of a priority for Mrs. Bercume to fulfill her teaching requirements. Working with an educators taxing schedule means that any extra activity needs to be planned out far ahead of time in order to ensure that there will be a chance to fit the activity into the schedule. To account for this type of problem, there should be a constructive dialogue between project team members and the teachers and administrators from schools involved in the project long before the teachers begin to schedule their year. Although last minute issues come up in a classroom that can affect whether there will be time for a lesson to be taught, most scheduling problems can be averted by allowing teachers to know far in advance exactly when they should expect to give up their time for events and extra lessons. Because it seemed to be difficult for this dialogue to occur, there should be a better and more organized facility for this interchange to take place. If teachers have trouble keeping in touch with project team members, there should be set requirements and deadlines for when events have to be scheduled. The benefit of this year's scheduling issues is that we are now able to look back and see where the problem occurred and what can be done to make improvements. This served as a good learning experience, and because of it, next year's project team will realize that scheduling with teachers involved needs to be a flawless process in order to attain success.

The reason that Rick did not feel comfortable teaching Jason and Dan's lessons is that he did not think he would be able to convey the correct information to the students based on what was documented in the lesson plans. The issue with this was that Jason and Dan had kept up with what Rick wanted them to accomplish and had gone through numerous revisions in order to have their lesson plans ready for the classroom. This goes back to the issue of unclear expectations discussed above. The beginning of the year when the IQP students were confused as to what was expected of them would have been the time to straighten out the times that would be designated to have the IQP students' lessons implemented. By the time that Jason and Dan's lessons were revised to their final state, Rick still felt like he would not be able to conduct the lessons as they were. In addition to this, because the end of WPI's academic year was approaching, it made it more difficult for Rick to help Jason and Dan with their lessons than it would have been if they were finalizing their lessons earlier in the year when things were not as hectic. Once again, this miscommunication and lack of clear expectations was not necessarily the fault of anyone involved. The fellows were not used to having to worry about anyone's lessons but their own, and because they were used to their own process of making lessons, it was difficult to come up with exactly what they expected from the IQP students. This and the fact that it was the first year of the project with no precedent made it difficult for the fellows to come up with these expectations. It took longer than expected for the fellows to come up with guidelines to give the IQP students on how they wanted the lesson plans produced, and by the end of the year many of the expectations had changed from their original form. Fortunately, with the benefit of hindsight and a clearer outlook on what the lesson writing expectations for IQP students should be, Rick has supplied us with some good suggestions for next years project that will help to get the IQP students' lessons implemented.

One thing Rick suggested is that the summer prior to the project, the fellow could work with the teacher to assemble a list of possible subject areas on which the IQP students can base their lessons. The fact that Rick supplied Dan and Jason with their unit topics did help greatly, but we can definitely see the benefit in giving some more specific options for lesson plans. Rick also suggested some scheduling changes to help the process. He said that at the very beginning of the year, the IQP students meet with their fellows and advisors and assemble a schedule that will permit for them to have their lessons entirely ready by the end of B-term. Although they do not have to be in their final revised state, they should be fully assembled with any necessary materials purchased and any prototypes built. Having everything purchased and assembled is a large step towards making sure everything will work and it allows the fellows to get a better understanding of how the lesson works so that they will be more comfortable to teach it. Rick also proposed a set of deadlines regarding the lessons that are to be implemented. By having the lessons to be implemented chosen by the end of A-term and the completed lessons handed in by the end of B-term, the IQP students are in a good position to have their lessons ready for implementation. Rick also proposed two "dry runs" in C-term. One dry run would occur at the beginning of the term so that the fellows could observe the lessons and come up with any suggestions or comments regarding improvements that need to be made. During the middle of C-term, another dry run would take place where the improvements were made and from the result of this run the fellows would make the final decision on whether the lessons would be good enough to implement in the classroom. This allows for the IQP students to know where they stand so that last minute decisions are not made regarding whether or not their lesson plans are to be implemented. This also allows them to know exactly what they need to do in order to get their lessons implemented, which was a big issue this year. After the dry runs, the lessons are shown to the classroom teacher in order to ensure their appropriateness, and together with the teacher, the fellows and IQP students decide who will implement the lessons. Rick suggested an implementation date of no later than the end of C-term, which ensures that the parties involved will not be running into any hectic last minute academic deadlines of their own. In addition to this, Rick made a point that it would be better for all research paper or addition aspects of the IQP to be designated for D-term in order to reduce interference with the lesson planning and create more time for lesson plans to be made. By separating these two aspects of the IQP, it allows the student to concentrate on each part individually and not have to worry about both at one time. Rick also made some suggestions regarding communication improvements that can occur to help lesson plan implementation. One suggestion involved the fellows and advisors meeting during the summer prior to the school year in order to determine a feasible lesson planning schedule for the IQP students to follow. This negates any ambiguity of expectations throughout the year and gives the IQP students a set idea of what they will be accomplishing from day one. In addition, the fellows and advisors will meet to touch base at the end of each term in order to assess the progress of the IQP students and assure that everything is on track. At the beginning of C-term, an additional meeting should be made to discuss any alterations that need to be made in the schedule in order to allow for lessons to be implemented. Rick also made some proposals about having the IQP students in the classroom. Because of the extreme importance of having the IQP students working in the classroom and gaining experience for their lessons, Rick suggested that science and engineering time in the classroom is set by the teacher at the beginning of each term so that the IQP students and fellows will not run into any scheduling conflicts with their own classes or responsibilities. Rick also underscored the importance of having the IQP students prepare progress reports and presentations for the rest of the PIEE group periodically. This serves two purposes, one being to allow for feedback and responses from the other project team members and the other to help the IQP student stay on task and allow him/herself to evaluate his/her own progress. With the consideration of these suggestions, the lesson planning process and opportunity for implementation could be greatly improved for next year.

Implementing our lessons was not the only thing made difficult from working with the teachers' schedules. Because the teachers had so little time to spare, our graduate fellows would have set days throughout the week where they would go into the classroom and teach. If our schedules did not mesh with the time that the fellows would go in and teach, we would not be able to observe their lessons being taught. In Jason and Dan's case, their schedules conflicted with the time that Rick was projected to conduct his lessons. Because of this, for much of the period where the IQP students would observe their fellows teaching, Jason and Dan were only able to go in at a time they had available and watch Mrs. Bercume teach other subjects (particularly mathematics) to the students. Jason and Dan found this time watching and assisting Mrs. Bercume in her lessons to be valuable, however, it did not serve as an adequate substitute for observing how fourth grade students handle engineering lessons. It was not until three weeks before the end of C-Term that Rick was able to coordinate his schedule with Jason and Dan so that they would be able to watch and help Rick teach his engineering lessons to the students. Seeing these lessons being taught as opposed to lessons from a different subject area had a profound effect on Jason and Dan. Studying the way students reacted to engineering lessons opened up a great deal of new ideas for Jason and Dan in addition to helping them determine which factors needed to be altered in order to make their lessons work for the students. The fact that Jason and Dan did not witness these lessons being taught until about three weeks before they had to hand in their final lessons made it a much more strained process to alter their lesson plans based on what they learned from being in the classroom. Thankfully, Jason and Dan were able to revise their lessons and take into account what they gained from seeing engineering being instructed to the students. Even though most of their time in the classroom was spent observing other subjects being taught, Jason and Dan were able to obtain an ample amount of knowledge from the short time they worked with Rick and his engineering lessons in Mrs. Bercume's class. The important detail here is that in order for a person to successfully create lesson plans, it is absolutely critical that he has an adequate amount of classroom experience, particularly in the subject area that pertains to his lessons.

Part III: Classroom Influences

We all profited immensely from spending time in the classrooms. Prior to working with these fourth graders, we knew that they would have an impact on the way we would have to design our lessons, but at the same time we had very little idea just how much they would affect what our output would become. Looking back on our experiences, it would have been impossible to create successful lessons without seeing how students manage to learn this type of material. Everything from how the students interacted with each other to how they felt about their abilities to comprehend the concepts put before them were factors that would be necessary for us to take into consideration when designing our lesson plans. This would be no better than designing a computer without taking into account the people that would have to use it and understand it. We could not have predicted many of the things that came to light when working with these students, and we feel that these experiences are important to share with anyone who would potentially be conceiving lesson plans in the future. The following paragraphs present some of the most valuable wisdom we gained from our classroom experiences throughout the year.

Unexpected Insights:

Initially, we were not quite sure what to expect when entering the classroom for the first time. It has been a long time since any of us have been in the fourth grade, and it is difficult to recall what that type of environment was like, especially from the perspective of a college student. This is part of the difficulty of relating to children. When a person is young he might feel as if he is greatly underestimated by adults. Children tend to not get the credit they deserve in many cases, and once people become much older they can easily forget how they would feel when their parents or teachers would not have faith that they had knowledge about something or possessed a certain skill. This is one important thing we were reminded of as we came into these classes. The children were capable of much more than we initially thought, and having the confidence that the students could achieve far beyond our preliminary expectations was all they needed to take that extra step and really strive to learn.

One thing that we were all very impressed with and surprised about was the enthusiasm of the students. At the age where children are in fourth grade they are fascinated by everything in the world, and it completely showed when we went to observe the students. Even something that might seem droning to an adult such as arithmetic drilling can be exciting to students with the right motivation. When made into a game format with the use of handheld slates, Mrs. Bercume's students absolutely loved practicing their multiplication tables. The fact that when it was time to move onto another subject the students begged for more multiplication problems illustrates the fact that children can be excited about anything. Games and competitions such as the multiplication tables example can be utilized for just about any type of lesson, and are a very easy way to get a student to be enthusiastic about a certain subject.

Consideration of Student's Traits:

The only problem that arises with a game type situation is that some students are generally much more timid than others, and will be more reluctant to raise their hands and give out an answer. One way that this problem is overcome can be shown in this very interesting occurrence. During the multiplication lesson Mrs. Bercume realized that as the students would write their answers on the slate they would look at each others answers and copy them. Although at first reaction this seems like this is nothing more than cheating, it actually has a very interesting effect. Fourth graders have very fragile confidence levels and their self esteem can be shattered very easily. By copying each other and using that as a learning tool, the students actually recognized patterns and were able to teach themselves and reassure themselves of their ability to do math. This strange occurrence actually helped the students to be confident enough to actively participate more and raise their hands to give out answers. Although it is not a good idea to encourage cheating, an interesting technique to keep in mind for lesson planning is to allow for students to bounce ideas off of each other so that they can become more confident in their abilities and not be so intimidated by telling teachers their ideas. By working with peers the students feel more comfortable than going straight to their teachers, and this can in fact be very beneficial to their growth in independence. At the same time it is important to keep in mind that some students will naturally take control of group work and others will stay in the background and feel too shy to contribute. As important as it is to allow students to work together, it is equally important to encourage equal participation and make sure that every student contributes to the group. We took this idea and incorporated it into the sections of our lessons that include student brainstorming. When brainstorming, it is crucial that every student is comfortable enough to share ideas. In a brainstorming environment, there are no wrong answers. This is a very encouraging place where students can voice their opinions and not be inhibited. These types of situations should be incorporated as often as possible and individual participation within groups should be supported.

The main goal is to give students a sense of self worth. This is a very formative time in the students' lives and because of this it is so essential that confidence is instilled within them. Once a child feels comfortable with his ability he will feel better about what he can do and will perform better. These students absorb knowledge extremely quickly and we were so impressed at how fast they were able to understand certain engineering concepts. It is not intuitive to think of fourth graders drawing circuit diagrams and understanding the concept of current flow, but it is quite possible for a child that young to comprehend those types of theories. If the lesson is written in a way that is appropriate for a student of that age, it is perfectly feasible.

Dealing with Classroom Issues:

One thing that needs to be taken into consideration in a classroom is that there are numerous ability levels amongst the students that a teacher will need to accommodate. It is a major balancing act to keep a lesson simple enough for students that take a little longer to understand concepts while keeping the lesson involved enough to keep the top level students engaged and interested in the subject matter. To accomplish this, an activity can be designed where the main section is planned to account for the low level students and be very simple but also have extra sections which are more challenging and can be reserved for when some students finish the simpler part. This will keep everyone equally involved while assuring that everyone gains from the lesson.

It is important to keep in mind that no matter how quickly some of the top students will be able to pick up information and move through an activity, all lessons should be designed to conform to a level that is appropriate for the students' age. This really came to light when we observed the fellows and their engineering lessons. Even though it was stated earlier that adults tend to underestimate what young students can understand, they can also overestimate how quickly the students can complete a task and how complex a task they can perform. One thing we miscalculated is how fast fourth graders can read. In our initial lesson plans the student procedures we included were not that concise and needed to be adjusted. When we realized exactly how quickly the students were able to read it served as a bit of a wake up call that there are definite differences in levels for which you can communicate with teenagers and with young children. It is important to make lessons for young students as comprehensive as possible. Children that young cannot handle complicated steps or wordy directions. It was interesting how long it took some students to get through a small simple sentence and make sense out of it. For this reason, it is very impractical to give students complicated lessons. Any diagrams that the students will have to use need to be crystal clear and easy to read. Visual aids, when done incorrectly, can almost be more of an obstacle than a utility. In addition to this, young students need very specific directions and lessons. Young children do not respond well to ambiguous statements and will not gain much from a lesson that is not explicit in its content. There were a couple cases in the classroom where a worksheet had a vague sentence in it and the students spent more time trying to figure out what it meant than they did solving the actual problem. It is very important to allow adequate time for a lesson to be completed, because young children tend to perform much slower than one would anticipate. In general, when writing a lesson that we thought would take an hour, we would plan for it to take two hours. Even the lessons that the fellows would write would often be stretched out over twice as long as they expected. It is important not to rush these students to learn, because they will not absorb information that way and it will almost be a waste of time to teach a lesson from which the students will not be able to gain anything. Conversely, in a situation where a lesson takes much less time than expected, a teacher should always be prepared and have extra activities for the students. As said before, there is not much flexible time in a school day and every minute should be used to its fullest potential.

Because of the time issue, a valuable goal to keep in mind is efficiency of lesson time. When possible, teachers should try to multi-task and take care of as many concepts as they can in one single lesson. Integrating multiple subjects into a lesson can be a great asset and can possibly allow for extra time in the future where a teacher can cover a topic he was not even planning on discussing. One thing we noticed was that when students first enter the school in the morning it takes them a very long time to get settled in and ready to learn. A teacher needs to get the students ready for the day quickly and effectively and minimize the time it takes them to get into the classroom and get settled. This efficiency alone can save a great deal of time; enough time so that when it is applied to a one hour timeslot for a lesson it can make an enormous difference.

Young students can have extremely short attention spans. Because of this it is very important to design lessons with the intent of constantly keeping the students involved. Activities that maintain a high excitement level and keep the students engaged will help them gain a great deal more out of the lessons than they would if they were working on a more passive activity. Hands-on lessons are the optimal kind to have in order to keep students engaged, and when working within an engineering subject area making a lesson hands-on is definitely not difficult to do. Another way to keep the students involved is give them a sense of achievement with their activity. Young children are easily discouraged and making them feel like they are accomplishing something great can really affect the way that they will go about their school work. Reinforcing the idea that they can handle the subject matter and keeping the lesson comprehensive will ensure that the students are engaged in the activity and benefiting from it. One particular student from our experiences was very capable but tended to not pay attention in class and cause disruptions. By giving this student a feeling of achievement he could potentially perform better and cut down on the problems he causes by not feeling a need to get everyone's attention. There is no guarantee that having well made lessons can prevent students from misbehaving but it is always a good thing to have a lesson that is designed to keep students involved and excited.

Sometimes there are disruptive students and other troublesome factors that lesson design alone cannot take into account. This experience impacted us greatly and helped us to determine what the most important part of implementing a lesson is. The lesson that is written on paper will only take you so far, but how a lesson is conducted is what determines whether or not the lesson will go over well. It can be frustrating to think that after all of the preparation that goes into writing a lesson plan it can become a complete disaster in the classroom, but this is a reality of teaching. A teacher cannot be afraid to discard parts of a lesson or even a whole lesson if it is not going well in a classroom. There are factors that cannot be predicted sometimes that will cause a lesson to not work at all, and for this reason it is important that a teacher has the skills to think on his/her feet and improvise. A baseball player can train as much as he thinks he needs to but when in a game situation anything can happen and anyone can make an error. Seeing how a student reacts in a certain situation and applying that to other problems that may come up is an important skill to have. Having backup plans and being as prepared as possible are critical for teaching lessons, but in a worst case scenario a teacher still needs to be able to come up with quick ideas and make good decisions as to what should be done. When working one on one with students we learned that although something might be explained one way in lesson directions, students seem to respond positively to improvised clarifications and analogies. If the students do not understand something the way it is explained, a teacher needs to come up with a better way to explain the topic on the spot. Most often the best way to explain a topic is by relating it to something the students understand very well. When conducting a circuit design lesson, the electrons flowing through a circuit were compared to cars on a highway. This was an analogy that the students were able to grasp easily and it averted the problem of having current flow be something that the students would not be able to comprehend. It is nearly impossible to follow a lesson plan exactly how it is intended to be done, so anyone that wants to teach children needs to be ready to make last minute changes and come up with explanations and activity ideas off the top of his head. It is one thing to become skilled at writing lesson plans, but in order to successfully conduct a lesson a person really needs to have these creative and quick thinking skills. One could say that this is really the art of teaching.

Part IV: What Have We Learned?

This project could have been approached in two different ways. We could have researched teaching, lesson planning, child behavior, and other subjects related to education. Then we could have used that knowledge to describe to teachers how we thought engineering should be taught to elementary school students that have not been exposed to engineering before. The other way this project could have been approached is by writing our own lesson plans, dealing with teachers and other people in the field of education, and going into the classrooms and working with the students ourselves. In retrospect, we feel that the only way this project could have been approached in order for there to be a successful outcome would be for us to actually go in and gain the experience of teaching and writing lesson plans. Teaching is not a passive action. It is a very involved art and it requires just as much practice as it does theory. Because of this, it was the experiences we had this year that we feel are more valuable than any other kind of knowledge about education we could have gained.

We learned that the process of creating lessons was a very complicated one. Scheduling is critical for the planning process to be successful and deadlines help to keep planners on task. Background research is a key component to making high-quality lesson plans but it does not substitute the need for ingenuity in creating lessons. Lessons need to be customized for the classroom in which they are going to be used, so it is important to make them appropriate. Throughout the process of creating lessons it is important to leave time to make revisions. There are always things that will need to be changed and adjusted in order to be suitable for a classroom. Clarity and comprehensiveness are key qualities to have in lessons, and traits of students should be taken into account when designing lessons.

We also learned about what could be done to make this project more successful in the future. Material restrictions and lesson format need to be taken into account long before lesson plan design begins, because this can cause problems and cost valuable time and effort. Scheduling is important in order for the project to be run efficiently, especially when working in a large group. Teachers are a special consideration when it comes to scheduling and they need to be treated as such. Communication is a key for the success of any project and clear expectations and planning can help things run quite smoothly. Overall, when dealing with such a time dependent activity like teaching, careful planning is of the utmost importance.

We learned a great deal from the students we taught in class. We were rather amazed by their capability and enthusiasm, and realized that all it takes is some faith in the children to have them succeed. It is very important to design lessons so that they can be used for students of all ability levels, although even the top students need to have things explained to them clearly and concisely. In addition, all students need sufficient time to perform tasks, and this needs to be heavily considered. Most importantly, teachers need to rely on their actual teaching skills rather than what sits before them in a lesson plan. When something on paper does not go as planned, a teacher needs to be able to improvise and work quickly if he/she wants a lesson to go well. Without having actual teaching skills, lesson plans are worthless.

Overall, this project gave us an entirely new perspective on the teaching profession. Many people do not give teachers the credit they deserve and consider them to be lazy workers that do not have many responsibilities and get many vacations. As our experience shows, this is entirely false. There is a great amount of hard work and preparation that goes into teaching, and to make it even more difficult teachers are required to work with minimal supplies, support, and time. Teachers are able to deal with this however, because they possess amazing creativity and skill in what they do. Teaching is truly an art, and teachers are truly professionals in their field.

Chapter IV: Conclusions

Throughout this year we have been taking part in something very special. The impact left by the work we are doing cannot be measured quantitatively, but as engineering education becomes a more integral part of public education in the state and throughout the country, people will be able to see the influence that projects such as these have on U.S. students. We do not need this proof however, simply because every time we enter the classroom and we see a student becoming excited about engineering and absorbing this information we know that our time and effort has been worthwhile. With help from the NSF and our partners in the Worcester Public Schools, we have already been able to establish a good relationship with the teachers and students of Midland St. Elementary and Elm Park Community School as well has contribute towards a lesson plan repository and gain some very valuable experience that can be used to efficiently and effectively carry out this project over the next two years. In fact, it is the lessons that we learned and the experience that we gained and not the actual lesson planning output that should be considered our greatest triumph this year. By now having the proper idea of how to go about creating lesson plans the IQP students and graduate fellows will be able to come up with ideas more quickly and easily. In addition, with a set template they will be able to document their lesson ideas with a greater efficiency. The fact alone that next year's group will have a better idea of what to expect as well as what needs to be done to get their lessons implemented is a great improvement in itself. The administration aspect of this project should continually progress as well, with project and classroom scheduling improvements and overall communication advancements making it easier to produce a quality yield. The expanded scope of the project next year will also be an acceleration towards the greater goal of having Worcester's youth become technologically competent. With new schools and grades being added, more teachers will become trained in effective methods to teach engineering so that over time they will be able to train their colleagues and eventually have a collective of knowledgeable and resourceful educators that will be prepared to teach to the state's frameworks and city's benchmarks. With each minute we are spending in the classroom, we are exposing young students to a vast new world and allowing them the opportunity to pursue a field that they might not have known about before. With the lack of minorities and women in technical fields, the level of diversity in engineering can only be enhanced by engineering education in an urban setting. The significance of what we are doing must not be underestimated, because the students represent the future of engineering and to begin their training now is a valuable investment. By giving our time and energy to this cause, we are helping to ensure that the future engineers of this world are enthusiastic and well prepared.

Appendix A: Professor Denise Nicoletti

When I was handed a copy of the grant written to the National Science Foundation to secure funding for this PIEE project, I flipped through the pages and thought to myself, "Great. More paperwork to pretend to be interested in.", but I found something surprising. The primary name on the grant was Professor Denise Nicoletti. My surprise quickly subsided as it occurred to me that a project like this, helping children become interested in engineering, was exactly something she would have had an instrumental hand in.

Professor Nicoletti was killed in a car accident in the middle of July after my sophomore year. I remember the day when I read the notifying e-mail at work and then stared at my monitor for almost 15 minutes. Professor Nicoletti was my advisor. Later on, I found out she was much more than that.

At a memorial service held at WPI I watched a stream of her colleges and friends address the packed room crowd about a countless number of projects she started at WPI. These included a room providing a place for the women of the Electrical and Computer Engineering department to study for their classes, and her most well known accomplishment, the creation of Camp REACH which I will talk about later on. The one thing she did that stood out the most was supporting her fellow professors. She started a daycare program for her colleagues with small children. It struck me that her generosity did not stop with her students and advisees, the girls of Massachusetts, or even the elementary school children of Worcester, but it even found its way into the lives of those with whom she worked.

By now you know a healthy amount about the PIEE Project and you now know that Professor Nicoletti was the driving force behind it. I'd like to talk about Camp REACH. It's a summer program for girls from Massachusetts schools, who are heading into 7^{th} grade. It gives them a taste of technology and engineering. As an engineering student, and a male, I've seen far too many instances of females counting themselves out of an education in these fields simply because of their gender. As each Camp REACH session grows from year to year, it is clearly making a difference.

I'd like to take this rare opportunity in an IQP paper to thank those involved with the PIEE project. There are many projects for students to participate, but I can't imagine one more personally fulfilling than this one. One behalf of my entire fourth grade team, I'd like to thank Professors Miller and Rencis, for working so hard to make this project a success. I'd also like to thank our IQP advisor, Professor Goulet for guiding through this process and for asking me to write this piece about Professor Nicoletti.

Michael J. Schenck