October 2006

Partnerships Implementing Engineering Education: 2nd and 3rd Grade Lessons

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Project Number: 51-JXR–0205

PARTNERSHIPS IMPLEMENTING ENGINEERING EDUCATION:

2ND AND 3RD GRADE LESSONS

An Interactive Qualifying Project Report

submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

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Date: May 2, 2006

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1. education
2. engineering
3. lesson plans

Abstract

Sponsored by the NSF, the Partnerships Implementing Engineering Education project was a collaborative effort between Worcester Public School teachers and Worcester Polytechnic Institute students to develop and deliver engineering and technology lesson plans that were accessible to teachers and ensured the sustainability of the Massachusetts science, technology, and engineering curriculum. We created and tested a comprehensive engineering curriculum for the second and third grade classrooms at Midland Street and Flagg Street elementary schools that supplemented the existing science curriculum.

Acknowledgements

Jessica and Cale thank second grade teachers Mary Beane and Susan O'Malley at Midland Street, and Jyoti Datta, Monica Wolf, and Robin Ring at Flagg Street; Michelle and Rob thank third grade teacher Nancy Mattus at Midland Street, and Liz Monticelli, Paula Renzoni, and Kim Hampton at Flagg Street, for their excellent participation in and professional attitude toward this project. We acknowledge the principals at both Midland Street and Flagg Street schools, Patricia McCullough and Gerald Hippert.

We are grateful for Jill Rulfs, a Principal Investigators of the PIEE project and our advisor, for her exemplary guidance and constant involvement.

We thank, with considerable appreciation, WPI graduate students Karen Kosinski and Steven Toddes for their invaluable help when bringing lesson plans into the classroom, in addition to their moderation between teachers and students.

We recognize the National Science Foundation and the Massachusetts Department of Education for the continued commitment to engineering and technology education in grades K–12.

Authorship Page

Jessica Rosewitz and Cale Putnam worked with graduate student Steven Toddes to develop and teach lesson plans for grade two, and Michelle Tucker and Robert Weir worked with graduate student Karen Kosinski to develop and teach lesson plans for grade three. Jessica, Cale, Michelle, and Robert all contributed equally to this project report.

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Executive Summary

This project, a collaborative effort between Worcester Public School (WPS) teachers and Worcester Polytechnic Institute (WPI) students, developed and delivered engineering and technology lesson plans to participating teachers that were accessible and ensured the sustainability of an engineering and technology curriculum. Although this subject matter is not tested on the Massachusetts Comprehensive Assessment System (MCAS) until fifth grade, our research show that it is beneficial to introduce these concepts in Kindergarten, because constant exposure to engineering fundamentals reinforces the subject matter and may produce higher scores on the MCAS.

The National Science Foundation (NSF) sponsored the Partnerships Implementing Engineering Education (PIEE) project between WPI and the WPS for three consecutive years. Entering the third and final year, we created and tested an engineering curriculum for the second and third grades that supplemented the existing science curriculum. We reviewed results from the past two years' projects to determine if the WPS "Benchmarks" and Massachusetts Department of Education (DOE) "Frameworks" were covered, and concluded that the existing lesson plans did not meet these requirements for engineering and technology. To ensure that our lesson plans helped the students meet these objectives, we created a "Lesson Plan Assessment Form" with which teachers evaluated lesson plan effectiveness and student comprehension. Using this information, we improved our lesson plans to be grade appropriate, accessible to teachers, and sustainable.

In cooperation with local elementary schools, we brought the lesson plans into nine classrooms on a weekly basis, where both the students and teachers anticipated learning about,

and applying engineering. Before presenting a lesson, we consulted with teachers to ensure that they were confident with the material, and compiled their responses into a “Background” section in each lesson plan. Once it was ready to be taught, we either observed or helped teach a lesson plan, in addition to answering students’ questions. Following lesson delivery, we made necessary changes to the lesson plans to be appropriate for the grade level and accessible to teachers.

We evaluated student understanding of engineering concepts by creating an “Engineering Review” for second and third graders. The review consisted of short, open-answer, and multiple-choice questions. According to the results of the engineering review, a majority of students retained at least fifty percent of engineering concepts. This was the students’ first exposure to engineering, which made the scores impressive, given the limited experience of each student in the subject area.

Combined, we made over thirty new second and third grade lesson plans that addressed all of the technology, engineering, and some general science curriculum requirements for Massachusetts schools. These lesson plans included materials to teach engineering, which we assembled in kits. A cost analysis revealed that comparable kits on the market today, such as Full Option Science System (FOSS), Delta Science Modules (DSM), and Science Curriculum Improvement Study (SCIS), were more expensive than ours. Analysis of these competitor kits indicated that teachers selected them because they included all of the necessary teaching materials for a science lesson plan, and could be obtained through the school system. We increased lesson plan accessibility by providing all of the necessary teaching materials, most of which were recycled, readily available with help from parents, and at low cost to obtain. The real advantage to our kits was that any teacher could obtain all the materials at a substantially lower cost from current school supplies or local stores.

The lesson plans and the PIEE program were evaluated using surveys for both students and teachers. The student survey gauged their reactions to the curriculum. We created a hands-on activity to accompany every lesson plan, and believe that these projects improved student understanding and retention of the material. We have had a positive impact on the students, since three quarters of both second and third graders indicated that they would consider engineering as a career choice, and all students answered that they enjoyed engineering. The teachers shared this enthusiasm when surveyed about our integration of engineering into the curriculum. Positive responses from survey participants indicated that our lesson plans taught required objectives, engaged the students, remained accessible to all teachers, and ensured the sustainability of this curriculum. In addition, there was a consensus that engineering should be introduced as early as possible at the elementary level, since waiting until the fifth grade, when engineering and technology is first tested in the MCAS, was too late. However, we found that existing curricula did not specifically address engineering and technology and, in some cases, those subjects were absent.

Our goal in this project was to develop a curriculum that covered the WPS and DOE learning objectives developed in conjunction with the MCAS. Another goal was to improve scores in the engineering and technology portions of the MCAS. The PIEE project encouraged teachers to introduce engineering and technology in Kindergarten in order to help students make informed decisions and prepare them to participate in a technological society, setting a strong foundation for future learning.

Introduction

One of the concerns of modern society is that engineering jobs are slowly being exported from the United States. The National Science Foundation (NSF) estimates that increased foreign competition in the engineering and science markets will decrease America's strength in the global market. (2004) This, combined with an impending wave of retiring scientists and engineers, underscores the need for the younger generation to explore engineering as a possible career. As a result, the presentation of science and engineering curricula in classrooms is becoming a priority to educators with help from the NSF.

In May of 2004, the NSF published their annual report "Science and Engineering Indicators 2004" that detailed the current state of engineering and technology in the United States. The report outlined how other countries, such as those in the European Union (EU), have been improving their position in the science, technology, engineering, and mathematics (STEM) market by "implementing policies designed to lure more of their citizens into STEM, keep their researchers at home" and, in some cases, "attract highly trained STEM personnel from abroad." Companies have started "opening high-technology operations in foreign locations, developing strategic international alliances, and consummating cross-national spin-offs and mergers." These trends have led to the spread of "technological know-how" and "scientific and technical capacity" around the world, and pose a risk to the United States' leadership in STEM. As the world continues to move towards a knowledge-based economy, other countries such as those in the EU have begun to gain ground in the technology market. Therefore, it is essential to give children the opportunity to explore engineering as they begin to think about their future. (S&E Indicators 2004 Overview)

To enable children to explore engineering, the NSF established the “Graduate Teaching Fellows in K–12 Education” (GK–12) to fund programs that promote science and engineering education. This project promotes a collaborative effort between universities and public schools in order to create or enrich an existing STEM curriculum. By partnering graduate and undergraduate students with public school teachers, the NSF hopes to promote STEM in the classroom, develop partnerships between universities and local schools, and encourage students to consider careers in STEM. (NSF, 2004)

The state of Massachusetts has set goals similar to those of the NSF with the belief that engineering and technology help children to develop strong intellectual and social skills. (Abruscato, 1996) The state of Massachusetts recommends teaching engineering and technology to students in kindergarten through twelfth grade because students can form opinions about certain professions as early as elementary school. As an additional benefit, teaching STEM encourages students to express themselves in a thorough and orderly fashion. (Jamerson, 2004) Researchers generally agree students should be taught how engineering and technology influences their lives and society as a whole. (Abruscato, 1996) To assess students’ progress in engineering and technology, the state of Massachusetts will test science and engineering skills. Students must pass these assessments to receive a high school diploma; thus, developing an engineering and technology curriculum is very important. The Massachusetts Board of Education first laid out Frameworks in 2001 that outline important aspects of technology to be tested, and in response, the Worcester Public Schools (WPS) published Benchmarks to meet them.

To give WPS a strong foundation to build their engineering and technology curricula, the NSF funded the Partnerships Implementing Engineering Education (PIEE) program to assist the WPS meet their new Benchmarks. In this program, WPS teachers collaborate with Worcester

Polytechnic Institute (WPI) undergraduate students, graduate fellows, and professors to create sustainable and accessible lesson plans that integrate both Massachusetts Frameworks and WPS Benchmarks into the classroom.

Engineering and technology is a relatively new topic for many elementary school teachers; therefore, the NSF created outreach programs, such as PIEE to help teachers access and apply engineering and technology. Studies indicate that only five percent of all elementary school teachers have a science or math degree, and as a result, many teachers may be uncomfortable with developing a lesson plan that addresses the engineering and technology Benchmarks set forth by the WPS system. (Interview with Mare Sullivan, 2005) An article in the *Journal of Professional Issues in Engineering* by Andrew Jeffers states that American students have deficiencies in the areas of science and math. "It is imperative that all individuals in our society have a basic level of technological competence that includes the ability to create, use, manage, and assess technology." (Jeffers, 2004) NSF Director, Rita Colwell indicated this need by stating:

> "We cannot expect the task of science and math education to be the sole responsibility of K through 12 teachers while scientists and graduate students live only in their universities and laboratories. There is no group of people who should feel more responsible for science and math education in this nation than our scientists and scientists-to-be." (Jeffers, 2004)

Unfortunately, many teachers are not required to take engineering courses while earning their collegiate degrees, and as a result find teaching engineering difficult. The article recognizes this need and reminds outreach groups that the:

> "…key to success is to provide the teachers with enough training to instill the technical skills and confidence they require. Teachers who successfully implement engineering into their curriculum will often share their success with peers, leading to the potential for reaching even more students." (Jeffers, 2004)

To assist teachers who may be struggling with engineering, many institutions, including universities, have started outreach programs like PIEE to help teachers provide their students with the foundation in science and engineering they need to meet the Frameworks set forth by the State of Massachusetts that will enable them to succeed in our modern society. By introducing a curriculum at the elementary level, PIEE hopes to spark an interest in engineering by challenging students to think creatively and collaboratively.

Background

Preceding Projects

This project seeks to continue and elaborate upon work of similar projects, thus it is pertinent to look at established processes, collected information, and relevant conclusions. One WPI student project, entitled “Implementing Engineering in Second Grade Classrooms,” analyzed the effectiveness of teaching engineering to second grade students. The project measured the effectiveness of lesson plans on student’s attitudes towards engineering by using simple feedback assessments. After administering surveys at both the beginning and end of their project, the IQP students discovered that their lessons did little to improve students’ attitudes toward engineering. Although eighty percent of the students indicated that they understood engineering at the completion of the project, fewer students expressed an interest in engineering, leaving the WPI students unsure about the long-term effects of their project on the students.

The education of grade two and three students is not the primary goal of this project; instead, PIEE seeks to create sustainable lesson plans that instructors can understand and effectively teach without prior training. Despite their self-professed lack of interest in engineering, the WPS students repeatedly exceeded the expectations of WPI undergraduates. (Chu et al., 2005) Unlike the grade school students, some teachers felt unenthusiastic about the STEM curriculum. The undergraduate students did not reach one particular conclusion, but believe that there appears to be a need for simple, straightforward engineering lessons that inspire confidence and a willingness to incorporate engineering and technology in the classroom. (Chu et al., 2005)

Child Psychology

An understanding of how children learn will facilitate the development of a method to teach engineering to young students. The following section will primarily discuss the learning habits of students that are seven and eight years old, corresponding to second and third graders. A spectrum of age and grade levels places age-specific habits in the context of a learning continuum.

Behavior and Cognitive Theories

There are several theories that attempt to explain the factors that produce learning in a child's mind, stemming from observation and scientific studies. While no definite answers exist with respect to the mind's acquisition of knowledge, insight has been provided into how one might approach teaching.

Piaget

Jean Piaget, a twentieth-century psychologist, developed a theory stating that children learn through four primary factors: maturation, experience, social transmission, and equilibration. Maturation is the development of the child's own nervous system and brain. The idea of experience is intuitive; essentially, a child gains information from both physical and mental sources. For example, a child can glean that a ball of clay has the same amount of clay in it as a sausage shape, though objects' dimensions might be different. This occurs through experimentation and observation of objects in different situations. Such research into hands-on learning promotes the idea of using projects for teaching some subjects rather than traditional teaching. Social transition is defined as a child learning after being told that a fact is true. This is considered traditional teaching; however, it can also refer to learning information by overhearing. The primary concept that Piaget enforces is that children cannot learn through transition without first gaining the basic concepts that are needed for proper understanding. Finally, equilibration means that the previous factors need to be balanced in order for a child to learn. The ideal learning situation for a child is the combination of experimenting while being informed with facts. (Piaget, 1972)

Age-Specific Traits

Beyond addressing all of the cognitive aspects of learning, for lessons to be effective, it is also necessary that they target the specific audience or age group that shall be receiving them. A second grade student, for example, would have difficulties learning fourth grade material, and a fourth grade student would find second grade material exceptionally easy.

Seven Year Old Students

According to Chip Wood, at the age of seven, students are hard workers and not as social as at other ages. The primary defining trait is the student's desire for his or her work to be both complete and perfect. They will take longer for projects, often asking for extra time, and use the eraser constantly. They prefer to work alone, and can sometimes be restrained in their communication with peers because of the fear of being ridiculed. Their writing and drawing can become minutely small and are anchored to the lines on the paper. Copying from the board can be difficult because their developing eyesight leads to trouble switching focus from the board to the paper. At this age, students become adept at classifying objects. They are ready to read silently and may whisper words as they read. (Wood, 2005)

Eight Year Old Students

Eight-year-old students are full of energy and ready to learn, but need guidance from both parents and instructors. They work quickly, and tend not to be attentive, often needing to hear directions twice. Liking to switch topics constantly, they are very curious and will lose focus as a result. This is also due to a short attention span. They are social and will often talk with peers while completing work, making group projects very successful. They are confident with their skills and will sometimes try to exceed their own abilities. Work tends to be organized but sloppy. Class projects are a good idea since they build unity among the students. (Wood, 2005)

Diversity

Diversity encompasses racial, physical, mental, and socioeconomic differences. NSF seeks to instill interest in engineering as early as Pre-Kindergarten to expose more students to engineering and the natural sciences. (*Shaping the Future*) Preparatory courses in a STEM curriculum determine how many young people prepare well for STEM careers, but failings in these areas on behalf of teachers and students can dull interest and waste talent, especially in women and minorities. The path taken by young people in approaching careers in STEM can be visualized as a pipeline. The pipeline model maps the progression of a student in preparatory science and mathematics following from elementary and secondary school to higher education, but many students drop out along the way, citing loss of interest and lack of preparation. Students may enter as early as third grade, but very rarely do so after junior high school. (Camp, 1997) The pipeline model predicts the level of involvement of scientists and engineers in all professions, and projects the future supply of those scientists and engineers branching into diverse job markets and careers. (Shaping the Future, 1996) Demographics of the resulting pool suggest it needs to be enlarged in quantity and quality so that STEM professionals come from all areas of American society. The Federal Government has only limited authority while the state boards of education and local school systems have the responsibility of reforming education. (Kimmel, 2001)

This STEM pool is not fixed in GK–12, but rather there is a core group, a “swing group” that may or may not enter the pipeline, and also “late bloomers.” (*Elementary and Secondary Education*) Diversity in the pool, from past and present observations, shows that women and minorities are underrepresented and that a general shortage of STEM professionals is inevitable. Thus, it is important to prevent outflow. Viewpoints vary with respect to concentrating efforts, but the consensus is that at all levels, a strong focus on continuation of STEM curriculum promotes future career choices in science and engineering. Student preparation is a major reason for outflow because of the academic intensity required to pursue a professional career. The conscientious students who pursue a specific STEM path are better prepared than late entry students simply because of their better technical backgrounds. Therefore, it is important that a student develop his or her technical foundation as early and often as possible. (*Elementary and Secondary Education*)

Diversity in the STEM pool is limited by female and minority participation. Women in the sciences tend to pursue life or health sciences, and minorities are less likely to attend college than whites, limiting opportunities for a STEM profession. Particularly for women, home environments do not usually encourage science or mathematics concentrations. Programs to sensitize parents, and positive encouragement by guidance counselors, help to counter discrimination against females in the STEM workforce. Minorities, especially black and Hispanic males, are interested in STEM fields, yet encouragement is often not strong enough that they pursue these fields; they also tend to be stifled by low socioeconomic status. State and local school districts that sensitize teachers to minority concerns still need to increase STEM course offerings and fair and proper access to resources, given that most schools with high minority populations are also in poor areas. (*Elementary and Secondary Education*)

Learning style also influences participation. White males traditionally have dominated science and math, and in the past, it was assumed that the teaching styles historically used were appropriate for all students. Deviations from those learning styles are perceived as wrong, and not rewarded by society. As a result, STEM fields deter women and minorities, seen as being a prejudice against them. Science education in the United States focuses on the testing of knowledge and lacks important domains, such as “processes, creativity, attitudes, and applications.” (*Elementary and Secondary Education*)

Diversity does not only apply to cultures; talented and gifted students add diversity to classrooms by enhancing peer learning. However, controversy arises from the problems inherent in determining which students are talented and gifted, the separation of them into advanced or special classes, and the accompanying social implications. Opposing views on the continuance of separation of those children to develop their education exist, labeling the administrators who choose to separate them as “elitists,” and as serving the upper-middle white class. (*Elementary and Secondary Education*) Then again, without advanced courses, talented and gifted students can become bored, unchallenged, and ignored by their school systems. Hands-on design experiences appropriate for specific grade levels puts both male and female students on the same level, and also give an open outlet for more gifted students, while not leaving any behind in the curriculum. (Crawford, 1994)

Family background is a strong influence on student path choice, with parents, close relatives, and teachers as critical role models in the decision to be a scientist or engineer. Thus, family, especially parents, who learn about STEM help children learn and pique interest in this area. (*Elementary and Secondary Education*)

Learning Methods

Every student has his or her own unique way of learning, whether it is constructivism, meaningful learning, rote learning, or a combination of these. Meaningful learning involves a student’s understanding of concepts and the ability to make connections between them, while rote learning is simply memorizing facts. Meaningful learning is generally preferred over rote learning, but it is more difficult for students since it encourages them to create relationships between words and concepts. An effective way to help students improve their understanding through meaningful learning is to use concept maps. These help students to visualize important relationships and make critical connections. A teacher plays a vital role by supplying students with the tools and guidance necessary to make those connections. The idea behind constructivism is that learning is not transferable from a teacher, book, video, or presentation to a student's brain. Instead, students begin to comprehend the new material by linking it with their existing understanding. (Martin, 2002) Ideally, a teacher may use a variety of instructional methods to provide their students with several opportunities to make connections and improve their understanding of presented material.

Children do not follow a uniform process of thought; therefore, one must tailor instruction to individual learning abilities. The basis for learning is described as natural curiosity, but each student's learning style is unique. The factors that affect the learning process are students' and teachers' educational experience, background, the context in which material is presented, and the learning environment. As such, teachers generally adapt their teaching for each individual student's strengths and weaknesses, based on his or her learning styles.

Constructivism

Constructivism allows children to form unique ideas and to connect new thoughts and understandings to their own lives. Learning involves three factors. First an idea is presented, made convincing to other investigators and proven, and then critiqued by the teacher. A new idea first explains each aspect of a phenomenon and predicts what will happen in untried circumstances. Ideas, results, and conclusions are shared between students. The idea must then be convincing to other investigators, referred to as "group agreement" or "social constructivism." (Martin, 2002) Lastly, the teacher volunteers comments and questions, which results in each student learning new things. This is a cyclical process since new ideas are continually presented, especially in a science classroom. Constructivism has a strong base in inquiry-based and discovery learning, and in assimilation and accommodation of new ideas. Students accommodate for and assimilate new ideas by asking questions, understanding, and accepting new ideas that correspond with old ones. (Martin, 2002)

A move toward constructivist teaching can help reform science, technology, and engineering education, when paired with a student's cognitive development and focused by higher-order thinking skills. Each student develops at a different pace, but it is important for the teacher to bring each student's cognitive development up to the next level of thinking, helping to foster new ideas and create a solid understanding of science, technology, and engineering. (Martin, 2002) In order for proper cognitive development to occur, meaningful learning and rote learning have to be applied.

Meaningful Learning and Rote Learning

Both meaningful and rote learning play a large part in the development of children's knowledge, however these learning styles should be implemented wisely and include the use of tools, such as concept maps. When children are first taught how to communicate with others, they learn words and language through memorization (rote learning). However, with the help of parents, teachers and experience, children learn the meanings of and the relationships between words and their environment (meaningful learning). This process is usually mastered by the time the child reaches grade school. (Duit, Frasher and Treagust, 1996)

Both rote and meaningful learning have a place in the classroom; however, meaningful learning generally dominates, which enhances the students' education. Rote learning should be blended with meaningful learning. For example, teaching vocabulary and spelling are two of the best ways to use rote learning because students must first memorize meanings before making deeper connections. On the other hand, rote learning can be misused, such as by using fill-in-the-blank worksheets to teach a lesson, because students do not learn meanings, relationships or definitions. (Duit, Frasher and Treagust, 1996) By using concept maps, teachers can identify students who do not understand the material, but who are able to memorize it. Concept maps require a student to outline the facts of a specified subject and then show how these facts are linked to each other. They are a particularly useful tool to help those struggling with meaningful learning, since concept maps focus on the connections and relationships between facts in a specified subject area. (Duit, Frasher and Treagust, 1996)

Learning Tools

Learning cannot occur until a student seeks explanation; tools exist that help teachers to facilitate this process. Conceptual change occurs when students are dissatisfied with their current beliefs, and when these beliefs fail to explain a new observation. Then students question the validity of their prior beliefs and conflict arises. Discrepant events, or unusual happenings, are a good method teachers employ to foster conflict in students' beliefs. It may be that a new concept needs to be explained, while the prior one remains valid, such as when magnets cause steel objects to float in the air and when gravity affects unsupported objects. This type of conceptual conflict is cognitive disequilibration, (Martin, 2002) and is defined as the dissatisfaction with what is actually happening and what ought to happen, an understanding developed by Jean Piaget. A teacher aims to obtain this cognitive disequilibration within each student as a necessary precursor to learning. A teacher presents a discrepant event as a tool used to help students question the cause of an event that may not make sense within the context of their previous knowledge.

Peer learning helps children broaden their perspectives by learning through interactions with others. Peer learning can be developed by debating conflicting viewpoints with the teacher acting as a moderator, and the students researching and presenting ideas in the form of pros and cons. Peer learning can also be done with cooperative learning, a situation in which groups of students attempt to achieve a common goal. Students learn from contacting different perspectives, and thus can formulate novel ideas. This has the potential to improve responsibility, attitude, and individual intelligence, especially for ideas and events that do not adhere to known facts. (Sawyer, 1995)

The engineering design process is another tool that helps the teacher accommodate different learning styles. Cyclic in nature, it can be started at any point, and therefore is adaptable to a number of learning styles, with a natural progression that promotes individual growth and success. (Sawyer, 1995)

Teaching Methods

Teaching methods describe the techniques teachers use to impart concepts and information. There are many different methods used to teach STEM in an academic setting. A teacher's childhood educational experiences influence his or her own teaching methods. (Lee, 2000) There are certain characteristics of teaching methods that do not apply to teaching in a STEM environment. Typically, a teacher lectures and then assesses student understanding. A teacher may allow time for students' questions, but the assessment is primarily independent, which leads to misconceptions and confusion for some students, and may result in low-test scores. The teacher is in part at fault for this error since there is no time allotted for sharing of ideas, activities, and class discussion, which are all ways for students to learn if the traditional method fails. The traditional method creates an added handicap for students with learning disabilities, such as trouble reading, or keeping their attention focused. (Brazeau-Ward, 2005) A hands-on activity holds the attention of elementary school children better than a traditional lecture. (Carroll, 1997) Teachers are able to appeal to the students' different learning styles with demonstrations, textbooks, and hands-on activities, each having their own advantages and flaws.

Laboratory Experiments

Laboratory investigation is a teaching tool that involves hands-on experiences, in which students visualize ideas and learn processes in a systematic learning cycle. Laboratory experiments help students understand information by allowing them to use their knowledge in a controlled environment. Models are tied with laboratory experiments and the learning cycle because both ask students to predict, observe, and explain, with an emphasis on identifying and discussing concepts. Once the teacher understands these concepts, problem solving can be undertaken to apply student knowledge and to legitimize their concepts and future learning. Problem solving may begin with questioning techniques that prompt students to consider their own problems, and then to solve them. Once students feel they are in control of what they know, in-depth learning and reflective thinking can take place; thereby motivating students to pursue topics outside of the classroom and make concepts seem more meaningful. (Sawyer, 1995)

Demonstrations

Demonstrations illustrate concepts and ideas that may be difficult to grasp, or that students cannot experience effectively, efficiently or safely on their own. Demonstrations should not replace student activities, but instead should foster children's curiosity about certain topics and clarify confusion that might occur when the student tries to perform a similar activity. (Abruscato, 1996) With demonstrations, children can practice making observations and recording data.

Textbooks

Textbooks provide students with information and help them link old topics with new ideas. Teaching can be done using only a textbook; however, children cannot learn science and technology without hands-on activities because they learn best through spatial and visual reasoning. (Abruscato, 1996) Textbooks are an excellent resource when used wisely as a background to new topics. They are also a great resource for terms and definitions, but should not be the centerpiece of a lesson. (Abruscato, 1996) Textbooks offer the students continuity and transition between topics, which are needed in the classroom.

Concept Maps

Concept maps help define and establish relationships among topics and are useful for visually linking topics within a given subject area. Concept maps are composed of words or short phrases that lay out the main and sub-ideas of a subject area. The most commonly used concept map format is a flow chart consisting of nodes (ideas) and links (relationships). This is especially helpful in the areas of engineering and technology because they require the use of discovery learning. (Duit, Frasher and Treagust, 1996) Concept mapping visually outlines subject areas and organizes ideas from the most general to the most specific. Concept maps can help show the nature of conflicting relationships, such as different viewpoints, that may exist between teachers and students. (Sawyer, 1995)

Discovery Learning

Discovery learning enhances the effectiveness of a lesson by involving students in hands-on activities. The concepts of a lesson, particularly in STEM areas, are best learned through a method described as inquiry-based or discovery learning. (Sawyer, 1995) This method employs hands-on and minds-on activities that students can do themselves. Discovery learning allows the students to construct their own knowledge, since they design their own experiments using the engineering design process. This results in a higher understanding of a given subject since students have the opportunity to experiment and learn from their mistakes rather than from a teacher who simply presents information. The concepts taught through discovery learning are generally related to past and future lessons. Abruscato concluded, “Learning through discovery is a personal, willful act on the part of the child that happens in an environment designed by the teacher." (1996)

Teachers use their knowledge and direction to guide students through the process of making their own discoveries and conclusions by supplying the students with useful materials and activities. They also assist the students in selecting and interpreting information that is given to them. "The teacher's responsibility is to help children move through a continuing series of experiences that include hands-on work with science materials and to challenge them to make sense out of their discoveries through writing, library research, mastery of science vocabulary, and a host of other activities that lead them to make still more discoveries. These hands-on activities should be new and unique to keep the interest of the students." (Abruscato, 1996) Otherwise, the lesson may fail to hold the students' attention. This is especially important in a diverse classroom where some students may feel underrepresented and respond by acting out. Direct involvement in learning activities initiates students' interest in STEM areas, which may influence future career paths. (Carroll, 1997)

The learning process for science education is cyclic in nature. Charles Barman, a college professor, has simplified the learning cycle into three main stages: exploration, concept introduction, and concept application. (1996) The following definitions explain how to use discovery learning in the classroom. (Abruscato, 1996)

> Exploration
> This is the first stage of the learning cycle. During this phase, the teacher plays an indirect role. The teacher is an observer who poses questions and assists individual students and small groups of students. The student's role at this time is very active. They manipulate materials distributed by the teacher.
>
> Concept Introduction
> During this stage the teacher assumes a more traditional role. The teacher gathers information from the students that relates to their experiences. This part of the lesson is the vocabulary building time, textbooks, audiovisual aides, and other written materials may be used to introduce terminology and information

> Concept Application
> At this time, the teacher poses a new situation or problem which can be solved
> on the basis of the previous exploration experience and the concept introduction.
> As in the exploration phase, the students engage in some type of activity
> (Abruscato, 1996)

These three stages are a good foundation for instructors when they teach in a discovery-learning environment, although they do not have to be followed precisely in order to be effective. Teachers generally make changes so that they create a comfortable environment for both themselves and their students; however, most of them use discovery learning to teach their students certain subjects, specifically science, “Expert teachers plan in ways that foster discovery within a context that helps children to acquire the knowledge, attitudes, and skills needed for success at school and life.” (Abruscato, 1996)

Discovery learning is most effective when students work in well-planned groups. Cooperative learning is an excellent approach to group work because students critique and support each other and are accountable for their own work and for learning about other group members’ material. The following is a chart comparing cooperative and traditional learning groups: (Abruscato, 1996)

Table 1: Cooperative learning groups vs. traditional learning groups

Cooperative Learning Groups	**Traditional Learning Groups**
Positive interdependence	No interdependence
Individual accountability	No individual accountability
Heterogeneous	Homogeneous
Shared leadership	One appointed leader
Shared responsibility for each other	Responsibility only for self
Task and maintenance emphasized	Only task emphasized
Social skills directly taught	Social skills assumed and ignored
Teachers observe and intervene	Teacher ignores group functioning
Groups process their effectiveness	No group processing

Successful group work can be accomplished by including positive interdependence, individual accountability, and small group skills into the lesson. “Teach for Positive

Interdependence" means that the teacher makes the students aware that the success of their project depends on every member agreeing on goals, objects and the roles they will carry out. "Teach for Individual Accountability" means that students have an awareness of the way they affect other group members' work. They are not only accountable for their learning and behavior, but are also responsible for helping their other group members with their work and productivity. The last strategy teaches interpersonal and small group skills. Skills taught may include active listening, praising other members for good work and appropriate distribution of leadership roles. (Abruscato, 1996)

Van Joolingen, a graduate student from the University of Amsterdam believes that students develop discovery skills using cognitive tools. Cognitive tools are defined as tools used in the learning environment to enhance cognitive processes, such as discovery skills. An example of a cognitive tool could be a pad and pencil, which would be used in the cognitive process for remembering items. Cognitive tools could also be visual representations; however, they are generally not used as the main instruments, but instead are used to help students with experiments. "Discovery learning is seen as a promising way of learning for several reasons, the main being that the active involvement of the learner with the domain would result in a better structured base of knowledge in the learner as opposed to more traditional ways of learning, where knowledge is said to be merely transferred to the learner." (Van Joolingen, 1999) In order for discovery learning to be successful, a number of discovery skills must be mastered, including hypothesis generation, experiment design, prediction, and data analysis, as well as planning and monitoring skills. If these skills are not mastered then incorrect data could result as well as inconclusive experiments and conformation bias.

Hypothesis generation refers to the process by which students generate new knowledge and concepts. Some students have a difficult time beginning this process, by limiting discovery learning in the classroom. Another problem that occurs in the hypothesis generation process is the lack of prior knowledge supplied to the students; therefore, they are not able to make adequate hypotheses, which results in poor discovery skills. One way to improve the hypothesis generation process is to use cognitive tools, which can range from supplying the students with hypotheses to giving them accesses to tools that will help them develop their own hypotheses. Discovery learning would not be successful without experiments, where the students are able to test their hypotheses. (Van Joolingen, 1999) Many skills, including social skills, are improved by discovery learning.

Lesson Kits

Lesson kits have an extensive history in the education world. The first kit-based science instructional program began in the 1960s to improve elementary science education. According to Shamansky, Hedges, Woodworth and George, these kits were often used by economically disadvantaged minority and female students. In the 1990s, second-generation kits were introduced in response to the standards-based movement. These kits produced better results in science and other curricula areas than traditional textbooks because most students learn better visually. (Klentschy et al., 1999)

Lesson kits, while sometimes costly, simplify lesson preparation by providing teachers with all necessary materials. The kits are a key element in discovery learning because they supply teachers with required materials for the hands-on part of the lesson. Either the school or the teacher can easily buy the kits from a supplier such as Delta Education, but unfortunately, many schools' budgets are tight and kits are often very expensive. Full Option Science System (FOSS) develops the activities for kits based on the academic aspect of learning. One FOSS goal is to provide teachers with an easy-to-use science program because teachers are most effective when provided with adequate instructional kits. (Delta Education) Schools do not always supply teachers with all the necessary materials and it may be inconvenient to access the desirable materials. According to Dianne Tarbet, a second grade teacher, there may not be enough money in a given budget to replenish materials, thus teachers often seek to find alternative methods of obtaining materials.

Funding

Small public school budgets have forced teachers to look for alternatives to obtain materials for their students. Research indicates that local governments and outside institutions provide no additional funding for general classroom supplies. The best way for teachers to obtain supplies is to seek out materials rather than money (E. Heinricher, personal communication, 14 September 2005). Elisa Heinricher, an instructional technologist at Bancroft School, says that one could find free batteries at drug stores from processed disposable cameras. Mare Sullivan, a K–8 teacher at Bellevue Christian School, mentioned that high quality magnets that normally cost upwards of forty dollars could be obtained from slaughterhouses for one-twentieth of the retail price, and straws can be found at some fast food restaurants free of charge (M. Sullivan, personal communication, 10 October 2005).

Teachers may also be able to obtain instructional supplies from students' parents. Joanne Holleman, a third-grade teacher in California, threw a "science shower" and sent invitations to parents requesting simple and inexpensive supplies. The response she received from parents was overwhelming. She set up an area in her school to collect the gifts and before long, the box was filled with supplies. The article concluded by reminding teachers in need of supplies that it is best to look for the items themselves rather than outside funding and sometimes all it takes is a little initiative. (How to make Hands-On Science Work for You)

Applications of the Teaching Methods

Teachers generally consider discovery learning, the use of textbooks and demonstrations as well as applying all the different learning styles of the children when creating an effective lesson. The lesson can then be organized into a lesson plan, in which the lesson objectives emphasize both the behavioral and cognitive theories. These lesson plans, when pertaining to engineering and technology should also include discovery learning, so that students understand the meaning of ideas and concepts, and how they relate to each other and to experiences.

Lesson Plans

Instructors use lesson plans to incorporate different teaching methods by means of various tools. Before the start of the school year, teachers construct a schedule of lessons to be taught for the upcoming year, then proceed to writing lesson plans. When writing these plans, teachers must keep in mind the different learning styles and techniques of the children. They must also decide which teaching methods work best for each specific lesson plan. When teaching science and technology, most instructors use all three teaching methods: demonstrations, textbooks, and discovery learning. Starting at the third grade level, lesson plans generally incorporate hands-on experience, including experimentation, exploration of the scientific process, and the interaction of facts, rather than memorization. Reading and writing can be integrated into science and technology lessons through asking students to keep records or construct graphs. Students' writing may include narratives based on science and technology or even on the engineering design process. (Brewer, 2001) The lesson plan is one of the most important aspects of classroom organization. While it is a guide for the teacher to follow when introducing new subjects and topics, it should not be self-contained. When each lesson references previous lessons through questions, demonstrations or diagrams, students, especially the younger ones, can distinguish how the similar topics connect to one another. (Abruscato, 1996)

Lesson Plan Structure

There is no universal format for the lesson plans; typically, they are based on a teacher's preferences and experience. This being said, an organized lesson plan usually includes the following categories: objectives, prerequisites, materials, lesson description, lesson procedure, and assessment/evaluation. The "objectives" section focuses on how the students will gain the knowledge and skills needed for the lesson. "Prerequisites" allows a teacher to prepare students and themselves for the lesson and ensure that the students are able to complete the lesson objectives. The "lesson description" section provides the teachers with an overview of the lesson, enabling them to choose whether they want to utilize that specific lesson. "Introduction," "main activity," "closure/conclusion," and "follow up lessons/activities" are included in the "lesson procedure" section. When a lesson circulates among teachers, each instructor should be able to follow a procedure without help from the creator. Lastly, the teacher has to be confident that each student has grasped the main points in the lesson. They can do this by collecting and evaluating the students' work using a grading rubric. If testing is going to be done on a certain lesson, the students should have the opportunity to practice what they have learned. (http://www.eduref.org/Virtual/Lessons/Guide.shtml)

The key component in the design of any lesson plan is clearly defined objectives, which provide teachers flexibility in carrying out a lesson. Some teachers are able to enter a classroom with only the objectives, and then teach the lesson based on the reaction of their class. Teachers have both the knowledge and experience to adapt a given lesson plan to their needs.

When creating a lesson plan to teach engineering and technology, there should be a section of the procedure set aside to allow children to test and redesign their models. If children do not succeed the first time, they should be encouraged to rework their designs because children learn more from mistakes and failures than from success. Children should use their results of testing to make improvements in their design, otherwise called closing the loop. (Ault, 1993)

Assessments with the Lesson Plan

Each lesson must have some form of assessment, whether it is quizzes, tests, teachers' evaluations of homework, reports, or projects to determine the effectiveness of the teaching method and the lesson itself. Assessments evaluate children's understanding of subject matter and allow teachers to revise lessons according to results. These older methods are not effective at evaluating the students' understanding of the subject matter. In recent years, newer methods of assessing children have evolved called authentic assessments. They include portfolios, direct observations and science journals, which assess student knowledge and encourage them to apply their knowledge. (Abruscato, 1996)

Use of Technology in the Classroom

Lesson plans should include the use of technology because students will be exposed to it in the future and it enhances their decision-making skills. Technology is the application of science; for example, children might use computers to learn about animal life cycles. Technology should be used as a tool to attract interest from students and should appeal to all children in a classroom. After this occurs, technology should be used to create good thinking habits, which may be applied to other subject areas such as mathematics and social learning. One of the major reasons that technology is integrated into elementary schools is so that children can enhance their problem-solving skills. In order to become technologically literate, the skills that must be mastered include defining variables, making measurements and interpreting data. The Science-Technology-Society (STS) is a program at many universities that is concerned with how technology and science affects the well-being of individuals and society. “STS approaches may use simulations of problems or actually involve children in investigating a topic within their community.” (Ault, 1993) STS believes that for children to understand technology and its impact, they must be taught using the inquiry method. “The goal of the STS approach is to help children become better decision-makers by understanding the role of science in making choices.” (Ault, 1993) This keeps the children aware of the positive or negative effects their decisions can have on society and the environment.

Sustainability

Since this project is in its final year, it considers the long-term viability of each lesson developed. In “The Introduction of Sustainable Development into Scientific Education,” Sophie Szymkowiak defined sustainability as “development that responds to the needs of the present without compromising the ability of future generations to respond to theirs” (2002). This definition mirrors the program’s aim to develop practicable lesson plans and kits. Although the aforementioned article discusses sustainability of engineering education at the collegiate and professional levels, one idea is particularly important to the development of lessons for grades K–12. The article notes that:

> “A teaching programme is an "artefact" which should be subject to permanent scrutiny, this being the only way in which it can adapt to evolutions in society. Adjusting it to societal evolution is in fact a prerequisite to its efficacy and viability.” (The Introduction of Sustainable Development into Scientific Education. 2002)

Lesson plans are templates for teachers to introduce material and as such, teachers will continually refine them to fit into their classrooms. A teacher with several years experience teaching engineering was interviewed about the development of sustainable lessons. Mare Sullivan teaches grades K–8 at Bellevue Christian School and suggested that before creating a lesson plan, the following questions should be considered:

1. Is this lesson appropriate for the age level?
2. Is this lesson appropriate for the engineering design process?
3. Can a teacher who is unfamiliar with the subject area, teach this lesson with minimal preparation?

These questions are important because they address three key components of a sustainable lesson plan. Lessons that cover material beyond students' capabilities tend to frustrate rather than encourage, and will hinder students' willingness to study that material in the future. A lesson that is inappropriate for the engineering design process will not help students understand or develop an appreciation for the process. Finally, if the lesson material confuses the teachers, they will more than likely pass that confusion to the student, which is often hard to correct later.

Mare also suggested that if additional feedback is required beyond that provided by the WPS, programs such as a local YMCA chapter and/or after school programs may be used as a resource. She mentioned that running several trials with the lessons in different environments is an excellent way to test the effectiveness of and to improve the lesson plan.

Surveys

Surveys collect constructive feedback from teachers about lesson plans so that the lessons may be improved. It is also important to understand and address any obstacles to teaching engineering that teachers perceive. Both goals require a specific type of survey method to acquire the proper information.

Construction

Two primary types of surveys are used: open-ended and closed-ended. Open-ended surveys are those in which responses are not limited to specific choices, while closed-ended surveys have a range of answers from which respondents choose. A closed-ended survey is generally best for statistical analysis and determining a general preference, whereas open-ended surveys are better to elicit information about specific improvements and opinions on a subject. (whatisasurvey.info, 2005)

Both forms of surveys require that questions be properly worded, clear, unambiguous, and minimize the number of possible interpretations. Misinterpretations can lead to answers that give useless or no feedback. It is equally important to ensure that, for a closed-ended survey, the selectable answers represent probable answers. For example, a question of “How many cars does your household own?” would not have selectable answers of “0–5, 6–10, 11–15, 16–20, 21 or more”, which are unrealistic responses except for those who might have a hobby of collecting cars; rather, “0, 1, 2, 3, 4, 5” is more acceptable for a typical United States household. Questions focusing on the most important issues are best because it is easy for both the respondent and the analyzer to be distracted by trivial matters. As such, a survey should go through tests and several revisions before making its final release. (whatisasurvey.info, 2005)

Implementation

For a survey to represent the views of the intended respondents, it is necessary for one to distribute it to a sufficiently large group that consists of randomly selected participants. Random sampling ensures that a survey is unbiased, be it socially, economically, or by another factor that may skew the results. The sample must also be of a sufficiently large size to give varying opinions that represent a general opinion. Making the survey amicable, thanking people for responding, and offering incentives, such as a small monetary reimbursement, can increase response rates. Self-addressed stamped envelopes also increase response rates by easing the load on the respondent. (whatisasurvey.info, 2005)

Analysis

How a survey is analyzed is often determined by the data itself. Only by looking at the data can one determine whether the mean, median, mode, variance, or percentile evaluation is the best option. Once a standard of analysis is chosen, a computer program for statistics, such as "SAS," is helpful in calculating the appropriate standard. (http://www.wpi.edu/Academics/Depts/IGSD/IQPHbook/ch10j.html)

While a survey may provide a clear view of a group's ideas and perceptions, there is always sure to be some minor discrepancy between the respondent group and the total group, which is called the margin of error. The margin of error varies with sample size; for example, a survey of one hundred people has a ten percent margin of error, a survey of one thousand people reduces that figure to roughly three percent, and at four thousand people, the margin of error is only one and a half percent. If a survey has fifty-five percent of respondents with a margin of error of five percent, then the results could mean that the total population contains either a larger majority, a complete split, or anywhere in between. (whatisasurvey.info, 2005)

Methodology

Scheduling and Organization

The Massachusetts Department of Education (DOE) standardized a set of objectives, or Frameworks, for a science, technology, and engineering curriculum (MSTEC) for grades Kindergarten through twelve (K–12) in May of 2001, and the WPS subdivided them into a specific set of Benchmarks a year later. The NSF funded the PIEE project, to create both a sustainable and accessible set of engineering and technology lesson plans for grades K–6 based on the Benchmarks. To meet this goal, our project focused on a curriculum for grades two and three, other groups worked on curriculum for Kindergarten and first grade, and fourth through sixth grades. To oversee the project's progress, another WPI student group was responsible for curriculum integration. This group reviewed lesson plans from all three students groups and ensured that they met the appropriate WPS Benchmarks and MSTEC Frameworks.

Our project supported teachers in the Midland Street and Flagg Street Schools, who implemented these lessons in their second and third grade classrooms. We subdivided tasks of lesson development and lesson integration between grades two and three. Each team consisted of two IQP students and a graduate fellow. The graduate fellows acted as the primary liaisons between PIEE students, public schools, and other PIEE groups.

The second grade team included Jessica Rosewitz, Cale Putnam, and graduate fellow Steven Toddes. We collaborated with second grade teachers Jyoti Datta, Robin Ring, and Monica Wolf at Flagg Street School, and Mary Beane and Susan O'Malley at Midland Street School. We scheduled lesson presentations weekly at both schools; on Wednesdays, we visited

Flagg Street School and on Thursdays, Midland Street School. Each visit lasted between one and two hours. In addition to class presentations, we spent extra time with teachers both before and after each lesson to discuss scheduling, lesson changes, preparations, and observations. We also met with the graduate fellows several times while developing a lesson to construct kits and ensure that the lessons were appropriate for the classroom.

The third grade team included Rob Weir and Michelle Tucker and graduate fellow Karen Kosinski. We integrated and evaluated lessons at both Flagg Street School with Liz Monticelli, Paula Renzoni, and Kim Hampton, and at Midland Street School with Nancy Mattus. We met with teachers when necessary to address concerns, questions, and suggestions regarding lesson drafts or to discuss any post-implementation questions.

To coordinate our efforts, we held weekly meetings with all group members, graduate fellows, and our project advisor, Dr. Jill Rulfs, to discuss progress and delegate tasks. In addition, we held weekly group meetings to discuss progress on our report, consolidate work, and delegate other tasks as needed. We also held grade-specific group meetings to develop, assess, and revise lessons as needed and evaluate our progress.

Lesson Plans

Before we wrote any lessons, the WPS teachers first supplied us with their science curriculum and schedule for the academic school year. To ease the teachers’ transition, we integrated engineering and technology Benchmarks and Frameworks into the existing science curriculum. We reviewed science Benchmarks and Frameworks to determine which activities were the most appropriate for incorporating engineering and technology. Each group took a slightly different approach to developing lesson plans.

In the third grade group, we delegated one science area to each member, and then outlined a series of lessons that would address that area (Appendix A). We then brainstormed a list of activities that met the corresponding Benchmarks and Frameworks, incorporating only one or two science Benchmarks and Frameworks into each. This let us place more emphasis on engineering and technology while minimizing the impact of our new lessons on the existing curriculum. The last step before writing a lesson plan was to determine whether worksheets should emphasize vocabulary (rote learning) or hands-on activities (meaningful learning). If a student needed to understand vocabulary, then we focused on rote learning. If the lesson objectives focused on engineering, then we used the meaningful learning approach in the worksheets.

In the second grade, we proposed ideas based on a general topic as well as the Benchmarks we wanted to meet, with an emphasis on engineering. We then chose an activity that we felt would be sustainable, accessible, and would effectively reinforce concepts. We then wrote the lesson plan as a group and determined what materials, worksheets, handouts, and teacher aids would be included.

Building the Lesson Plan: Components and Organization

We followed a standardized format when we wrote a lesson plan (Appendix B). The following table outlines and describes the parts of a lesson plan.

Table 2: Components of our lesson plans

Title	A clearly stated name and a detailed descriptive sentence
Information box	A table including summarized information about a lesson that enables a teacher to determine grade-appropriateness, seasonality, or curriculum fit; includes Benchmarks and Frameworks that each lesson covers and a summary of key vocabulary words (see Figure 1)
Summary	A short paragraph that includes main points from the procedure, key words, and a main objective
Learning Objectives	Definitions of Benchmarks covered in a lesson
Additional Learning Objectives	Extra engineering, technology and science objectives
Required Background Knowledge	Prerequisite material for a lesson
Essential Questions	Questions developed from the Benchmarks, Frameworks, and objectives that mirror subject matter that students are required to learn
Introduction/Motivation	A creative and interesting activity or class discussion about key words and concepts
Procedure	Systematic steps a teacher follows in order to complete the lesson
Materials List	A quantitative list of materials and locations of materials needed for a lesson
Vocabulary with Definitions	Definitions of all science, technology, and engineering vocabulary, assisting teachers with concepts with which they may not be familiar
Assessment//Evaluation	Approaches to test students' comprehension of lesson material
Lesson Extensions	Suggested activities for follow-up lessons
Attachments	Student worksheets, supplements, and teacher's notes
Troubleshooting Tips	Any obvious or predictable problems that may occur while teaching a lesson
Safety Issues	Information about lesson sections that are potentially harmful to students
Additional Resources	Other resources to help a teacher understand a lesson better before it is taught in the classroom

Figure 1: The format for the "Information Box"

Grade Level	Either "2" or "3"
Sessions	Number of sessions, as well as length of each in minutes
Seasonality	Fall, Winter, or Spring, if appropriate
Instructional Mode(s)	Groups, discussion or hands-on design
Team Size	Individual students, small groups, or whole class
WPS Benchmarks	Listed by code
MA Frameworks	Listed by code
Key Words	List of engineering, technology, and science words

Attachments

We attached worksheets and resources to the end of each lesson plan and included extra background information for the procedure, relevant websites, and recommendations for children's literature, where applicable. Each lesson included several different types of student worksheets: *Blueprints*, writing sheets, drawing activities, and material properties exercises. *Blueprints* helped students to draw their designs before a construction process, emphasizing the creation and planning segment of the Engineering Design Process. We drew these *Blueprints* in a computer aided design or graphics program to help students imagine themselves as engineers. Each *Blueprint* had one-inch square gridlines, a simple diagram, or outline sketch of the task, instructions, a title box, and a space for their name.

We included at least one worksheet in every lesson plan, consisting of a short writing or drawing activity. Each worksheet assessed student comprehension and focused children's attention on the material at hand. Each worksheet began with a space for the student's name and the date. We then wrote the activity procedure, which included simple and straightforward instructions for the activity. Since students were still developing their handwriting skills, lines were triple-spaced and boxes were made large enough for students to draw their design or picture.

Lesson Assessment

We assessed lessons by observing them in the classroom. After each lesson was completed, both the observers and the teacher completed separate assessment forms (Appendix

C). Using a combination of open-ended and direct questions, our assessment forms gauged the lesson's performance, and identified weaknesses that needed attention. The open-ended questions encouraged the assessor to expand his or her answer and to identify ways to improve the lesson. The reactions of both students and teachers were also important. If students appeared distracted or confused, and/or the teacher had difficulty teaching a lesson, we noted and addressed it at our meetings. These forms helped us maintain a permanent record, and to improve the sustainability and accessibility of our curriculum.

Verbal and written communications apart from the assessment forms were also effective ways to gather feedback about our lessons. We discussed lesson performance during weekly meetings and regular e-mails with teachers. Sometimes we did not feel lessons met our expectations when they were implemented in the classroom. Although some lessons may have engaged the students, if the lesson did not meet its objectives, we reevaluated the lesson content, and modified it accordingly.

Since the PIEE program operated in multiple classrooms, we had several opportunities to evaluate and improve a lesson's procedure and content between subsequent implementations. Some of the items on which we focused while looking at the results of a lesson implementation were worksheets, models, and key questions (Appendix C). Worksheets accompany most lessons and are an important component because they reinforce student comprehension. EDP lessons, for example, include a design worksheet to help students complete the first stages. This type of worksheet fosters student creativity and helps them understand the scope of engineering. In the terrarium lessons, we focused on the students' ability to observe, and modify their design based on observations. Our mechanics lesson on simple machines contained a worksheet assigned at the end of a presentation that evaluated students' engineering vocabulary and their ability to describe machines and their uses.

Corrections and the Final Version

The final version of a lesson was the product of peer review, several revisions, and usually one or more trial presentations in the classroom. We supplied the WPS teachers with surveys to acquire feedback; teachers were willing to suggest improvements to the lessons. We reviewed each lesson plan according to our observations, evaluations, and guidance from the graduate fellows, focusing on content, grammatical coherence, clarity, and sustainability.

After we made final corrections, we compiled a binder of our lesson plans and presented copies to each participating WPS teacher, and to the Curriculum Integration group. The Curriculum Integration group constructed an internet-based electronic database of the lesson plans from the entire project.

Teacher Interaction

Before we introduced lessons into the classrooms, we forwarded them to the WPS teachers at least one week in advance and then met with teachers to answer questions and listen to suggestions. We presented lessons to students on a weekly and bi-weekly basis to accommodate the teachers' schedules.

We were available in the classroom to provide support to teachers, to help answer questions, and to help students with their work. In rare situations when a teacher did not have sufficient time to prepare for, or have the background knowledge to present a lesson, we presented it while the teacher observed.

Student Interaction

During each lesson implementation, we typically took a passive role in order to observe the lesson, note the teacher's approach to the lesson, and assess students' reactions. This helped us identify anomalies and errors in the lesson plan and its execution. Regardless of a teacher's involvement during a lesson, he or she was present in a classroom to maintain discipline and observe the lesson. We took both active and passive roles when interacting with students. Construction projects, for example, prompted us to act as teacher's assistants, giving students the opportunity to ask us questions, and to show them how engineers like ourselves approached real situations.

Results

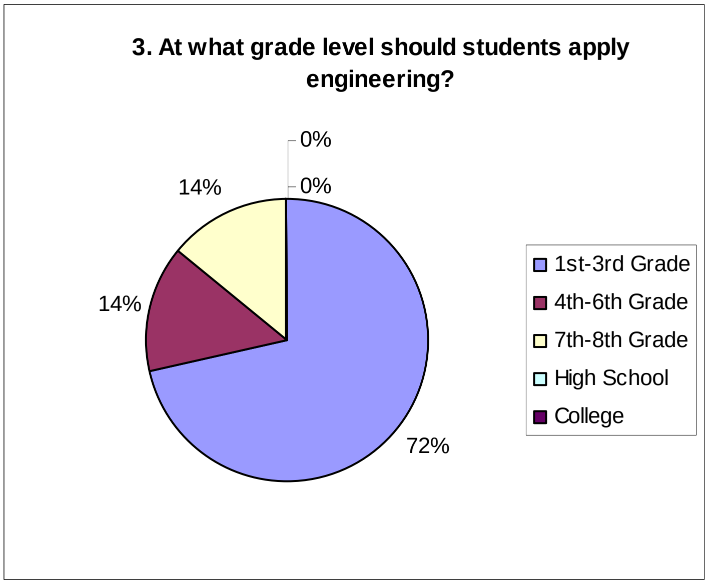
Teacher Surveys

To help us determine the success and impact of our lessons, we asked teachers how they perceived engineering and our lesson plans. We also asked teachers about the source of most of their teaching material. To acquire this information, we sent a survey of eight questions to all of the teachers who participated in the PIEE program. (Appendix E)

The first question on the survey asked if teachers would encourage students to explore engineering as a career. One-hundred percent of the teachers answered that they would. We were initially concerned that there might be some form of prejudice against engineering that prevented it from being taught in elementary school. Based on the responses, this is clearly not the case. The result of this question is surprising, as there is very little exposure to engineering in schools, and engineers are not often presented as frequently as doctors and teachers are in children's books. It was encouraging to see that teachers do want their students to know about engineering and that there is no bias against it.

The following two questions both relate to the appropriate grade levels for the exposure and application of engineering. We wanted to know if teachers felt that engineering was too difficult a subject for their students. The first question asks when students should first be exposed to engineering. Once again, one hundred percent of teachers felt that students should be exposed to engineering at a young age. The enthusiasm the teachers had for our lessons makes this result an expected one. However, we still recognized that there is a difference between introducing a subject and asking students to apply new knowledge. We asked a follow-up question to solicit the teachers' opinions with respect to grade-level appropriateness of applied engineering, which is defined as using the engineering design process to design and construct an object.

Figure 2: Question 3 on the teacher survey



As seen in Figure 2, seventy-two percent of teachers believe that first through third grade students should be able to apply engineering principles. We expected the upper grade levels, primarily high school and college, to receive the most responses, and were surprised to see that most teachers feel the subject matter is appropriate for much younger students. The two questions taken together display a majority view that engineering education is both viable and beneficial when taught at an early age.

In determining what obstacles would need to be overcome to make engineering widely taught, we wondered if there was a perception of difficulty in teaching the subject matter to second and third grade students.

Figure 3: Question 4 on the teacher survey

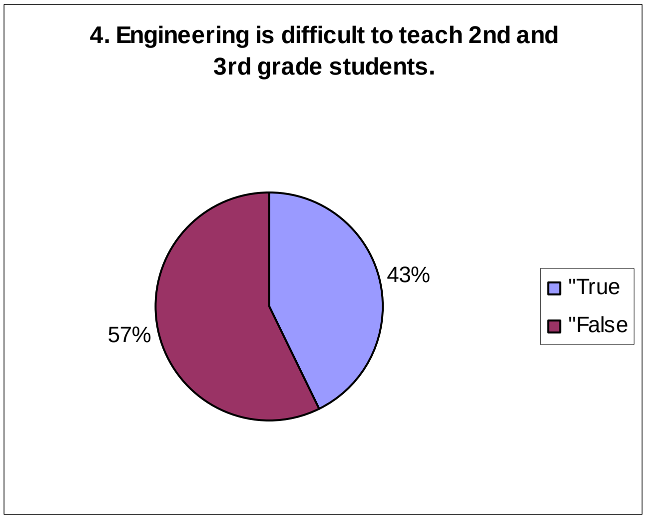
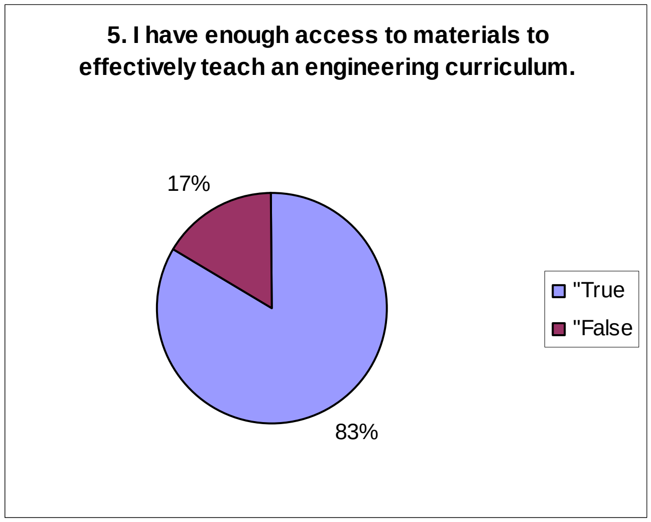


Figure 3 displays that a slight majority of teachers felt that engineering is not a difficult subject to teach to their students. The responses to this question were the most evenly divided of any true or false question in the survey, and it displays how individual teaching styles can affect the difficulty of presenting a lesson. We worked hard to make lesson plans as easy to teach as possible, and the result of this question validates our push for accessibility.

In many cases, our lesson plans required several additional materials, used both as teaching tools and for hands-on projects. We wanted to find out if teachers felt they could acquire the necessary materials to teach the engineering curriculum.

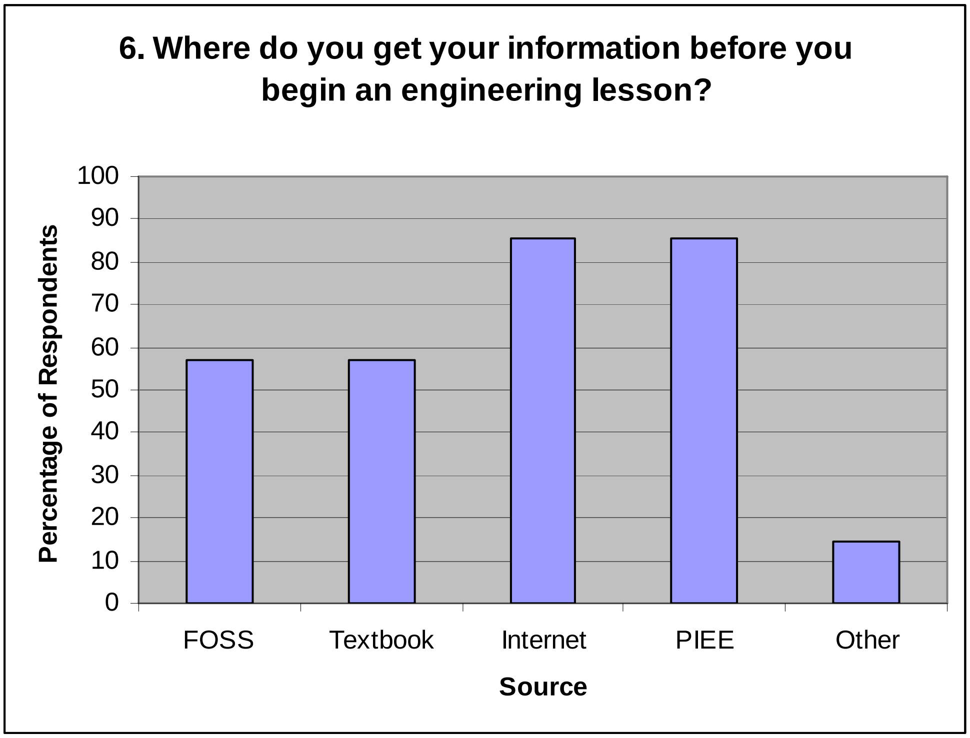
Figure 4: Question 5 on the teacher survey



As shown by Figure 4, a majority of teachers feel that they can acquire materials for lessons easily. In writing lessons, we anticipated that some teachers would encounter difficulty getting materials; this is reinforced by the seventeen percent who felt they did not have enough access. To remedy this, we devised lessons with a minimum of materials or with easily purchased or recycled materials so that they could effectively teach the subject.

Lessons that are new often require teachers to learn new information in order to teach them properly. We wanted to know from where teachers obtain this information so that we can know if we included the correct and enough resources in our lessons.

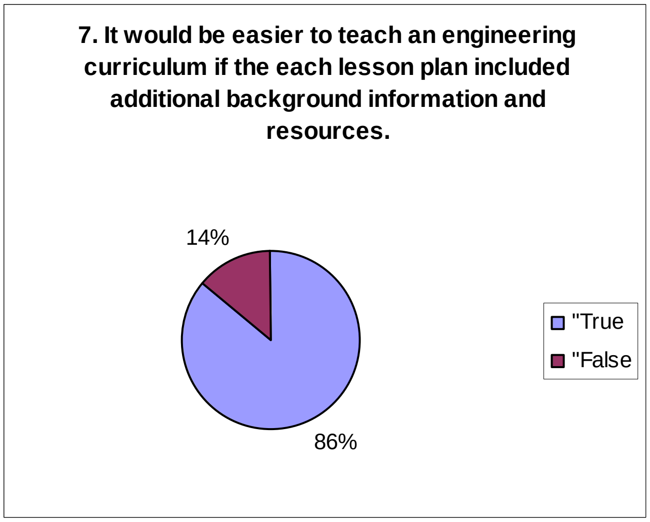
Figure 5: Question 6 on the teacher survey



Many teachers replied with more than one answer to this question. It is not a surprise to see that, according to Figure 5, the PIEE program is a primary source to most teachers surveyed, as they were involved in the program, and it shows the importance of our lessons. The internet is also a main source of information, and it follows that teachers are computer literate and willing to complete outside research, supporting our use of internet links in lesson plans. The FOSS kits and textbooks are also widely used, the responses for each being used by about fifty-seven percent of the teachers. The FOSS kits formed the basis of the pre-existing engineering curriculum before the PIEE program was implemented, and many teachers continued to rely on them. In retrospect, we should have looked more closely at textbooks when creating lesson plans; however, at that time we were not aware of the heavy reliance on them.

The next question was designed to determine whether teachers thought that additional background information and resources in our lessons would help them to teach more effectively.

Figure 6: Question 7 on the teacher survey



As displayed by Figure 6, a majority of teachers felt that extra resources, typically included in the “Additional Background” or “Appendix” section of a lesson, improve accessibility. For the teachers that did not feel it would help, there may be a variety of factors involved. They may find the subject matter simply too difficult (see Figure 3), or at the other extreme they may be comfortable enough with the subject matter that those resources are not necessary.

For the final question, we wanted to know the role of cost in engineering education. We asked teachers if the cost of a lesson factors into the decision to teach, or not teach, a lesson.

Figure 7: Question 8 on the teacher survey

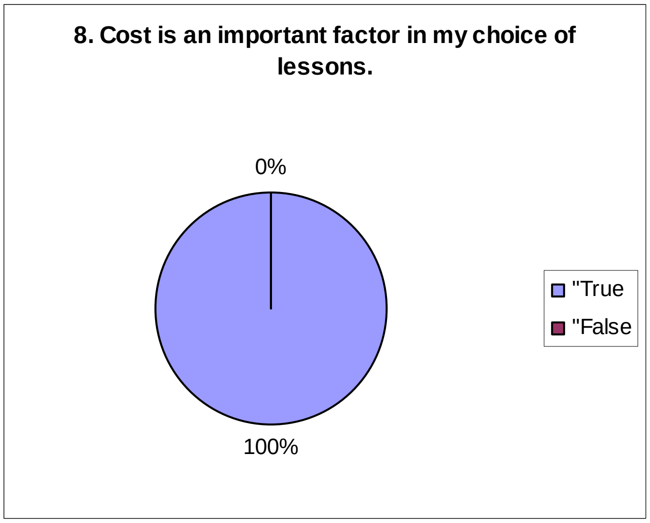


Figure 7 shows that all of the respondents consider cost to be an important factor in lesson choice. Thus, it follows that keeping the price of teaching engineering lessons down is important to keeping them sustainable. In our lessons, we tried to use the cheapest materials possible. Purchased items were kept to a minimum and recycled materials, such as empty soda cans and scrap cardboard, were used wherever possible. These measures will allow the teachers to look at the lessons from an educational standpoint and not from the cost standpoint.

This survey shows that teachers are willing and committed to presenting an engineering curriculum. It also shows that our lessons will be successful when fully implemented. It gives us great confidence in our curriculum and the ability of teachers to present it.

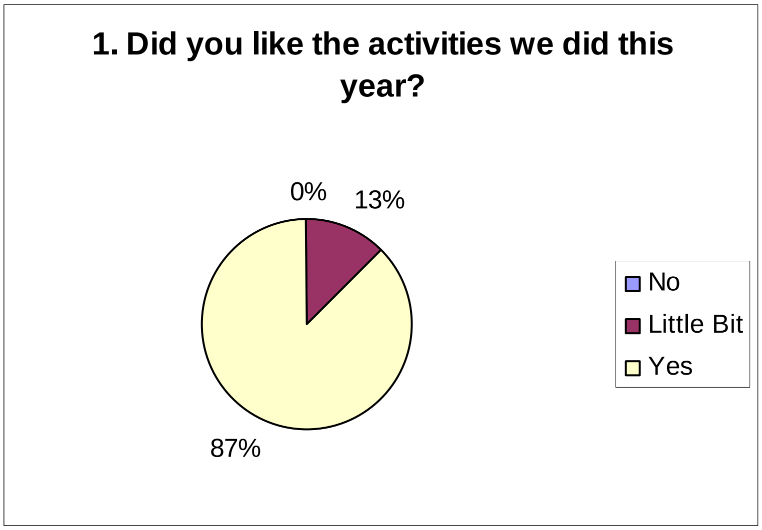
Student Surveys

In addition to collecting teacher feedback, we gathered information from the students. To assess the response and the effect of our lessons we administered a survey to the students to see if the students enjoyed learning about engineering, if they had applied it to their activities outside of the classroom, and if they were interested in becoming engineers when they grew up. We felt that these questions would tell us how well our curriculum was received by the students and how students outside the program would respond to it.

Second Grade

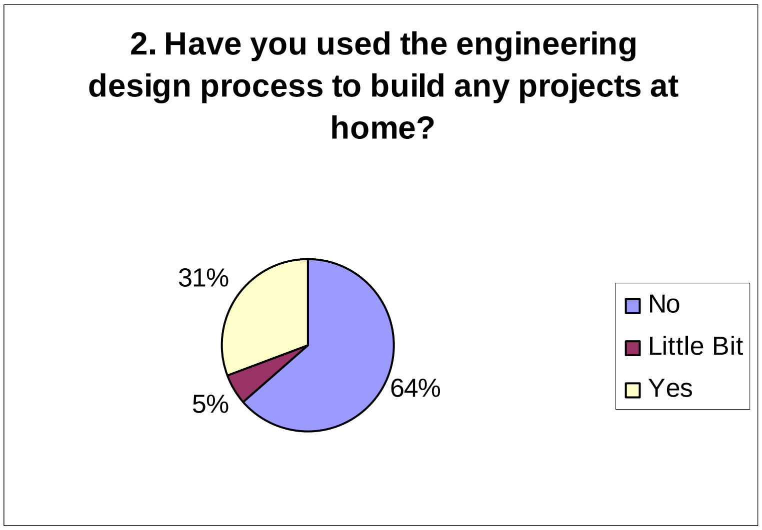
The first question, shown in Figure 8, asked if students liked the lessons that we implemented this year. Every student replied that he or she liked the lessons at least a “Little Bit.” This shows that we have succeeded in creating lessons that engage the students. We conclude that we have sparked student interest in engineering.

Figure 8: Question 1 of the grade two student survey



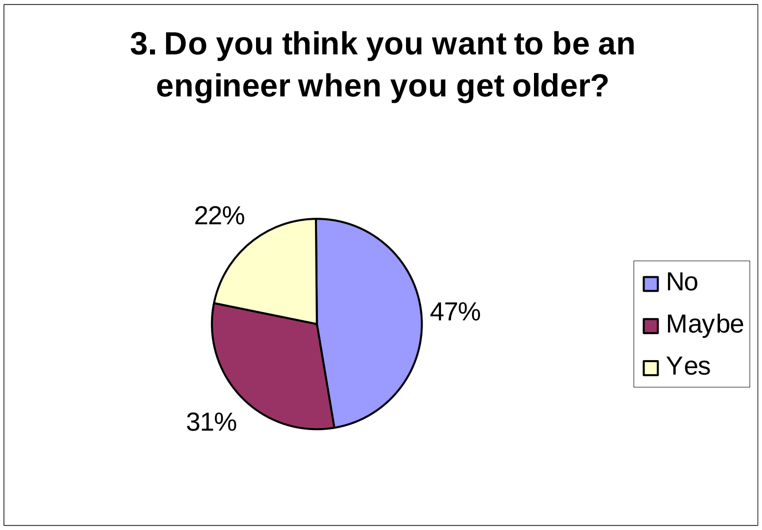
The next question, shown in Figure 9, was used to determine if students were then applying what they had learned about engineering outside of school. Thirty-six percent of students have been interested enough in the subject matter to use it at home. The majority of students did not build any projects at home, but this may not be directly connected to interest in the subject matter. Many students who are interested in engineering simply may not have had the means to engage in the activities at home. Nevertheless, students' undertaking engineering outside the classroom is a positive result.

Figure 9: Question 2 of the grade two student survey



The final question, displayed in Figure 10, was to determine whether students felt that they would now want to become engineers in the future, after having completed the lessons. More than half of the students said that they might want to be engineers when they get older. This is perhaps the greatest measure that the lessons were successful. Students now have a displayed interest in engineering and in becoming an engineer. This student response proves that an engineering curriculum can have a positive effect on students, even at such a young age.

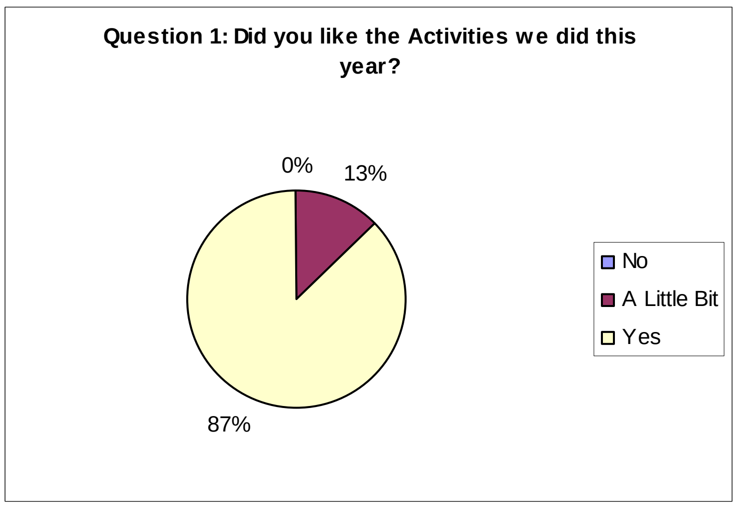
Figure 10: Question 3 of the grade two student survey



Third Grade

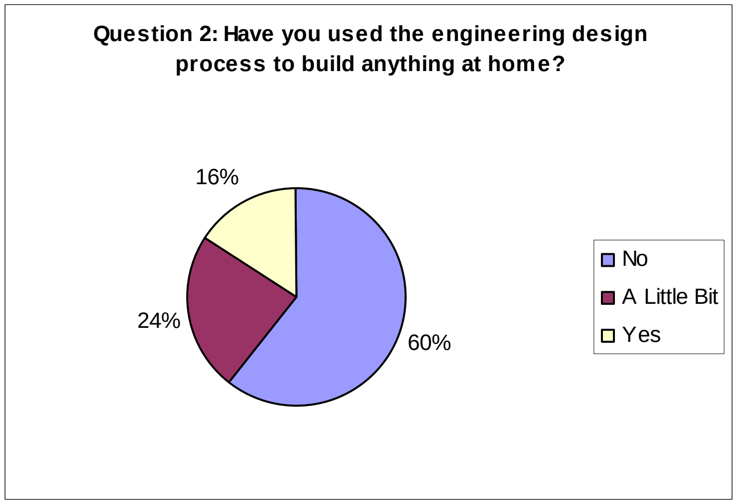
When asked if they had enjoyed the activities we did this year, over ninety percent of the students indicated that they enjoyed our lessons while the remaining students found them to be at least a little interesting (Figure 11). Many students cited that they enjoyed our hands-on lessons the most, such as the Maple Sugaring and the Tree House lessons.

Figure 11: Question 1 of the grade three student survey



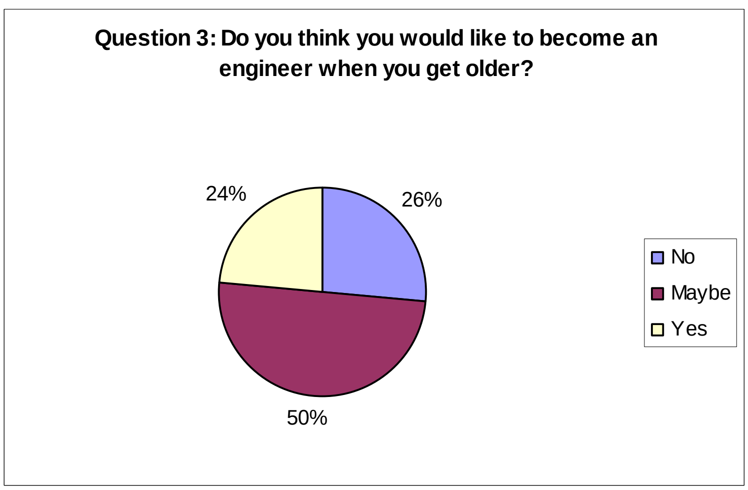
When we asked the students if they had used the engineering design process at home, roughly forty percent of students indicated that they had (Figure 12). Many students who used the process indicated that they built toys, or enclosures for toys.

Figure 12: Question 2 of the grade three student survey



When the students were asked if they wanted to pursue engineering when they became older, roughly a quarter of the students indicated that they wanted to become engineers and half of the students indicated that they might pursue it (Figure 13). Some of those who were not interested indicated that they wanted to pursue other careers. Of those who were interested, electrical, computer, software, and chemical were the most popular disciplines.

Figure 13: Question 3 of the grade three student survey



After reviewing these statistics, we believe that our project and curriculum was a success since the majority of the students enjoyed learning about engineering and applying it both in and outside of the classroom. With over seventy-five percent of the students interested in considering engineering, we feel that our project will broaden their career options when they became older.

Teacher Assessment Forms

Second Grade

We used oral and written assessments from teachers to edit lesson plans for accessibility, sustainability, and grade level appropriateness, both before and after presentation in a classroom. We scheduled meetings at WPI in the evenings with teachers and reviewed lesson plans in advance, corresponded via e-mail, visited the schools to present lesson plans and talk with teachers, and encouraged teachers to complete written assessment forms. These methods allowed us to troubleshoot lesson plans and to have immediate results for the next lesson presentation, whether that was during the next day in a different classroom, or next year for a new class.

Meetings

Our meetings were very productive, with respect to editing the "Procedure" section of lesson plans. In addition, we edited the lesson plan procedure for grade level appropriateness, especially in relation to the motor-skills of second grade students. We also edited the "Essential Questions" section based on the amount of information that students could understand.

One grade two teacher, Jyoti Datta, came to the WPI campus in the evening to discuss our Birdhouse lesson plan; we asked her opinion of the lesson plan before we presented it for the first time in her classroom. Our "Procedure" at this point included directions for students to work either in groups or individually to design a blueprint and construct the houses. Jyoti noticed that we did not include specific instructions for students working in groups and she thought that conflict would occur if a group of four students could only build one birdhouse, but have four different blueprints. She suggested that the students choose one thing from each individual blueprint, and then redesign a new birdhouse on a group blueprint that would incorporate all four students' ideas. This small addition to the "Procedure" encouraged teamwork, brainstorming, group discussion of design, and problem-solving skills. These results demonstrated that open communication with teachers improved lesson plan content, as well as student enjoyment and understanding.

During meetings, we discussed the materials to be used in upcoming lessons. We learned that schools could generally supply materials like Popsicle sticks, crayons, markers, tape, glue, rulers, scissors, straws, and pipe cleaners. We also learned that we could rely on parents to send materials to school with their children, which further reduced lesson costs.

E-mail

We mainly used e-mail correspondence to schedule lesson plan presentations, but teachers also suggested edits to lesson plans in e-mails. This method of correspondence often was the best way for a teacher to contact us outside of lesson plan presentation. It also encouraged faster turnaround time for questions, edits, and scheduling. In general, teachers preferred to speak to us in person about suggestions for changing a lesson plan, but we did receive e-mails from teachers concerning a lesson plan that we were to present the next day. This was possible because we sent lesson plans to teachers via e-mail so that they could view them beforehand.

In the Classroom

Teachers preferred to meet in their classrooms to discuss lesson plans if they could not meet at WPI in the evening. Generally, we spent a few minutes speaking with teachers directly before presenting a PIEE lesson plan to a class. This often resulted in last minute suggestions that immediately improved a lesson plan. We later made corrections to the lesson. Monica Wolf liked to make suggestions in this way, and we found that her comments, when we applied them as we presented a lesson plan, helped us to run it smoothly. In one particular lesson plan, we assumed that second grade students would know how to build a small-scale tower out of straws, cardboard, tape, pipe cleaners, soda cans, and Popsicle sticks. However, Ms. Wolf suggested that we make a small demonstration model while introducing the activity, and showing pictures of towers from around the world. This worked out very well, especially in showing the students how to tape cans to the base, how to use "X" and triangle cross braces out of straws to make a frame stronger, and how to make a project without glue.

Lesson Plan Assessment Form

We provided a "Lesson Plan Assessment Form" (Appendix B) to teachers so that we could have a written record their suggestions after we presented a lesson plan in the classroom. However, many teachers forgot to complete the forms and we did not receiver more than a few forms back from teachers. The forms we did receive gave us an idea of what teachers thought of sustainability and accessibility, since we did not ask teachers directly about these things in the classrooms.

Jyoti Datta and Susan O'Malley both completed the forms for the Birdhouse lesson plan, and both teachers provided positive feedback about such components as grade level appropriateness, student understanding, cost effectiveness, lesson plan strength in the curriculum, and strength of individual components. There is a difference between how these two teachers responded that correlates with their individual experience with the PIEE project. Jyoti has been involved with the project for all three years, so she has knowledge about basic engineering concepts and the curriculum that is supposed to be covered. Susan on the other hand was a new teacher at the start of the school year and a new teacher with the PIEE project. In particular, she provided good opinions about making the lesson plan more specific so that teachers would feel less apprehensive about teaching engineering to their students, since the lesson plan would explain everything in detail, from the "Learning Objectives" to the "Required Background Knowledge" to the "Troubleshooting Tips." These opinions altered our lesson plan writing style to be more specific, and helped us to improve the lessons.

Third Grade

The teacher assessment forms and verbal feedback from the teachers were the most useful tools for making the lesson plans compatible for third grade students. (See Appendix B) After completion of a lesson, teachers completed assessment forms and commented about changes that could be made. We used these comments to revise the lesson plans so that they could be taught in any third grade classroom. Overall, the teachers were satisfied with the lesson plans and there were minimal corrections that had to be made to them. One teacher, referring to the tree house design lesson, said, "the children remained engaged and interested in the lesson from initiation to completion," which we believe is due to the use of group work and hands-on activities. In addition, the teachers gave us positive feedback on the worksheets and all of them agreed that the students learned the material, which was shown through the worksheets. The teachers also agreed that the "Background Information" and "Vocabulary with Definitions" were helpful in preparing to teach a lesson. All the teachers agreed that, “Materials were definitely cost effective and appropriate.”

When the teachers were first exposed to the lesson plans, they were satisfied but there was room for improvement. After completing all the lesson plans, the teachers agreed that a few of them needed corrections and they helped to improve them. Two of the biggest problems that we encountered were grade level appropriateness of the material and background knowledge. Some of the lessons were too difficult for the students and they became frustrated or lost interest. The Reason for Seasons lesson plan is one example of a lesson being too difficult. The students did not understand the concepts of how the sun revolves around the Earth and rotates on its axis. When we presented it to the class, the teacher knew that students would not understand all concepts and helped us alter it that day. She created an activity for the students that helped them understand the concepts better, even though this lesson was more appropriate for fifth and sixth graders.

Some lessons can be difficult for students if they are not exposed to appropriate background knowledge. The Water Cycle lesson is an example. One teacher saw that the students were having a difficult time understanding the concepts; therefore, she created an example to explain them better. We used these examples in the beginning of the worksheet and the teachers now use it to introduce the lesson. When it was introduced into a different classroom with the corrections, the students were able to understand all relevant concepts.

Price List Comparison

Second Grade

The kit we included with the grade two lesson plans contained materials for every lesson, packaged in a large box. Many materials overlapped lesson plans, making the one umbrella kit feasible. The single kit also aided the process of obtaining materials and renewing depleted supplies easier than with many small kits.

The lesson plan kit we made for the PIEE project does not present a large financial burden to either the teachers or the school, since we have provided in each lesson plan a list of materials and where they can be obtained, most from current school supplies and local stores. We used recycled materials, such as ½-gallon plastic milk cartons for the Birdhouse lesson plan, and recycled cardboard for the Tower lesson plan. Teachers in turn advised us to use current school supplies to supplement our lesson plans and to ask parents for materials beforehand, which they were happy and willing to send in with the students. As such, our assessment of the cost of the grade two lesson plan kit provides one average cost for all materials that we used throughout the school year. In addition, many supplies are a one-time expense, such as the fish and reptile tanks, and the associated filters and lamps.

We prepared a price list, listing all materials, price, quantity, and where to obtain them. We then summed a total average price, and compared this to prices for Delta Education kits. The total cost for the entire PIEE kit is $225.76, shown in Table 3, whereas the average cost for a single kit from FOSS, DSM, or SCIS is $235.46, shown in Table 4. It is not feasible for a Massachusetts public school to spend approximately $235 on a kit that would cover only one area of technology or engineering, when a teacher could compile a comprehensive kit covering all required curriculum areas in one low cost trip to local stores.

Table 3: Cost of components for the grade two lesson plan kit

PIEE 2nd Grade Lessons Kit			
Materials	**Quantity**	**Location**	**Classroom Cost ($) ~20 students**
A large container w/lid	1	Pet Center	22.99
Plants	As necessary	Home Improv. Store, Nursery	
Gravel	½ Gallon	Pet Center	2.49
Sand	½ Gallon	Home Improv. Store	3.66
Soil	½ Gallon	Home Improv. Store, Nursery	1.57
Bark	¼ Bag	Home Improv. Store, Nursery	3.88
Charcoal	¼ Bag	Hardware store, food store	13.00
Jar w/ lid or ½ pint dish	1	Pet Center	3.49
Trowel	1	Home Improv. Store, Nursery	5.72
Plant mister	1	Home Improv. Store, Nursery	1.68
Small animals: Toad & Salamander	2	Outside	0.00
Food: Crickets	Undefined	Pet Center	0.10/each
Food: Salamander Food	1	Pet Center	2.49
Heat lamp	1	Pet Center	13.99
Heat lamp bulb	1	Pet Center	9.49
Water dish (plastic tub)	1	Pet Center	3.49
Small animals: Chameleons	2	Pet Center	30.00
A large container	1	Pet Center	14.99
Plants	Water plants	Home Improv. Store, Nursery	
Aquarium Salt	1/2 tsp per gallon	Pet Center	2.79
Water filter	1 w/ replacement filters	Pet Center	12.24
Small animals: Fish	2	Pet Center	0.58
Food: Tropical Fish Food	1	Pet Center	2.49
Glass baking dish	1	Home & Kitchen Center, Target	12.99

Rocks, wood	Undefined	Home Improv. Store, Nursery	5.74
Small animals: Fiddler/Hermit Crabs	2	Pet Center	5.00
Food for crabs	1	Pet Center	4.99
Food: feeder fish	Undefined	Pet Center	
12-inch ruler	1 per student/group	Classroom supply	0.00
Aluminum foil	1 roll	Grocery store	0.79
Clear tape	1 roll	Drugstore, office supply store	2.04
Duct tape	1 roll	Hardware store	3.95
Lightweight cardboard	Several pieces per group	Recycled	0.00
Milk cartons (1 or ½ Gal.)	1 per student/team	Recycled	0.00
Permanent markers	Several sets	School supply	0.00
Plastic drinking straws	1 package	Grocery store, dollar store	1.75
Plastic wrap	1 roll	Grocery store	0.99
Popsicle sticks/tongue depressors	1 package	Craft supply store	3.95
Scissors	1 pair per group	School supply	0.00
Scraps of colored paper/fabric	Undefined	Recycled	0.00
String	1 roll	Hardware store, toy store	1.00
Pipe Cleaners	1 package	Craft Supply Store	1.00
Cardboard Base (~6 in sqr)	1 per student	Recycled	0.00
Soda Cans	~2 per student	Recycled	0.00
Lever/Crane Kit	1	PIEE	0.00
Large food container	1	Kitchen stores	12.99
A variety of crushed cookies	2 cups each	Food stores	4.00
A variety of cookies/crackers/candies	2 types	Food stores	4.47
Jell-O, with crackers/cookies/candies	1	Food stores	0.63
Large laminated grid sheet/whiteboard/chalkboard	1	School supply	0.00
Toothpicks	1 package	Grocery store, dollar store	0.99
Plastic Cutlery	1 package	Grocery store, dollar store	4.00
Paper plates	1 package	Grocery store, dollar store	1.49
Napkins	1 package	Grocery store, dollar store	1.88
		Total	**225.76**

Table 4: List of Delta Education prices for comparable grade two kits, separated by applicable lesson plans

PIEE Lesson Plan	**Comparable Kit**	**Delta Education Item #**	**Price ($)**
Motion/Rollercoaster/Ramps	DSM III Force and Motion - Complete Kit	WW738-6025	399.00
Motion/Rollercoaster/Ramps	Science in a Nutshell®-Energy and Motion Class Pack	WW750-2945	178.00
Motion/Rollercoaster/Ramps	Machines and Motion	WW790-6733	513.75
	Linda Poore-Machines and Motion Teacher Guide	WW201-8780	39.95
Motion/Rollercoaster/Ramps	Balance and Motion - Complete Module	WX742-5015	519.00
Motion/Rollercoaster/Ramps	Idea Factory™ Force and Motion Kit	WW110-8567	19.95
Balance/Crane/Lever	Science in a Nutshell®-Clever Levers Class Pack	WW750-3110	178.00
Simple Machines	Science in a Nutshell®-Simple Machines Cluster	WW750-2538	179.98
Simple Machines	Simple Machines Library	WW025-3936	41.70
Terrarium	SCIS 3+ Life Cycles - Complete Kit	WW703-2046	855.00
Terrarium	Science in a Nutshell®-Animal Observatory Class Pack	WW750-5266	178.00
Terrarium	Science in a Nutshell®-Is It Alive? Class Pack	WW750-5288	178.00
Birdhouse	Nest View See-Thru Birdhouse	WW025-3336	14.95
Fossils/Dirt	Science in a Nutshell®-Fossil Formations Class Pack	WW750-3154	178.00
Fossils/Dirt	Rock, Fossils, and Soil	WW790-6755	399.65
	Linda Poore-Rock, Fossils, and Soil Teacher Guide	WW201-8802	39.95
Fossils/Dirt	I Dig Fossils Video	WW221-2100	15.95
Fossils/Dirt	DSM III Soil Science - Complete Kit	WW738-6011	367.00
Amazing Mine/Pulley	Science in a Nutshell®-Pulley Power Class Pack	WW750-3000	178.00
		Average Cost	**235.46**

Third Grade

Many elementary school teachers are concerned with the cost of materials needed for a lesson because some schools have restricted budgets. Teachers can order kits from Delta Education that includes supplies for a third grade class of forty students, where most of the kits exceed one hundred dollars. Our lesson plans require a minimum amount of inexpensive materials; however, teachers must visit several different stores to collect all the materials. The prices for several lesson plans can be seen in Table 5.

Table 5: Price list for the grade three lesson plan kits

Materials	**Quantity**	**Price per Class $**	**Description**	**Brand**	**Store**
Water Cycle Part 1					
Clear Plastic Container	1	1.97	6.5qt	Rubbermaid	Wal-Mart
Blue Food Coloring	1	2.99	4-multi color	Betty Crocker	Stop and Shop
Water	-	-	-	-	-
Plastic Wrap	1	1.39	100 square feet	Stop and Shop	Stop and Shop
Tape	1	-	-		Classroom
Lamp with 100 Watt Bulb	-	-	-	-	-
Icepack	1	0.99	Small	Rubbermaid	Wal-Mart
Total		**7.34**			
What is a centimeter?					
Metric Ruler	20	5.40	12in	Wal-Mart	Wal-Mart
Total		**5.40**			
Water Cycle Part 2					
Paper	1	2.84	500 sheets	Georgia-Pacific	Wal-Mart
Clear Cups	1	1.99	18-10 oz(clear)	Stop and Shop	Stop and Shop
Cold Water	-	-	-	-	-
Room Temperature Water	-	-	-	-	-
Hot Water	-	-	-	-	-
Ice Cubes	-	-	-	-	-

Total		**4.83**			
Sound Machine					
Dry Kidney Beans	1	0.89	16 oz	Goya	Stop and Shop
Paper Plates	1	3.99	9 in	Stop and Shop	Stop and Shop
Rubber Bands	1	0.46	3in x 1/8in	Alliance	Wal-Mart
Popsicle Sticks	100	2.88	1-box	Waddle Wedoo	AC Moore
Small Round Cardboard Box	20	19.40	-	Nicole	AC Moore
Stapler	1	-	-	-	Classroom
Medium Sized-Sheet of Paper	1	3.79	12in x 18in	Art Street	Michaels
Wax Paper	1	1.29	75 square feet	Stop and Shop	Stop and Shop
Total		**32.70**			
Rock Candy					
Sugar	1	2.59	5 lb	Stop and Shop	Stop and Shop
Water	-	-	-	-	-
Food Coloring	1	2.99	4-multi color	Betty Crocker	Stop and Shop
Wooden Spoon	-	-	-	-	-
Wax Paper	1	1.29	75 square feet	Stop and Shop	Stop and Shop
Large Pot	1	19.99	20 qt	Ekco	Stop and Shop
Pencils	24	0.97	1-package	Papermate	Wal-Mart
Embroidery Floss	3	0.87	8.7yd	DMC	Stop and Shop
Heating Source	-	-	-	-	-
Measuring Spoons	1	1.47	1/8-1 cup	Wal-Mart	Wal-Mart
	1	1.24	1/8 tsp-1tbsp	Wal-Mart	Wal-Mart
Total		**31.41**			
Reason for Seasons					
Blue Clay	1**	1.00	12 oz (rainbow)	Roseart	Michaels
Yellow Clay	1**	1.00	12 oz (rainbow)	Roseart	Michaels
Large Sheet of Paper	1	5.99	30-22"x16"	Crayola Floor Plan	Michaels
Toothpicks	1	0.59	750-flat wood	Stop and Shop	Stop and Shop
Embroidery Floss	3	0.87	8.7 yd	DMC	Stop and Shop
Globe					
Total		**9.45**			
*Calculations were done based on a 20 student class					
**A total of two packages should be bought					

Lesson Summaries

All the lesson plans were created in order to cover Benchmarks and Frameworks, which will help the students improve their scores on the MCAS. All of the lesson plans are summarized in Tables 6 and 7 and the complete lesson plan can be viewed in Appendices K and L.

Second Grade

Table 6: Lesson summaries for grade two

UNIT	LESSON	SUMMARY	MSTEC FRAMEWORKS	WPS BENCHMARKS
A: Living and Non-Living Things				
	2.A.1: Terrarium Lesson	During this unit, the students will experience living, nonliving, and once living things through the design, building, and observing of a terrarium. They will decide what kind of things are needed in a terrarium and as a class will build an actually terrarium. They will then discuss which things are living, nonliving and once living inside as well as observe different patterns and happenings in the terrarium.	K-2.TE.1.1 K-2.TE.1.2 K-2.TE.1.3	02.SC.IS.01 02.SC.IS.02 02.SC.IS.04 02.SC.IS.05 02.SC.IS.06 02.SC.TE.01 02.SC.TE.02
	2.A.2: Birdhouse	This lesson introduces children to the idea of "structure." It provides them with the opportunity to design and construct both a shelter for their terrarium, and a birdhouse or feeder. Additional objectives include the strengthening of teamwork and manipulative	K-2.TE.1.1 K-2.TE.1.2 K-2.TE.1.3	02.SC.IS.01 02.SC.IS.02 02.SC.IS.03 02.SC.IS.05 02.SC.IS.06 02.SC.TE.01

		skills, and the provision of a context in which students use the Engineering Design Process.		02.SC.TE.02 03.SC.TE.03
	2.A.3: Fossils	This lesson teaches students about fossils and that they represent once-living organisms from millions of years ago. It also teaches the students about the layers of the earth, representing different chronological periods. It challenges the students to use the engineering design process to design, make, and test a tool or excavating fossils.	K-2.TE.1.1 K-2.TE.1.2 K-2.TE.2.1	02.SC.IS.04 02.SC.IS.05 02.SC.IS.06 02.SC.TE.04
C: Simple Machines				
	2.C.1 Human Body Parts as Tools	This lesson introduces children to the idea of parts of the human body as tools that can be used to complete various tasks. The students also learn how animals use parts of their bodies in similar ways to humans. They then design a human being for a specific task.	K-2.TE.2.1 K-2.TE.2.2	02.SC.IS.01 02.SC.TE.05
	2.C.2 Ramps/Motion	This lesson introduces children to the idea of "motion" as well as a basic version of Newton's Laws. Students are allowed to explore motion through creating a simple track system to overcome several obstacles. Additional objectives include the strengthening of teamwork and manipulative skills, and the provision of a context in which students use the Engineering Design Process	K-2.TE.2.1	02.SC.IS.01 02.SC.IS.02 02.SC.IS.03 02.SC.IS.04 02.SC.IS.05 02.SC.IS.06 02.SC.IS.03 02.SC.IS.04
	2.C.3 Balancing Crane	This lesson works in conjunction with the Balance and Motion, and Simple Machines lessons. In this activity, each student will experiment with balance and motion. To begin, the students will redo a demonstration, initially by the teacher, with rulers about the center of gravity and balance. Next, the teacher will demonstrate how a construction crane is a real life engineering application of balance. Then the students will use small levers to understand balance hands-on, graduating to the larger crane	K-2.TE.1.3 K-2.TE.2.1	02.SC.IS.02 02.SC.IS.03 02.SC.IS.04 02.SC.IS.06 02.SC.TE.03 02.SC.TE.04

		to solve a problem based on observations and predictions. The students will have the task of moving an object from one pod to another using the crane, requiring them to predict how to solve the problem and give an explanation based on solid evidence. The students will learn how to predict and test, as well as proper tool use and material properties. This lesson focuses on the functionality of a design.		
	2.C.4 Pulleys/The Amazing Mine Story	This lesson works in conjunction with the Balance and Motion, and Simple Machines lessons. In this activity, each student will be given an opportunity to experiment with a simple pulley. Each student should discover that pulleys do make lifting easier. The students should then discuss with the teacher places where people use pulleys for lifting. The teacher should then read “The Amazing Mine” story, which illustrates the uses of pulleys, levers, and ramps to make work easier. The students should predict how the miner would use the simple machines.	02.SC.IS.01 02.SC.IS.02 02.SC.IS.03 02.SC.IS.06 02.SC.TE.02 02.SC.TE.04	K-2.TE.1.2 K-2.TE.2.1
D: The Engineering Design Process/Materials				
	2.D.1 Tower	In this lesson, students will construct a tower from natural and manmade materials. Students will use the engineering method to plan their tower, identify which natural or man-made materials best suit their purpose, identity what makes a tower stable, construct a tower, and complete a written, self-evaluation. The lesson is meant to focus on both structures, and the uses of natural and manmade materials.	K-2.TE.1.1 K-2.TE.1.2 K-2.TE.1.3 K-2.TE.2.1	02.SC.IS.01 02.SC.IS.03 02.SC.IS.04 02.SC.IS.05 02.SC.IS.06 02.SC.TE.01 02.SC.TE.02 02.SC.TE.03

Third Grade

Table 7: Lesson summaries for grade three

UNIT	LESSON	SUMMARY	MSTEC FRAMEWORKS	WPS BENCHMARKS
A: Introduction to Engineering				
	3.A.1 Sparky's Engineer	The children's book Sparky's Engineer describes various engineering professions and serves to introduce students to the types of activities undertaken by a number of engineers. A KWL chart introduces the lesson. A worksheet with writing prompts concludes the lesson by allowing students to explain their knowledge of one particular type of engineering.	-	-
B: The Engineering Design Process				
	3.B.1 Tree House	The five parts of this lesson introduce children to the idea of "structure." They provide an opportunity for students to design and construct a model tree house, and to select and use appropriate materials and tools. Additional objectives include the strengthening of teamwork and manipulative skills and the provision of a context in which students use the Engineering Design Process.	3-5.TE.1.1 3-5.TE.1.2 3-5.TE.2.1 3-5.TE.2.2 3-5.TE.2.3	03.SC.TE.01 03.SC.TE.02 03.SC.TE.03 03.SC.TE.04 03.SC.TE.05 03.SC.IS.03
C: Materials				
	3.C.1 Materials to Build	This lesson introduces students to materials and their properties; students will have the opportunity to manipulate and discuss these properties.	3-5.TE.1.1 3-5.TE.2.2 3-5.PS.1.1	03.SC.TE.01 03.SC.TE.04 03.SC.PS.02
	3.C.2 Properties of Materials	This lesson expands students' knowledge of material properties by familiarizing them with different types of materials and their applications in real-world situations.	3-5.TE.1.1 3-5.TE.2.1 3-5.PS.1.1	03.SC.TE.01 03.SC.TE.04 03.SC.PS.02

	3.C.3 Sound Machine	This lesson introduces students to volume and pitch through the creation of a sound machine. It also allows children to review the Engineering Design Process while strengthening their teamwork and manipulative skills.	3-5.TE.1.1 3-5.TE.1.2 3-5.PS.1.1	03.SC.TE.01 03.SC.TE.02 03.SC.IS.03 03.SC.PS.08
	3.C.4 Minerals Observe and Identify	This lesson provides students with the opportunity to observe various properties of minerals and to record their observations in a notebook.	3-5.TE.1.1 3-5.ES.0.1 3-5.ES.0.2	03.SC.TE.01 03.SC.IS.01 03.SC.IS.02 03.SC.IS.03 03.SC.IS.06 03.SC.ES.01 03.SC.ES.03
	3.C.4 Rocks Observing Properties	This lesson allows students to study various types of rocks. After students have discussed “rocks” and “minerals,” they will observe and record observations about rocks using a “Rock Journal.”	3-5.TE.1.1 3-5.ES.0.3	03.SC.TE.01 03.SC.TE.04 03.SC.IS.01 03.SC.IS.02 03.SC.IS.03 03.SC.IS.05 03.SC.IS.06 03.SC.ES.02 03.SC.ES.05
	3.C.6 Making a Rock and Mineral Collection	This lesson extends students’ understanding of rocks and minerals by having them create a rock collection and design an enclosure for these rocks using classroom materials.	3-5.TE.1.1 3-5.TE.2.1 3-5.ES.0.1 3-5.ES.0.2 3-5.ES.0.3	03.SC.TE.01 03.SC.TE.03 03.SC.TE.04 03.SC.IS.01 03.SC.IS.02 03.SC.ES.03 03.SC.ES.04 03.SC.ES.05
	3.C.7 Soil Water Retention	Students will investigate the properties of various soil types. They will make predictions about the quantity of water that soil and sand mixtures can retain, and will then design an experiment to test these predictions.	3-5.TE.2.2 3-5.TE.2.3 3-5.ES.0.5	03.ES.TE.05 03.SC.IS.01 03.SC.IS.04 03.SC.ES.06 03.SC.ES.07 03.SC.ES.08
	3.C.8 Soil Composition	The objective of this lesson is to extend students’ understanding of the composition of	3-5.ES.0.4	03.TE.SC.05 03.SC.IS.01

		soil with a hands-on activity. Students will examine a variety of soil samples with a hand lens and will then create their own soil mixtures of organic and inorganic materials.		03.SC.IS.04 03.ES.SC.09
D: Plants and Animals				
	3.D.1 Plants Structure	Sketches are commonly used to capture information on paper. After learning to identify various plant structures and their respective functions, students will demonstrate their knowledge by sketching each structure and describing its function.	3-5.TE.2.1 3-5.LS.0.3	03.SC.TE.04 03.SC.LS.07
	3.D.2 Plant Life Cycles	Students will learn to construct a diagram that demonstrates how plants change in a predictable pattern called a *life cycle*. A diagram is a useful way to convey various types of information, and shows the distinct stages through which a generic plant passes.	3-5.TE.2.1 3-5.LS.0.3	03.SC.TE.04 03.SC.LS.07
	3.D.3 Corn and Bean Life Cycles	Students will learn to construct a diagram that demonstrates how corn and bean plants change in a predictable pattern called a *life cycle*. A diagram is a useful way to convey various types of information. The diagram will show the distinct stages through which the plants pass.	3-5.TE.2.1 3-5.LS.0.3	03.SC.TE.04 03.SC.LS.07 03.SC.LS.09
	3.D.4 Growing Plants	This lesson provides students with the opportunity to design, construct, and test a container for growing plants. Students will apply their knowledge of the Engineering Design Process and will observe the various stages of the plant life cycle. After observing, students will also record information in an organized manner and will practice sketching various plant structures.	3-5.TE.1.1 3-5.TE.1.2 3-5.TE.2.1 3-5.TE.2.2 3-5.TE.2.3 3-5.LS.0.3 3-5.LS.0.9	03.SC.TE.01 03.SC.TE.02 03.SC.TE.03 03.SC.TE.05 03.SC.IS.01 03.SC.IS.02 03.SC.IS.03 03.SC.IS.04 03.SC.IS.05 03.SC.IS.06 03.SC.LS.07 03.SC.LS.08
	3.D.5 Animal Life Cycles	Students will learn to construct a diagram that	3-5.TE.2.1	03.SC.TE.04

		demonstrates how animals change in a predictable pattern called a *life cycle*. In general, a diagram is a useful way to convey various types of information; this particular diagram will show the distinct stages through which an animal passes.	3-5.LS.0.3	03.SC.LS.07
E: Maple Sugaring				
	3.E.1 Maple Trees Structure	Students will study important structures of maple trees and will learn to sketch maple bark, fruit, leaves, and twigs. This lesson provides background information useful for continued study of maple trees and the maple sugaring process.	3-5.TE.2.1 3-5.LS.0.2	03.SC.TE.04 03.SC.LS.06
	3.E.2 Collecting Maple Sap	Students will use their knowledge of the maple sugaring process to design a container for maple sap collection. The Engineering Design Process (EDP) will provide students with a framework for designing the container.	3-5.TE.21 3-5.LS.02	03.SC.TE.03 03.SC.LS.06
F: Solids, Liquids and Gasses				
	3.F.1 Water Cycle Part 1	This lesson reinforces basic concepts learned about the water cycle. Children will revisit the various phases of water (ice, water, water vapor) and will recall facts that they have learned about the characteristics of solids, liquids, and gases. After confirming that students have a solid understanding of evaporation, condensation, and precipitation, the instructor will create a simple working model of the Water Cycle.	3-5.TE.2.2 3-5.PS.0.3	03.SC.TE.04 03.SC.PS.05 03.SC.PS.06
	3.F.2 Water Cycle Part 2	After seeing a demonstration of the water cycle (see lesson 3.F.1 The Water Cycle: Part 1), students will diagram and label the water cycle on their own. The students will also confirm that water expands when cooled.	3-5.TE.2.2 3-5.PS.0.3	03.SC.TE.04 03.SC.PS.06 03.SC.IS.04
	3.F.3 Rock Candy	This lesson introduces children to the creation of sugar crystals, which occurs when water evaporates from a saturated sugar-water	3-5.TE.2.2 3-5.PS.0.3	03.SC.TE.04 03.SC.TE.05 03.SC.PS.03

		solution. Students will have the opportunity to explore the metric measuring system and will practice writing laboratory reports. Students will experience evaporation first-hand and will learn that sugar dissolves in hot water.		03.SC.PS.06 03.SC.IS.06
G: Graphing and the Metric System				
	3.G.1 What is a Graph?	This lesson introduces students to bar graphs, line graphs, and pie graphs. It also provides the students with an opportunity to interpret information and to create graphs from given data.	3-5.TE.2.2	03.SC.TE.04
	3.G.2 What is a Centimeter?	This lesson introduces the students to the metric system with respect to the length of objects. Students will become familiar with measuring common objects, such as a pencil or desk, and will learn how centimeters compare to inches.	-	03.SC.TE.05

Engineering Review

Second Grade

The engineering review given to the second grade students at Midland Street and Flagg Street schools (Appendix F) produced very different results. In the classrooms where we spent the least time presenting our engineering lesson plans (Figure 16), the students scored poorly. However, in the classrooms where we spent the most time (Figure 15) the students scored well, showing good comprehension and application of engineering. We used a grading rubric (Appendix H) where a correct answer was worth one point.

The combination of all the classrooms (Figure 14) shows a general comprehension of engineering material, with the recurring scores being 13 and 15 out of 19 total points. Most students retained at least 50% of all engineering material throughout the year. This percentage was a successful evaluation of the effectiveness of our lesson plans because the students not only remembered important concepts, but could also apply them in a test setting.

The week before we tested them, we held short review sessions with the students, orally covering the major topics on the engineering review. The topic that we incorporated into at least one part of each lesson plan was the engineering design process (EDP). We separated this question out from the rest (Figure 17), and the recurring score was zero, showing that fully a third of second grade students did not understand the steps of the EDP, even if their favorite lesson, such as the Tower lesson, was founded on the

EDP. This result seemed skewed because we did not provide specific EDP worksheets for the students to complete; instead, we separated the steps of the EDP into worksheets. If there had been a worksheet for each lesson that tested the students on what parts of the EDP they had completed, then their understanding of this concept may have been better.

Figure 14: Score distribution for the grade two Engineering Review

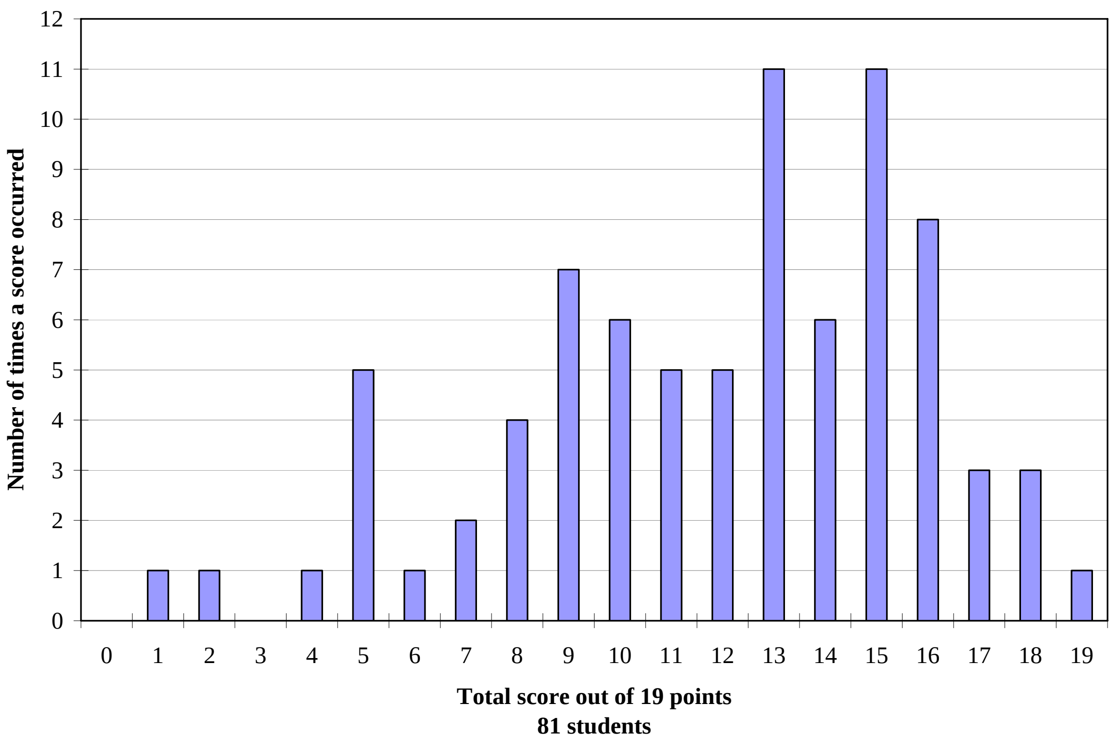


Figure 15: Score distribution for the grade two Engineering Review of the classroom in which the most time was spent on engineering

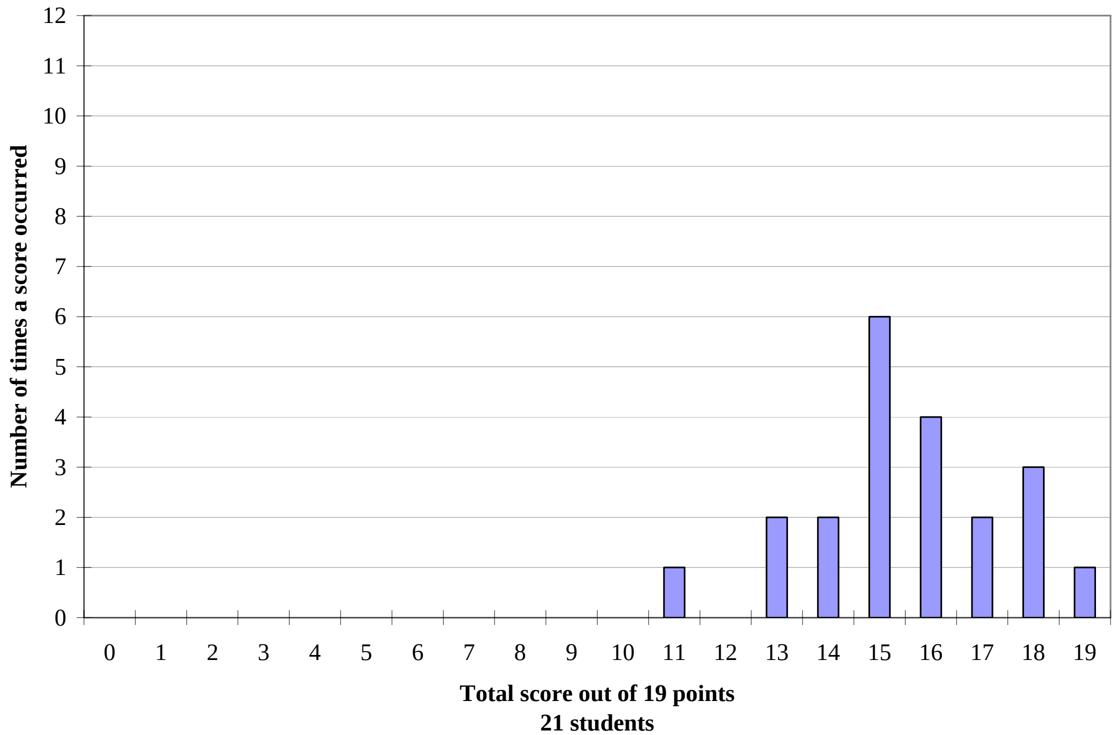


Figure 16: Score distribution for the grade two Engineering Review of the classroom in which the least time was spent on engineering

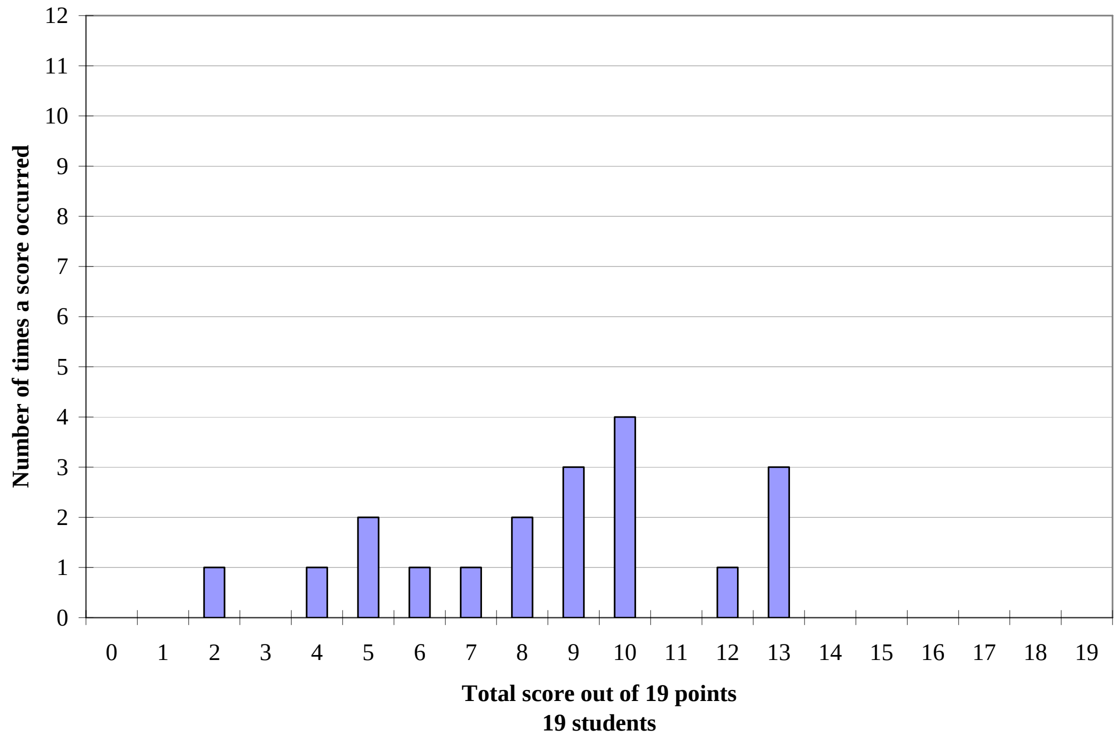
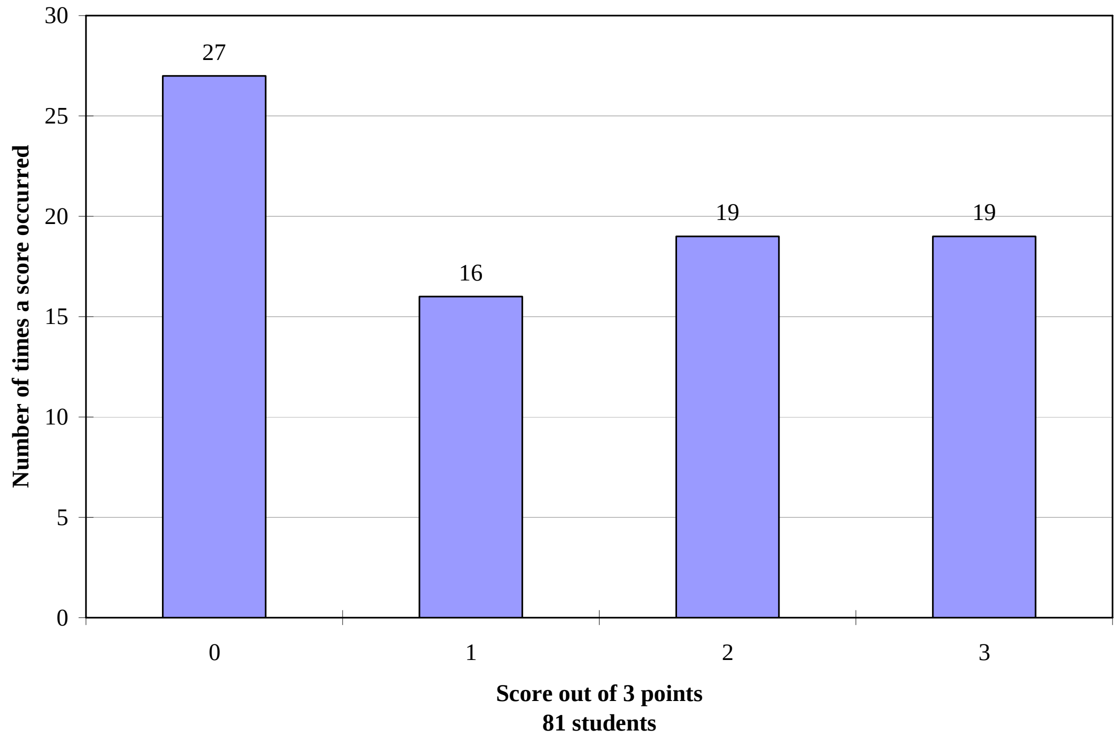


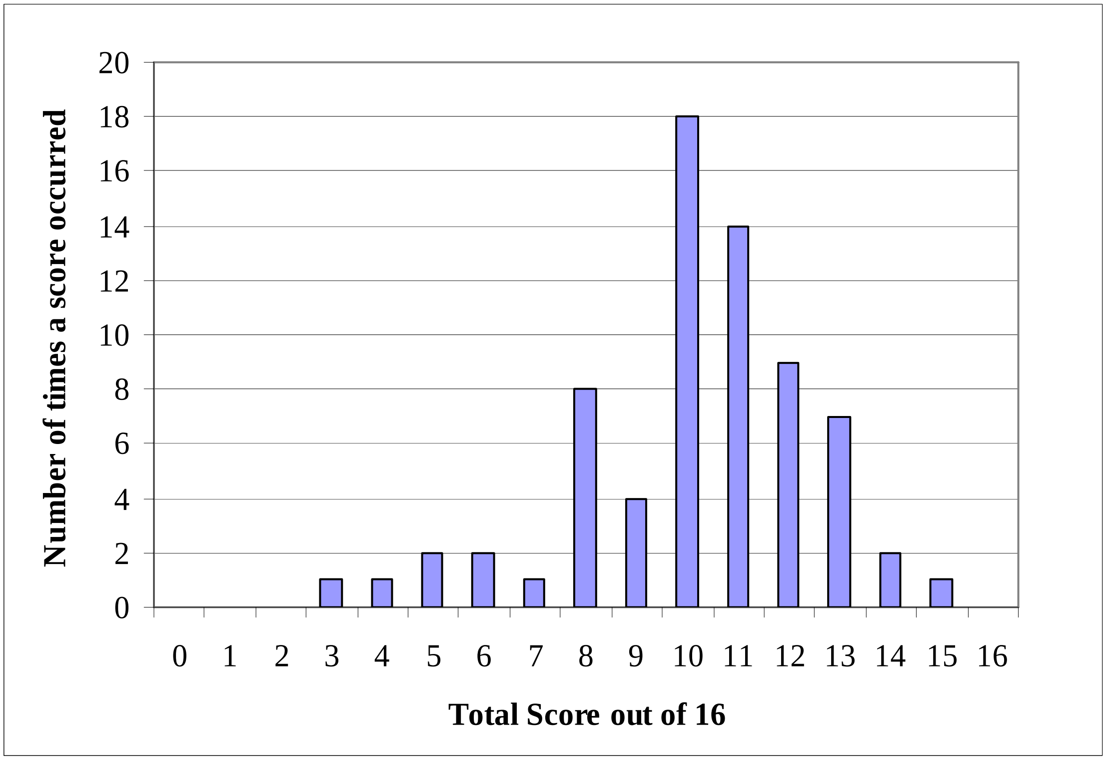
Figure 17: Score distribution for question 9 of the grade two Engineering Review concerning the engineering design process



Third Grade

The engineering review measured how well the students comprehended and retained material taught to date. It consisted of several short, simple, multiple-choice questions. (See Appendix G) Teachers administered the review, which we then collected from each classroom. We used a rubric (Appendix I) to calculate the number of questions answered correctly, where the distribution can be seen in Figure 18.

Figure 18: The distribution of the number of questions answered correctly on the grade three Engineering Review



The maximum number of points that a student could earn was sixteen. The grading was strict, especially for question two, and thus there were no perfect scores. A score of nine or higher indicated that the students have retained a good amount of knowledge pertaining to engineering and technology. Out of seventy students, fifty-five obtained a score between nine and fifteen, indicating that they understood and retained the information. This was based on the engineering review that we created. Had we asked different questions, we may have obtained different results. In general, the students easily remembered recent lessons, but had some trouble with lessons taught at the beginning of the year. This could be seen through questions four, five (Figures 19) and six. Questions four and five involved the water cycle, which was recently taught in the classroom. A majority of the students answered these questions correctly, whereas most of the students answered question six incorrectly (Figure 20). Question six required knowledge of the definition of "Civil Engineer," which was a part of the Sparky's Engineer lesson plan, which was taught at the beginning of the year.

Figure 19: Score distribution for questions 4 and 5 of the grade three Engineering Review, where the subject was taught recently in the classroom

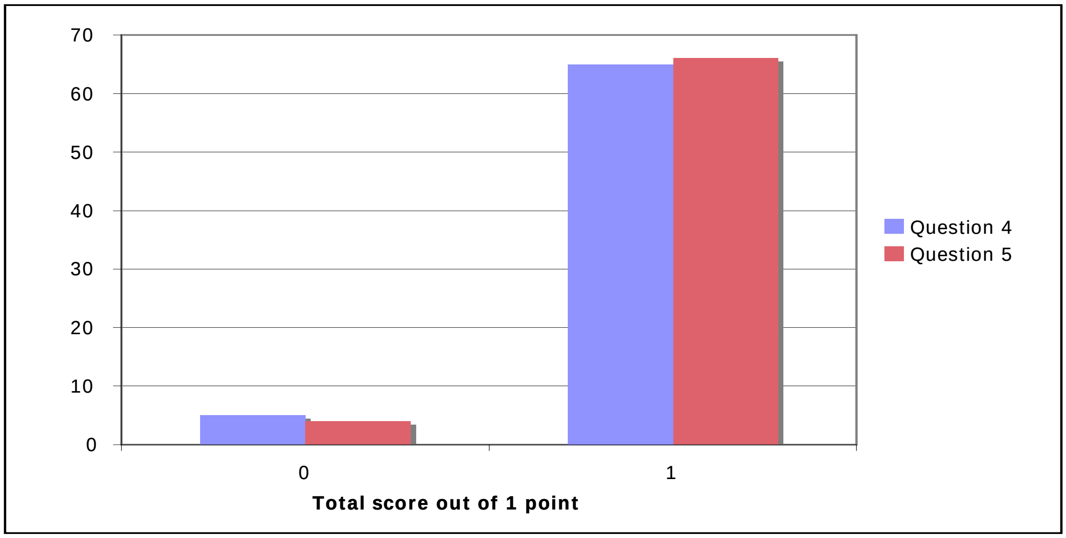
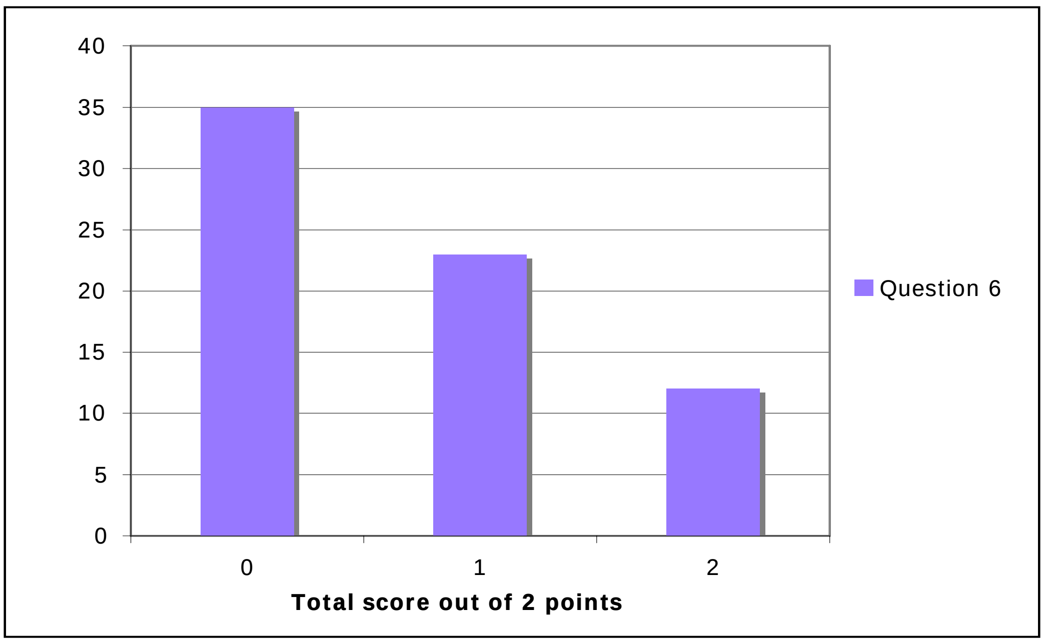


Figure 20: Score distribution for questions 4 and 5 of the grade three engineering review, where the subject was not taught recently in the classroom



Conclusion

Several second and third grade teachers in local schools mentored our efforts and were willing to incorporate our lessons into their curriculum plans. Not only were the teachers excited, but also the students shared that same enthusiasm about engineering in every lesson. We observed lesson plans as they were presented in the classroom and used the teachers' expertise and the students' reactions to improve them. The majority of our lesson plans were successful because of the hands-on nature of the engineering design process. Some of our more popular lesson plans included building a model tree house in the third grade and problem solving with a rollercoaster in the second grade. In order to evaluate students' understanding of engineering concepts from our lesson plans, we used a distribution of grades from an "engineering review," consisting of short open-answer and multiple-choice questions. It showed that a majority of students retained at least fifty percent of the engineering concepts covered in the lesson plans. When polled, three quarters of both second and third grade students indicated that they would consider an engineering profession, increasing diversity of the professional market.

Elementary school teachers, when surveyed about the current state of the science, engineering, and technology curriculum in the WPS, indicated that they were comfortable teaching basic engineering lessons. In addition, there was a consensus that engineering should be introduced at the elementary school level. However, we found that the existing curricula lacked engineering and technology material. In 2001, the Massachusetts Department of Education (DOE), spurred on by the need for new engineers in society, was the first state to establish statewide Frameworks for K–12 education.

Each lesson plan that we created included a complete list of materials, bundled together in a kit. We did a cost analysis of these kits, including initial and maintenance expenses. Teachers use competitor kits, such as FOSS, DSM, and SCIS, because they are complete, self-contained kits that include all of the necessary teaching materials for a science lesson. Our lesson kits were less expensive than other kits and provided all of the necessary teaching materials, most of which were recycled and readily available.

The positive response from participating teachers and students indicated that our lesson plans introduced basic concepts of engineering and engaged the students with hands-on activities. Developing lessons that met these conditions ensured the sustainability of this curriculum by making lessons more accessible to teachers. Weekly classroom visits helped teachers become more familiar with engineering and technology, which should help improve scores on the engineering and technology components of the Massachusetts Comprehensive Assessment System (MCAS). Our project supports Massachusetts Department of Education’s emphasis on engineering and technology in elementary education to encourage students to pursue careers in these fields.

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Appendix A: Unit Structure Example

Unit – Plants and Animals

I. Plant Structures: (LS.04)
   a. Lesson 1: **sketch** a generic "plant" with all structures (TE.04)
   b. Lesson 2: **diagram** a generic "plant" with all structures, name and function (TE.04)

II. Maple Trees: (LS.06)
   a. Lesson 1: **diagram** a **maple tree** with all structures, name and function (TE.04)
   b. Lesson 2: field trip to Heifer Project International (HPI) to see **maple sugaring** (TE.03)
      i. Use the Engineering Design Process (EDP) to **design** a solution to the **problem** of **collecting/storing** maple sap

III. Plant and Animal Life Cycles (LS.07 and LS.08)
   a. Lesson 1A: create a **diagram** of the **plant life cycle** using pictures (TE.04 and LS.07)
   b. Lesson 1B: create a **diagram** of an **animal life cycle** using pictures (TE.04 and LS.07)
   c. Lesson 2: Grow plants from seed (LS.08)
      i. Part A: create a **graphic organizer** to represent all important aspects of planting/growing seeds (TE.04) – *create examples for this lesson*
      ii. Part B: (IS.01) **Write a list of questions** that relate to plant growth (ex. amount of light needed, type of soil that is best, amount of water needed, amount of time it takes for seed to sprout, differences between various types of plant seeds, etc.). **Predict** the answers to these questions. Create a set of **experiments** that will test these predictions.
      iii. Part B: (TE.01, TE.04) **List** all **materials** needed to plant seeds.
      iv. Part C: (TE.01, TE.04) Create a **labeled diagram** of how these **materials** will be put together before seeds are planted.
      v. Part D: (LS.08, IS.01) **Plant the seeds** under a variety of conditions so that predictions can be tested appropriately.
      vi. Part F: (IS.03) **Keep a record** (journal, pictorial calendar, etc.) of seed growth; document the appearance and shape of special plant structures (stem, leaves, roots, flowers, seeds) and use the metric system to record the plants' daily growth. When the plants have finished growing, graph this information using the metric system.
      vii. Part G: (IS.04) **Compare** seed growth to **predictions**. Compare growth of seeds grown under identical conditions. Compare growth of different types of seeds.

Unit- Physical Science

I. Materials and their properties (PS. 01 and PS. 02,)
   a. Lesson 1: **Identify** several **materials** and describe their uses (TE. 01)
   b. Lesson 2: **List** the properties of several **materials** (TE. 01, TE.04)

II. The Water Cycle (PS 05 and PS 06)
   a. Lesson 1: Demonstrate the **water cycle**
   b. Lesson 2: **List** the different phases in the **water cycle** (TE. 04)
   c. Lesson 3: **Diagram** the **water cycle**; making sure to label the direction of the cycle and the three different phases (TE. 04)
      i. Use the Engineering Design Process to **design** a method to **demonstrate** how water expands (PS.06)

III. Sound (PS. 08)
   a. Lesson 1: **List** materials that can be used to construct a **sound machine** that changes volume and pitch. **Record** the desired dimensions using a ruler (TE 01 and TE. 05)
   b. Lesson 2: Use the engineering design process to **design** and then **construct** a sound instrument that changes volume and pitch (PS. 08)
      i. Create a **graphic organizer** to **record** the different volumes and pitches (TE 04)

Unit- Earth/Space Science

IV. Rocks and their Properties (ES.01, ES.02, ES.03, ES 04, ES 05)

a. Lesson 1: Explain what minerals are and **identify** several different kinds of rocks (metamorphic, igneous, and sedimentary). (IS.03)
b. Lesson 2: Explain the natural processes that create these rocks and **list** the physical properties of these rocks (hardness, color, luster, cleavage, and streak). **Identify** some possible uses for these some of these rocks. (TE.01, TE.03, IS.02)
c. Lesson 3: Acquire some rocks and minerals and **examine** them by looking for differences, similarities. Based on those **observations**, spend time collecting rocks from outside the classroom or a field trip and **document** these findings using **charts and diagrams**. (IS.02, IS.03, IS.04, IS.05, IS.06, TE.02, TE.04, TE.05)

V. Soil and its Properties (ES.06, ES.07, ES.08, ES.09)

a. Lesson 1: Describe how soil is formed and give examples of how and why this takes place. (IS.03)
b. Lesson 2: Recognize, **discuss, and document** the different properties of soil. (Color, texture, water retention, ability to support plant growth). (IS.03, IS.06)
c. Lesson 3: **Experiment** with different kinds of soil to see how much water it will retain using the metric system. **Document** all data and use **charts and graphs** to represent findings. (IS.02, IS.03, IS.04, IS.05, IS.06, TE.01, TE.02, TE.05)
d. Lesson 4: observe sand and topsoil with a magnifying glass, **record** how the sand resembles minerals, and note if any parts of the topsoil resemble organisms. Note any differences in color, texture, odor, and clumping due and **explain** why this may occur. Mix topsoil and sand together in varying proportions to represent samples of different types of soils and document these findings. (IS.02, IS.03, IS.04, IS.05, IS.06, TE.02, TE.05)

Appendix B: Teacher's Lesson Assessment Forms

Teacher's Lesson Plan Assessment Form

School: ____ Grade Level: _______

Name of Lesson: ____

Name of Instructor: _____________________________ Date: _____________

Please complete this lesson plan assessment to help our team improve the lesson plan. After circling your response, please take time to tell us why you chose that response and how we could improve this lesson. We thank you in advance for your feedback!

1. Was the lesson plan appropriate for the grade level?

No Partially Yes

____
____
____
____

2. Did the activities/evaluations in the lesson challenge the students to think creatively?

No Partially Yes

____
____
____
____

3. After looking at the students' work, do you think they understood the information in this lesson?

No Partially Yes

____
____
____
____

4. Do you think that the materials used in this lesson were appropriate and cost effective?

No Partially Yes

5. Did this lesson plan meet the specified Worcester Public School Benchmarks?

No Partially Yes

6. How would you evaluate the overall quality of the lesson plan?

Poor Average Excellent

7. Did you, the teacher, experience difficulty while executing any parts of the lesson plan?

No Partially Yes

8. Do you, the teacher, feel that you could teach this lesson without assistance from the PIEE project?

No Partially Yes

9. What was the strongest component of this lesson and why was it important to you?

10. What was the weakest component of this lesson and what would you change if you were to teach it in the future?

11. Would you like to make any additional comments?

Thank you for your input!

Appendix C: Observer's Lesson Assessment Form

Observer's Lesson Plan Assessment Form

School: ____ Grade Level: _______
Lesson: ____ Session: ______
Instructor: ____ Unit: ______
Observer: ____ Date: __________

For each question, please make notes and observations.

1. How are the students' attention spans? i.e.: Excellent/Good/Fair/Poor.

____
____
____
____
____

2. What are the students' reactions? i.e. Level of enthusiasm or lack thereof.

____
____
____
____
____

3. After looking at the students' work, did the students understand the information in this lesson? i.e. Yes/Partially/No.

____
____
____
____
____

4. Were the materials used in this lesson appropriate and cost effective? i.e Yes/Partially/No.

____
____
____
____
____

5. How well did the teacher answer the students' questions in relation to engineering and technology?

____
____
____
____
____

6. Do you, the observer, feel that the teacher could teach this lesson without assistance from the PIEE students and fellows? i.e. Yes/Partially/No.

7. What components of this session seemed the most effective?

8. What components of this session seemed the least effective?

9. Troubleshoot this session. What are the ways you would modify it? i.e. kit modification, teacher, and/or student difficulty.

Thank you for your input!

Appendix D: Student Survey

Student Feedback Form

Name: ______________________________ Date: ________________

Thank you for letting us, the WPI students, come into your classroom to help you learn about engineering this year! Please answer the questions below; your answers will help us learn about the activities and lessons we have done this year. If you would like to write more, please use the lines below each question.

12. Did you like the activities we did this year?

No A Little Bit Yes

Which was your favorite activity?

____

____

____

13. Have you used the engineering design process to build anything at home?

No A Little Bit Yes

If so, what did you make?

____

____

____

14. Do you think you would like to become an engineer when you get older?

No Maybe Yes

If so, what kind of engineer would you like to become?

____

____

____

15. Is there anything else you would like to share with us about engineering?

____

____

____

____

____

____

____

Thank you!

Appendix E: Teacher Survey

Teacher Survey

Name:______________________________ Date:_____________

Please choose the response which best matches your feelings!

1. Engineering is an occupation I would encourage students to explore.
   a. True
   b. False
2. At what grade level should students be introduced to engineering?
   a. 1st-3rd Grade
   b. 4th-6th Grade
   c. 7th-8th Grade
   d. High School
   e. College
3. At what grade level should students apply engineering?
   a. 1st-3rd Grade
   b. 4th-6th Grade
   c. 7th-8th Grade
   d. High School
   e. College
4. Engineering is difficult to teach to second and third grade students.
   a. True
   b. False
5. I have enough access to materials to effectively teach an engineering curriculum.
   a. True
   b. False
6. Where do you get your information before you begin an engineering lesson?
   a. FOSS
   b. Textbook
   c. Internet
   d. PIEE students
   e. Other
7. It would be easier to teach an engineering curriculum if the each lesson plan included additional background information and resources.
   a. True
   b. False
8. Cost is an important factor in my choice of lessons.
   a. True
   b. False

Thank you for your input!

Appendix F: Second Grade Engineering Review

Second Grade Engineering Review

Name: ______________________________ Date: _____________

1. What makes an object balanced? ________________________

____

____

____

2. Name two objects that use balance to work.

____

____

3. Name as many parts of the seesaw in the picture as you can, using engineering words. ________________________________

____

____

4. Name two things you might find that are ramps. ______________

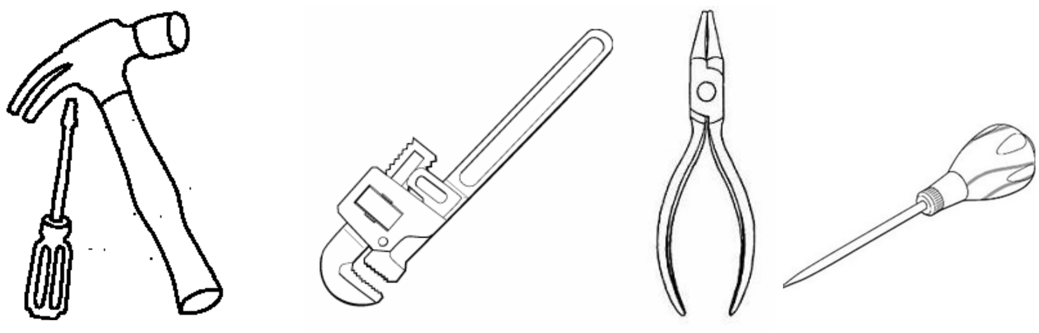
____

5. Choose a tool from the ones below and describe what you would use it for. Circle your tool. ________________________________

____

____

____



6. What is a habitat? ______________________________________

____

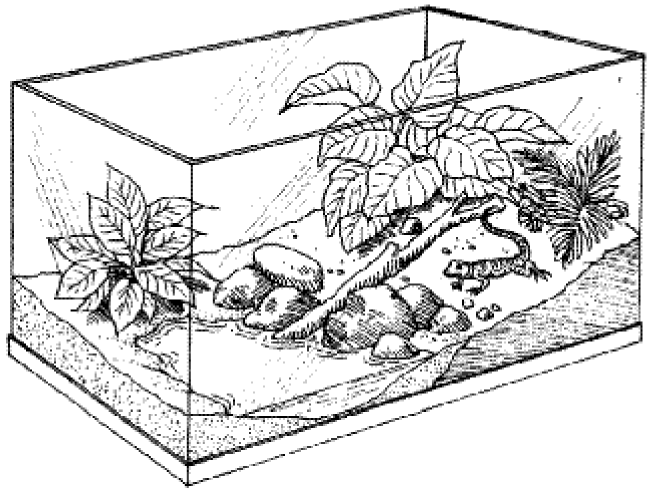
____

____

7. What things do you see in the terrarium below that are living, nonliving, and once living? Living: ________________________

Nonliving: ____

Once-living: ____



8. Name one animal and describe its shelter. ________________

____

____

____

9. What steps in the Engineering Design Process have you used?

What for? ____

____

____

____

10. Where do natural materials come from? ____________________

____

____

Appendix G: Third Grade Engineering Review

Third Grade Engineering Review

Name: ___________________________________ Date:_______________

1. **What type of engineer is most interesting? _____________________________**

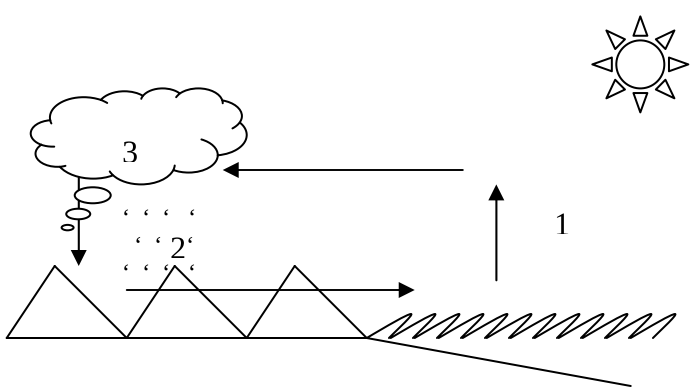
2. **Imagine that you want to make a tent in the backyard with your friends. You look outside and around the house and find some materials. Circle the materials that you would use to make a tent. You may circle more than one.**

String	Sneakers	Leaves	Pieces of wood
Paper towels	Sheets	Cardboard boxes	
Canvas Tarp	Wrapping Paper	Silk	

3. **List two additional *properties* of a feather.**

Soft________ ____________________ ______________________

Look at the diagram below and answer the following questions.



4. **At which number in the diagram does condensation occur? ___________________**
5. **At which number in the diagram does evaporation occur? ___________________**

6. What kind of engineer designs bridges, roads, and buildings?

____

7. What is a word for water when it is solid? ___________________________________

8. Name one way that maple sap is collected from maple trees: ___________________

____

9. Water vapor is a:

(a) gas (b) liquid

(c) solid (d) none of these

Appendix H: Rubric for the Second Grade Engineering Review

Table 8: Grading rubric for the grade two Engineering Review

Question	Total Points Possible	Points	Deductions	Correct Answers	Incorrect Answers
1	2	1 per correct answer	-	Equal weight on each side; Stable; Steady	-
2	2	1 per correct answer	-	Seesaw; crane; bicycle; unicycle; motorcycle; etc.	-
3	2	1 per correct answer	-	Fulcrum; Lever; Weight; Counterweight	-
4	2	1 per correct answer	-	Hill; Parking lot ramp; Slide; Moving ramp; etc.	-
5	1	1 per correct answer	-	A hammer hammers something; A screwdriver screws/pries something; A wrench turns something; etc.	-
6	2	1 per correct answer	-	A habitat is a home; A habitat provides food, water, shelter	-
7	3	1 per correct answer	-	Living: lizard, plant Nonliving: sand, water, rock Once-living: stick	-
8	1	1 per correct answer	-	Animal and its shelter	-
9	3	1 per correct answer	-	Design; Materials List; Build; Test; Redesign	-
10	1	1 per correct answer	-	Nature; Earth	-
Total	**19**	**19**	**0**		

Appendix I: Rubric for the Third Grade Engineering Review

Table 9: Grading rubric for the grade three Engineering Review

Question	Total Points Possible	Points	Deductions	Correct Answers	Incorrect Answers
1	1	1 per correct answer	-	Any engineer	-
2	6	1 per correct answer	- 1 per incorrect answer	String; Leaves; Pieces of wood; Sheets; Cardboard boxes; Canvas tarp	Sneakers; Paper towels; Wrapping paper; Silk
3	2	1 per correct answer	-	Soft; Light; Long; Smooth; Straight; etc.	-
4	1	1 per correct answer	-	3	-
5	1	1 per correct answer	-	1	-
6	2	2 per correct answer; 1 per close answer		Civil Engineer (Close answers: Architect or construction engineer)	
7	1	1 per correct answer	-	Ice	-
8	1	1 per correct answer	-	Bucket or Tubes	-
9	1	1 per correct answer	-	(a) Gas	-
Total	**16**	**16**	**- 4**		

Appendix J: Glossary

Benchmark: Specific topics, categorized by grade level, which the city of Worcester requires teachers to teach.

Discovery/Inquiry Learning: A type of learning that relies on exploration and experimentation, and in which an instructor leads a group of students through an activity with the goal of the students discovering for themselves new concepts rather than memorizing them.

DOE: Massachusetts Department of Education.

Engineering: The branch of science and technology concerned with the design, building, and use of machines, and structures to improve the standard of living.

Engineering Design Process: A series of steps that engineers use to guide them as they solve problems. The engineering design process is cyclical and can begin at any step. (http://www.mos.org/doc/1559)

Framework: Specific topics, categorized by grade level, which Massachusetts mandates that all teachers teach.

Lesson Kit: A combination of materials needed for a specific lesson, or group of lessons, provided with the lesson(s) and that satisfies our requirement for a hands-on activity.

Meaningful Learning: The achievement of a deep understanding of complex ideas that are relevant to students' lives (http://www.projecttime.org/about/meaningfulLearning.html, 23 April 2006)

MSTEC: The Massachusetts Science and Technology/Engineering Curriculum is the set of Frameworks developed by the Massachusetts Department of Education, which outlines the basic science and engineering concepts that need to be learned by students in each grade level.

NSF: National Science Foundation.

PIEE: Partnerships Implementing Engineering Education is a partnership between teachers in the Worcester Public Schools (WPS) and Worcester Polytechnic Institute (WPI) graduate fellows and undergraduate students, by which lesson plans incorporating engineering into the K–6 curriculum are developed and implemented into schools.

Rote Learning: A type of learning, where the students memorize information without making connections, such as vocabulary.

Science: The systematic study of the structure and behavior of the physical and natural world through observation and experiment.

Technology: The application of scientific knowledge for practical purposes.

WPI: Worcester Polytechnic Institute.

WPS: Worcester Public Schools.

Appendix K: Second Grade Lessons

2.A.1 Terrarium Lesson

Living and Non-Living things in the classroom

Grade Level	2
Sessions	1 – 45 minutes 2 – 60 minutes 3 – 30 minutes
Seasonality	Beginning of the year (year long project)
Instructional Mode(s)	Whole class, Individual
Team Size	None
WPS Benchmarks	02.SC.IS.01; 02.SC.IS.02; 02.SC.IS.05; 02.SC.IS.06; 02.SC.ES.02; 02.SC.LS.02; 02.SC.LS.03; 02.SC.LS.08; 02.SC.TE.01; 02.SC.TE.02
MA Frameworks	K-2.ES.1; K-2.ES.3; K-2.ES.4; K-2.LS.1; K-2.LS.2; K-2.LS.3; K-2.LS.4; K-2.LS.7; K-2.LS.8; K-2.TE.1.1; K-2.TE.1.2; K-2.TE.1.3
Key Words	Science, Living, Nonliving, Habitat, Terrarium, Engineering

Summary

During this unit, the students will experience living, nonliving, and once living things through the design, building, and observing of a terrarium. They will decide what kind of things are needed in a terrarium and as a class will build an actually terrarium. They will then discuss which things are living, nonliving and once living inside as well as observe different patterns and happenings in the terrarium.

Session 1: Terrarium Design

Summary of Session

The students will design a terrarium of a given type and will draw a picture to show what sort of things they are including in their design. They will also write the things they are including and why. This will give the teacher an idea of what the students are thinking involving terrariums and what they might have in them.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 2

1. **02.SC.LS.03** Students will be able to identify the ways in which an organism's habitat provides for its basic needs.
2. **02.SC.IS.05** Students will record observations and data with pictures, numbers, or written statements.

Additional Learning Objectives

1. At the conclusion of this lesson, the students will be able to identify various types of habitats.

Required Background Knowledge

Prior to this lesson the teacher should have introduced what makes something living and something nonliving and the students should probably have talked about different types of terrariums by discussing different habitats (i.e. the desert, the woods, the ocean, a lake, a swamp, etc.) and how they are different.

Essential Questions

1. What kinds of things do you think are found in a given habitat and why?

Introduction / Motivation

The students' motivation for this exercise is that they get to decide for themselves what their terrarium needs in it. They also can use crayons or markers to draw a picture of what they think they should include.

Procedure

The instructor will…

1. Introduce what makes something living and nonliving.
2. Provide the students with the attached worksheet.

The students will…

1. Discuss types of terrariums and habitats (i.e. the desert, the woods, the ocean, a lake, a swamp, etc.), and how they are different.
2. Complete the worksheet by drawing and listing the things they would include in the terrarium.

Materials

Materials per class	**Amount**	**Location**
Worksheet	One per student	PIEE/WPI Graduate Fellows

Materials per student	**Amount**	**Location**
Worksheet	One	PIEE/WPI Graduate Fellows

Vocabulary with Definitions

1. *Desert* – A dry barren region that is usually sandy and without trees
2. *Habitat* – Place where a plant or animal grows or lives in nature
3. *Living* – Things that undergo life processes such as growing, reproducing, eating, and drinking
4. *Non-living* – Things that were never living
5. *Once-living* – Things that were alive at one time or were once part of a living thing
6. *Swamp* – Land covered by water that has shrubs and trees
7. *Terrarium* – A small container in which you sometimes keep living plants and small animals
8. *Woodland* – Forested land covered with trees and shrubs

Assessment / Evaluation of Students

The worksheet can be used to asses the students' learning.

1. Did they list things that would make sense to include?
2. Did they tell why?
3. Did they include the objects they listed in their drawing?

Lesson Extensions

None

Attachments

1. Terrarium worksheet

Troubleshooting Tips

There should not really be too much trouble with this lesson. If students do not know what to include you can prompt them to think about what they might see if they went to the desert (as an example).

Safety Issues

None

Additional Resources

None

Name: ________________________________ Date: ____________

Terrarium

Definition: A small closed container where you keep and observe some living plants and small land animals, such as turtles and lizards.

List three things living or nonliving, you would put in your terrarium. Tell why.

1.____

____

2.____

____

3.____

____

Draw your terrarium.

Session 2: Terrarium Building

Summary of Session

The students will build classroom terrariums given a set of materials.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 2

1. **02.SC.LS.03** Students will be able to identify the ways in which an organism's habitat provides for its basic needs.
2. **02.SC.IS.05** Students will record observations and data with pictures, numbers, or written statements.
3. **02.SC.IS.01** Students will ask questions about objects, organisms, and events in the environment.
4. **02.SC.TE.03** Identify and describe the safe and proper use of tools and materials (e.g., glue, scissors, tape, ruler, paper, toothpicks, straws, spools) to construct a simple structure.

Additional Learning Objectives

Students will learn that "building" something is not necessarily just limited to a bridge or a house.

Required Background Knowledge

Previous lesson

Essential Questions

1. What kinds of things do you find in a given habitat?
2. How can you assemble different materials to build a habitat for living things?

Introduction / Motivation

Tell the students that they are going to build a small habitat to keep in their classroom. A small animal will probably get the kids excited to be building its home, if available. The teacher can also show the students the materials and ask why that material is important to have in the terrarium.

Procedure

During this lesson, the class will build a terrarium of a given type. If more than one class is simultaneously completing this project, each class may build a different kind of terrarium. The teacher should procure the necessary materials for the desired habitat (a list of specific materials is attached) and then the students can be given different jobs in assembling the habitat, making sure everyone gets a turn to help. The attachment also provides information on including an animal in the habitat. Once the habitat is complete, the students can observe what happens in the habitat over time and keep notes. They can also help with the upkeep (i.e. adding water, feeding the animal(s) if there is one, etc.).

Materials (Terrarium Specific)

Woodland

Materials	Quantity	Shops
A large container w/lid	1	Pet Center (Petco)
Plants	As necessary	Home Improv. Store, Nursery
Gravel	½ Gallon	Pet Center
Sand	½ Gallon	Home Improv. Store
Soil	½ Gallon	Home Improv. Store, Nursery
Bark	¼ Bag	Home Improv. Store, Nursery
Charcoal	¼ Bag	Home Improv. Store, Nursery
Jar lid or ½ pint dish	1	
Trowel	1	Home Improv. Store, Nursery
Plant mister	1	Home Improv. Store, Nursery
Small animals	toad & salamander	Pet Center (Petco)
Food for animals	crickets & salamander food	Pet Center (Petco)

Desert Oasis

A large container w/lid	1	Pet Center (Petco)
Heat Lamp	1	Pet Center (Petco)
Water dish(plastic tub)	1	
Plants	As necessary	Home Improv. Store, Nursery
Gravel	½ Gallon	Pet Center
Sand	1 Gallon	Home Improv. Store
Soil	none	Home Improv. Store, Nursery
Bark	¼ Bag	Home Improv. Store, Nursery
Charcoal	¼ Bag	Home Improv. Store, Nursery

Jar lid or ½ pint dish	1	
Trowel	1	Home Improv. Store, Nursery
Plant mister	1	Home Improv. Store, Nursery
Small animals	chameleons	Pet Center (Petco)
Food for small animals	crickets	Pet Center (Petco)

Aquatic

A large container	1	Pet Center (Petco)
Plants	Water plants	Home Improv. Store, Nursery
Gravel	1 Bag	Pet Center
Aquarium Salt	1/2 tsp per gallon	Pet Center
Water filter	1 w/ replacement filters	Pet Center
Small animals	4-6 Swordtails/Mollies (Male and Female) and Snails	Pet Center
Food for small animals	Tropical Fish Food	Pet Center

Shoreline

A large container w/lid	1 (Lid is a necessity)	Pet Center
Glass Meat Loaf Pan	1	Home & Kitchen Center
Plants	As necessary	Home Improv. Store, Nursery
Sand	2 Gallon	Home Improv. Store, Nursery
Gravel	½ Gallon	Pet Center
Rocks, wood	As necessary (shade/climbing)	Home Improv. Store, Nursery
Jar lid or ½ pint dish	1	
Trowel	1	Home Improv. Store, Nursery
Small animals	Fiddler & Hermit Crabs	*****
Food for small animals	Crab food and occasional feeder fish	Pet Center

Vocabulary with Definitions

1. *Desert* – A dry barren region that is usually sandy and without trees
2. *Habitat* – Place where a plant or animal grows or lives in nature
3. *Living* – Things that undergo life processes such as growing, reproducing, eating, and drinking
4. *Non-living* – Things that were never living
5. *Once-living* – Things that were alive at one time or were once part of a living thing
6. *Shoreline* – Area including the beach and just beyond
7. *Swamp* – Land covered by water that has shrubs and trees

8. *Terrarium* – A small container in which you sometimes keep living plants and small animals
9. *Woodland* – Forested land covered with trees and shrubs

Assessment / Evaluation of Students

1. Do the students actively participate?
2. Are they able to take part in discussion about why you need certain things in the terrarium?

Lesson Extensions

None

Attachments

1. Notes for teacher preparation

Troubleshooting Tips

Make sure everyone gets a turn to help build the terrarium and everyone has a job to do. In addition, if the terrarium includes some type of animal it will need to be fed and may need to be cleaned depending on the choice of animal.

Safety Issues

There may be safety issues relating to the type of animal used in the terrarium. Certain animals may bite or could carry diseases. All the above-mentioned animals should pose a minimal bite risk, but children should wash their hands after handling the animals.

Additional Resources

McCormick, Jann (2005). *Set up a Terrarium*. Retrieved November 18, 2005, from Spike's Science Projects Web site: http://spikesworld.spike-jamie.com/science/ecology/c241-02-terrarium.html

Bartlett, R.D. and Patti (2005). *The Ultimate Terraria*. Retrieved November 18, 2005, from PetPlace.com Web site: http://petplace.netscape.com/articles/artShow.asp?artID=1721

Notes for Teacher Preparation

Aquatic Terrarium
Materials (for inside terrarium)

- Gravel
- Aquatic plants
- A couple larger rocks (cleaned)
- Water

Suggested animals – Live Breeders including Mollies and Swordtails

Assemble gravel, larger rocks, and fill with water. Add the filter and suggested salt. After the terrarium has been running for 1 hour or more, add the fish by first floating them in their bags in the tank. After 15 minutes, gently pour the fish into the aquarium. This terrarium is simple to assemble. Be sure to buy only one species, but the male and female of that species (females are the plump ones). Use both natural and plastic plants, so that the babies can hide from their hungry parents. Within about 1 month, the students should notice small semi-transparent fish, which are fish babies. Feed them once or twice daily, and make sure not to overfeed.

Woodland Terrarium
Materials (for inside terrarium)

- Gravel
- Sand
- Soil
- Charcoal
- Small trees or plants
- Tiny ferns
- Moss
- A couple larger rocks/pieces of bark
- Small lid or ½ pint dish

Suggested animals – Sow or pill bug, salamander, newt, toads, snails

Layer approximately 1” gravel, ½” sand, ½” charcoal and 2-3” soil in the container. If you are making more than one habitat, you can use the sand and gravel for the other habitats. Plant tiny plants and ferns and place moss. Place larger rocks and bark where desired. Once again, if a small animal is to live in the habitat you will need to make sure if has some source of food. You can use the pond as a water source. The pond water needs to be changed daily, from a jar of day old water.

Desert Terrarium
Materials (for inside terrarium)

- Sand
- Small cacti
- A couple larger rocks and/or dried wood

- Small lid (for making a water “pond”)

Suggested animals – Desert lizard, geckos, small snakes

Cover the bottom of the container with sand. Plant the small cacti. These will need a couple of drops of water every so often to be able to survive. Place larger rocks and/or dried wood where desired. Once again, if a small animal is to live in the habitat you will need to make sure it has some source of food. You can use the pond (like a desert oasis) as a water source. If lizards are used, then a heat source such as a heat lamp or heat rock should be used to prevent the lizards from dying. You can substitute a portable shop light for a heat lamp, purchased cheaply at a home improvement store.

Swampland Terrarium (non-animal alternative to aquatic terrarium)
Materials (for inside terrarium)

- Gravel
- Sand
- Peat moss
- Tiny ferns
- Small vines
- Other plants that enjoy wet climates
- Wood and bark pieces
- A large contained area (like the jar lids above but larger) to create the water part of the swamp

Mix together sand, peat moss, gravel, and place in the bottom of the container 2” deep. Also, make sure, when you fill the terrarium that you add in the contained area that will hold water. Plant tiny ferns, plants, and vines. Place wood and bark pieces.

Shoreline Terrarium
Materials (for inside terrarium)

- Sand/Gravel
- Grasses
- A couple larger rocks and/or dried wood
- Large Tub or Glass Meat Loaf Pot
- Shells
- 1 tsp of Aquarium Salt

Suggested animals – Fiddler Crabs or Hermit Crabs

For Fiddler Crabs: Place the meatloaf pan in then bottom of the tank. Fill in Gravel and Sand as desired. The crabs should be able to walk into the dish, though; sand does not need to cover the bottom of the dish. Add 1 tsp of salt per gallon to the water.
For Hermit Crabs: Use less sand and more gravel, but make a sloped terrarium with small jar lid/tub at the bottom.

All: Add plants and fill tub or pan with water. Add shells and rocks as desired. Both of these animals are “climbers” and the students should always remember to keep the lid on the terrarium.

Session 3: Terrarium Observation

Summary of Session

The students will now write their observations about the terrarium in their classroom. They will investigate which types of living, nonliving, and once living things are inside the terrarium. There will also be a class discussion of their findings.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 2

1. **02.SC.IS.01** Students will ask questions about objects, organisms, and events in the environment.
2. **02.SC.IS.05** Students will record observations and data with pictures, numbers, or written statements.
3. **02.SC.IS.06** Students will discuss observations with others.
4. **02.SC.LS.03** Students will be able to differentiate between living and nonliving things based on their characteristics.
5. **02.SC.LS.08** Students will observe small animals in the classroom while they find food, water, shelter, etc.

Additional Learning Objectives

None

Required Background Knowledge

Previous lessons

Essential Questions

1. What things in our terrarium are living, nonliving, and once-living?
2. What things do you see happening inside the terrarium?

Introduction / Motivation

The students' motivation for this lesson is that they now get to see what is happening inside the terrarium that they helped build. If an animal has been included, what is that animal eating and drinking? What does it do within the habitat?

Procedure

The teacher should first provide the students with the worksheet about what is living, nonliving, and once living and let students fill it in. A class discussion of what they found can follow. The other worksheet is an extension activity when the kids have finished work early. They answer the given questions and draw a picture (the picture could be on a larger sheet of paper if the teacher wanted to use it as more of an art project).

Materials

Materials per class	Amount	Location
Worksheets	One of each type per student	PIEE/WPI Graduate Fellows

Materials per student	Amount	Location
Worksheets	One of each type per student	PIEE/WPI Graduate Fellows

Vocabulary with Definitions

1. *Observation* **–** To watch something. Sometimes when we are observing something, we might write what we see.

Assessment / Evaluation of Students

The worksheets can be used to asses the students' learning.

1. Did they list correct living, nonliving, and once living things?
2. Did they make good observations about the habitat?
3. Was their writing understandable with good grammar, spelling, and printing?

Lesson Extensions

If several classrooms are participating in the terrarium lesson at the same time, the students in each classroom should talk to the other students about their terrariums. This will encourage the students to discuss their observations, and will create a sense of ownership of the terrarium.

Attachments

1. Terrarium worksheet

Troubleshooting Tips

It will be a good idea to have students observing the terrarium a few at a time.

Safety Issues

Make sure if there are animals in the terrarium, the students do not handle the animals without a teacher or other adult's supervision.

Additional Resources

None

2.A.2 Birdhouse

Construction of simple, functional forms using the Engineering Design Process

Grade Level	2
Sessions	1 at 20 minutes 2 at 20 minutes 3 at 20 minutes 4 at 40 minutes 5 at 20 minutes
Seasonality	Fall, Spring
Instructional Mode(s)	Whole Class
Team Size	Individual
WPS Benchmarks	02.SC.IS.01; 02.SC.IS.02; 02.SC.IS.03; 02.SC.IS.05; 02.SC.IS.06; 02.SC.TE.01
MA Frameworks	K-2.TE.1.1; K-2.TE.1.2; K-2.TE.1.3
Key Words	Blueprint, Design, Dimension, Prototype, Ruler, Structure

Summary

This lesson introduces children to the idea of “structure.” It provides them with the opportunity to design and construct both a shelter for their terrarium, and a birdhouse or feeder. Additional objectives include the strengthening of teamwork and manipulative skills, and the provision of a context in which students use the Engineering Design Process.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 2

1. **02.SC.IS.01** Ask questions about objects, organisms, and events in the environment.
2. **02.SC.IS.02** Tell about why and what would happen if?
3. **02.SC.IS.03** Make predictions based on observed patterns.
4. **02.SC.IS.05** Record observations and data with pictures, numbers or written statements.
5. **02.SC.IS.06** Discuss observations with others.
6. **02.SC.TE.01** Identify and describe the characteristics of natural materials and human made materials.

Additional Learning Objectives

1. Students will identify and describe the proper use of tools and materials (e.g., glue, scissors, tape, ruler, paper, toothpicks, straws, spools) to construct simple structures.
2. Students will be introduced to the concept of measurement and dimension, as well as recording data.

Required Background Knowledge

Not all students may be able to measure, so it is a good idea to conduct a mini-measurement lesson of sorts before Part 5.

Essential Questions

1. What is a structure?
2. Why do people build structures and what are they used for?
3. What kinds of animals build structures/homes?
4. What steps would you use to build a structure?
5. Why would you choose certain materials for a structure?
6. What is a ruler and what do you use it for?

Introduction / Motivation

The instructor might begin the lesson by asking students what they have seen in their terrariums, and specifically, the behaviors of their animals. The instructor will then explain that the class will build a shelter for their animals to modify a habitat. The class will then construct either a birdhouse or bird feeder, depending on the time of year. Extensions for this lesson also include constructing a “shelter” for the animals in the terrarium.

Part 1 can be combined with Part 5 (or Part 3 and Part 5). When the students are designing the birdhouse/feeder, they can measure and record the parts of their birdhouse/feeder beforehand, and then replicate the measurements during the construction phase.

Procedure

Part 1

1. Discuss the idea of shelter with the students, noting that sometimes, because people want to, and not because the animals require it, people like to build shelters for animals. Introduce the idea of a structure, such as a house.
2. Provide each student with the “My Birdhouse” blueprint. Explain that they will be building a prototype of a new birdhouse or birdfeeder. Inspire conversation about the blueprint, by asking the students what materials they might like to use. Encourage the students to be creative, and that no ideas are wrong; just be sure there is justification for the design.
3. Have the students design a birdhouse on the worksheet. The outline is of a ½ gallon milk carton, and is provided for a rough outline.

Part 2

1. The students will work individually, or divide students into small groups of three to four.
2. Show students the materials and tools available (see Materials List) for the birdhouse/feeder design and construction.
3. Provide each student with a “Design” worksheet (see attachment at end of lesson).

4. Lead students through the worksheet. Now that they see the materials they have, they can think of creative ways to achieve their design intentions with the materials they have.

Part 3 (Do this part only if the students are working in groups. If the students are working individually, skip this part and move on to Part 4.)

1. Group the students in threes or fours, and hand out the individual blueprints from Part 1.
2. Each student will write down, either on the front or back of the blueprint, four things (or any number of things that the teacher feels is appropriate) from his or her design that he or she feels are the most important.
3. Inspire conversation about the blueprint, by asking the students what they might like to change, i.e. color, additional parts, other modifications, or decorations.
4. Hand out one new blueprint per group, and each student must choose one thing out of his or her four to make a group birdhouse. Therefore, the group blueprint will incorporate one important thing from each student.
5. Allow the students to work in teams, designing a new group blueprint to add the features they have discussed and would like to add.

Part 4

1. If the students are working in groups, ask students to reform previous groups.
2. Refresh students' memories with respect to their design ideas and the materials they have chosen for construction, and hand out the blueprints.
3. Allow the students time to construct their models; some classes may require more or less time to construct (approximately 25 minutes). Instead of the students cutting their own holes, just have them trace the holes with a marker, and cut the holes for the students.
4. After each student/group has finished constructing their model, ask the students to describe the function of their birdhouses and bird feeders and explain why they added particular elements.

5. Give each student an “Improve” worksheet. Ask students what they could change about their birdhouse to make it more convenient or comfortable for the birds, and ask them to write it down on the worksheet.

Part 5

1. Ask students to reform previous groups. Each group should now have a prototype of their birdhouse, as well as the group blueprints drawn on the provided worksheet, “My Birdhouse.”
2. Introduce a simple tool, a 12-inch ruler, and the concept of dimension and its notation (1 inch). Discuss the concept of measuring objects and the importance of doing it, i.e. so that someone else can look at the blueprints and reproduce the prototype, and so that the students can describe and compare their birdhouses. Also, ask the students what would be important dimensions of their birdhouses to record on the blueprints.
3. Have the students in each group take turns measuring the outside dimensions (such as the height and width of the birdhouse, as well as the height of the hole) and recording the data on the blueprint.
4. Ask each group to present the measurements of their prototype to the class (not intended to be lengthy, simply say what the height and width are, and how tall the hole is).

Materials List

Materials per class	Amount	Location
12-inch ruler	One per group	Classroom
Aluminum foil	One box	Grocery store
Clear tape	Undefined	Drugstore, office supply store
Duct tape	One roll	Hardware store
Lightweight cardboard	Several pieces per group	Recycled
Milk cartons (1 or ½ Gal.)	One per team	Recycled
“My Birdhouse” worksheet	One per student	Lesson plan
Permanent markers	One set per team	Office supply store
Plastic drinking straws	Several pieces per group	Grocery store, dollar store
Plastic wrap	One roll	Grocery store

Popsicle sticks/tongue depressors	Several pieces per group	Craft supply store
Scissors	One pair per group	Classroom
Scraps of colored paper/fabric	Undefined	Recycled
String	One roll	Hardware store, toy store

Vocabulary with Definitions

1. *Blueprint* – A drawing of an object you plan to build, a map of how something will be constructed
2. *Design* – A plan for making something
3. *Dimension* – A measurement of length between two things
4. *Inch Ruler* – A simple tool used to measure the dimension of an object in inches
5. *Prototype* – An original model of something you design
6. *Structure* – Something made up of a number of parts that are held or put together in a particular way

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Observe student groups at work.
2. Collect student worksheets.
3. Determine whether students understood the Engineering Design Process.

Lesson Extensions

1. (Engineering) As they students observe their terrarium, they may wish to construct a shelter for their animals. As a class, the students could build a cave, hut, or other shelter. Though they will not have an original blueprint, they can follow a similar procedure:
    - Ask what the animals in the terrariums need for a shelter.
    - Design a shelter and make a blueprint.
    - Choose appropriate materials based on the environment and material properties.
    - Construct a prototype structure.
    - Measure and record the dimensions of the structure on the blueprint.
    - Put structure in terrarium and observe how the animals react and interact with it.
2. (Science) Discuss other animals that build structures: Beavers, Birds, Ants, Bees, Squirrels, Groundhogs, and the animals in your classroom.

3. (Science/Engineering) Students can decide to place a birdfeeder/birdhouse outside, in the playground for example. Then they can observe if birds or other animals use it. What features of the birdhouse are animals using and why? Based on their observations, do the students think that their design can be improved in any way?

Attachments

1. Birdhouse Design Worksheets
2. My Birdhouse Blueprint Worksheets
3. Birdhouse Improvement Worksheets

Troubleshooting Tips

1. Craft glue takes considerable time to dry, so tape is preferred.

Safety Issues

1. Teacher should have the students outline the hole on the birdhouse/milk carton and cut it for them. A good resource for proper scissor use is: http://kid.lifetips.com/subcat/65307/educational/correct-scissor-use/

Additional Resources

1. Wauer-Ferus, Loraine (1999). *Bird Houses & Feeders*. Retrieved October 30, 2005, from Billy Bear for Kids and Teachers: Billy Bear's Playground Website: http://www.billybear4kids.com/holidays/earthday/birds/house.htm
2. Langis, Judith (2005). *Structures*. Retrieved October 27, 2005, from ThinkQuest for Tomorrow's Teachers Website: http://t3.preservice.org/T0211983/design.html
3. *Correct Scissor Use*. Retrieved October 30, 2005, from Life Tips Website: http://kid.lifetips.com/subcat/65307/educational/correct-scissor-use/

Name: ______________________________ Date: ___________

Design

Material	Why will you use the material to construct your birdhouse?
Aluminum Foil	
Clear Tape	
Duct Tape	
Lightweight Cardboard	
Pipe Cleaners	
Plastic Drinking Straws	
Plastic Wrap	
Popsicle Sticks	
String	

Name: ________________________________ Date: ____________

Improve

What can you do to your Birdhouse or Bird Feeder to make it better?

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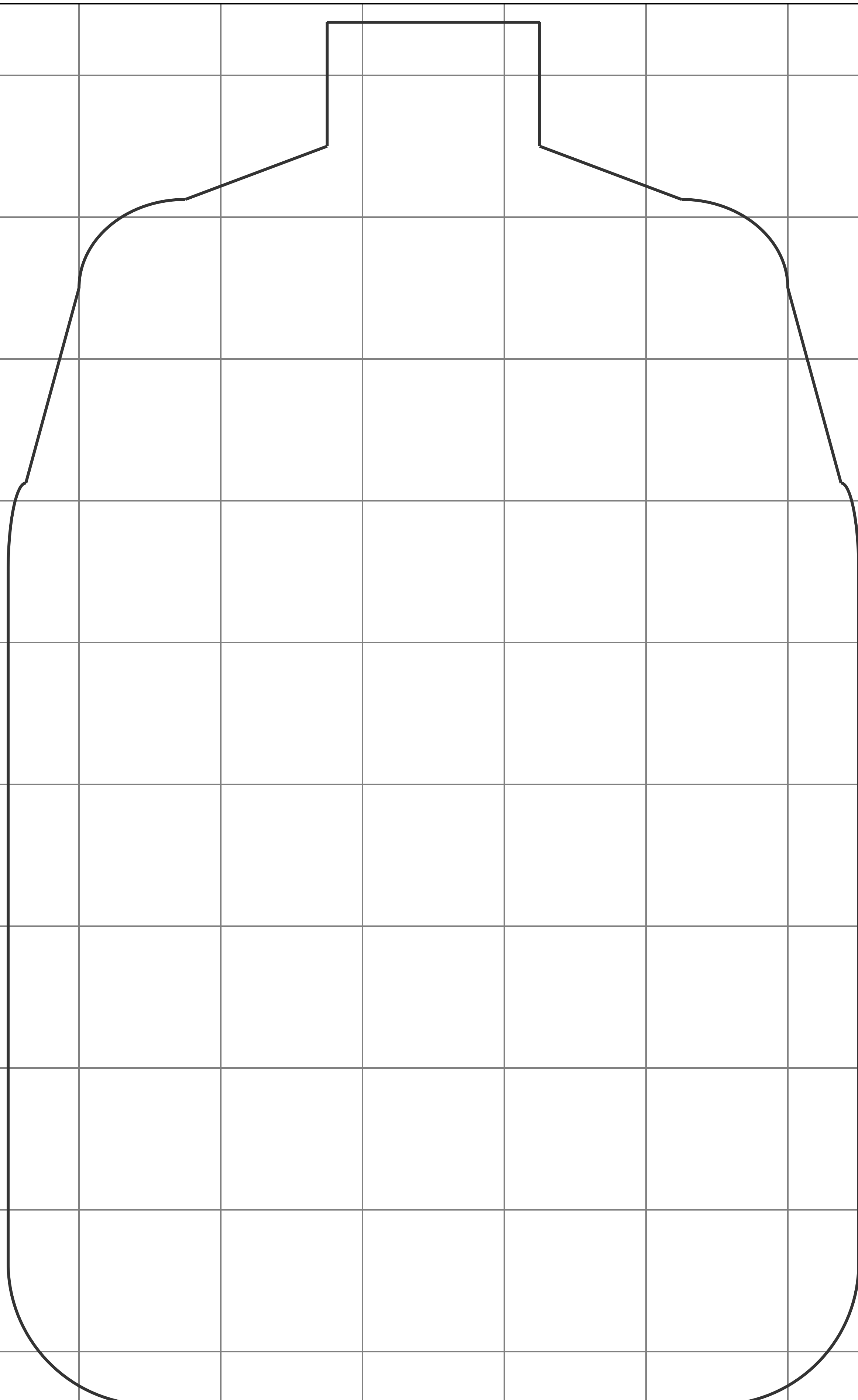


My Birdhouse	Name:

2.A.3 Fossils

Making a Tool to Explore Fossils with the Engineering Design Process

Grade Level	2
Sessions	1 – Build a Tool, 15 Minutes 2 – Fossil Dig, 25 Minutes Extra 10 minutes for eating and cleanup
Seasonality	None
Instructional Mode(s)	Whole class
Team Size	Individual
WPS Benchmarks	02.SC.IS.04; 02.SC.IS.05; 02.SC.IS.06; 02.SC.TE.04
MA Frameworks	K-2.TE.1.1; K-2.TE.1.2; K-2.TE.2.1
Key Words	Extinct, Fossil, Grid, Layers, Organism, Species

Summary

This lesson teaches students about fossils and that they represent once-living organisms from millions of years ago. It also teaches the students about the layers of the earth, representing different chronological periods. It challenges the students to use the engineering design process to design, make, and test a tool for excavating fossils.

Session 1: Soils and Fossil Dig

Summary of Session

Students will use the engineering design process to make a prototype of a tool used for digging for fossils. Then they will help the teacher in creating a model of the earth's layers with fossils embedded in it, investigating the model by separating it into quadrants, and creating a graphical representation of what fossils they found in the earth's layers.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 2

Students will…

1. **02.SC.IS.04** Name and use simple equipment and tools to gather data and extend the senses.
2. **02.SC.IS.05** Record observations and data with pictures, numbers or written statements.
3. **02.SC.IS.06** Discuss observations with others.
4. **02.SC.TE.04** Identify tools and simple machines used for a specific purpose.

Additional Learning Objectives

2001 Massachusetts Curriculum Frameworks for Grade 2

Students will…

1. **T/E 1.1** Identify and explain the steps of the engineering design process, i.e., identify the problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign.
2. **T/E 1.2** Demonstrate knowledge of pictorial and multi-view drawings (e.g., orthographic projection, isometric, oblique, perspective) using proper techniques.
3. **T/E 2.1** Identify tools and simple machines used for a specific purpose, e.g., ramp, wheel, pulley, lever.

Required Background Knowledge

For the students…

An understanding of the Engineering Design Process at the elementary level will facilitate their investigation of the soils and fossil dig. The basic steps are:

1. Ask: What do I want to do? What is the problem? What have others done?
2. Imagine: What could be some solutions? Brainstorm ideas. Pick one to start with that you think will work the best.
3. Plan: Draw a diagram of your idea. Make lists of materials you will need to make it. Decide how it works. How will you test it?
4. Create: Build a prototype. Test it. Talk about what works, what doesn't, and what could work better.
5. Improve: Talk about how you could improve your product. Draw new designs. Make your product the best it can be!

For the teacher…

There are pictures provided at the end of this lesson that show many common tools used in digging for fossils. They are common household items.

Essential Questions

1. Can students explain the purpose for each part of their tool?
2. Can students diagram their portion of the fossil dig on the worksheet?

Introduction / Motivation

Fossils represent once-living things that inhabited the earth many years ago. Show students the example pictures provided at the end of this lesson. Tell the students they will be digging for fossils, but that they must first make a tool to do so.

Procedure

Part 1 – Build a Tool

1. Show the students the pictures provided at the end of this lesson. They are common tool used in digging for fossils.
2. Explain to the students that they will be conducting their own fossil dig, but that they must make their own tool or set of tools.

3. Pass out the materials and be sure that the students follow the basic steps of the engineering design process, filling out the provided materials worksheet. There is extra space provided on the worksheet for the students to add extra materials.

Part 2 – Fossil Dig

Note: This lesson requires substantial preparation, both with materials and in teaching the students.

1. Prepare all materials beforehand, and set them out unmixed in plastic containers or bags.
2. Introduce the students to fossils. Include all required background knowledge and vocabulary.
3. Introduce the concept of systematic investigation of an area of soil dividing the area into squares in a grid. Cut the food model of the earth's layers into equal squares and distribute one to each student, along with the Grid worksheet.
4. Each student places his or her square on a paper plate and carefully picks it apart using their tool(s), making sure to record where each "fossil" was found in their square on the "Grid" worksheet. All parts of their square are grouped by type on their plate, for example, all animal crackers together.
5. After digging apart their squares, students then count how many of each type of material is on their plate.
6. Students construct a class bar graph on a large laminated poster board grid, whiteboard, or chalkboard.
7. Students analyze the graph to see if all the squares were the same or different.
8. The class discusses how this procedure is used by scientists to systematically study a plot of soil.
9. The students eat their square and cleanup.

Materials

Materials per class	Amount	Location
Large food container, preferably transparent, wide and deep, such as a large Tupperware	One	Kitchen stores

container or baking dish		
A variety of crushed cookies, all of different color (i.e. Oreo, chocolate chip, colored sugar cookies, oatmeal cookies, peanut butter cookies	Between 1 and 2 cups of each variety of crushed cookie	Food stores, preparation required
Cake mix	1 – 2 kinds	Food stores, preparation required
A variety of animal shaped cookies, crackers, candies, i.e. animal crackers, teddy grahams, Swedish fish, gummy worms, gummy bears, other animal/insect shaped gummy, cookie, cracker	5 to 10 pieces per type of cracker, cookie, candy	Food stores
Pre-made transparent Jello shape, with mostly fish shaped crackers, cookies, candies in it – feel free to put in other animals as well	One, about 5" square/round, and approximately 2" deep	Food stores, preparation required
Large laminated grid sheet, whiteboard with grid drawn on it, or chalkboard with grid drawn on it	One	Office supply stores, school supply

Materials per student	**Amount**	**Location**
Popsicle sticks	Several	School supply
Toothpicks	2 – 3	Food stores
Straws	1 – 2	Food stores
Plastic Cutlery	2 – 3	Food stores
Tape	Undefined	Office supply stores
Paper plates	1	School supply
Napkins	2 – 3	School supply
Materials worksheet	One	PIEE
Grid worksheet	One	PIEE

Vocabulary with Definitions

1. *Extinct* – Describes a species that is no longer living or existing, such as the many species of dinosaurs.
2. *Fossil* – A remnant or trace of an organism of a past geologic age, such as a skeleton or leaf imprint, embedded and preserved in the earth's crust.
3. *Grid* – A pattern of regularly spaced crisscrossing lines that form squares, like on a map.

4. *Organism* – A living thing; an organism can be any individual form of life, such as a plant, animal, insect, bacteria, or fungus.
5. *Species* – One type of living thing, grouped by similar attributes and assigned a common name, such as a horse, dog, cat, or human.
6. *Layers* – A flat part of something, such as a cake, that is different than the othe parts. In this lesson, layers refer to different types of food or soil, similar to the layers of the earth. Layers are determined by similar weight and texture. Over time, actual soft layers of soil are turned into rock and subsequently covered by other layers. The bones of once-living organisms can become trapped in the soft layers and then preserved once that layer is turned into rock.

Assessment / Evaluation of Students

1. Did the students make an effective tool? (Did the tool break? Did it help the student to pick apart the layers?)
2. Did the students complete the "Materials" worksheet?
3. Did the students clearly label the parts of their square on the "Grid" worksheet?

Lesson Extensions

1. Inedible Fossil Dig: Soil and natural materials may be used as substitutes for the food products, to make an inedible version of the Fossil Dig. Common materials would be sand, dirt, gravel, sticks, leaves, rocks, and wood chips.

Attachments

1. "Fossil Grid" Worksheet
2. "Fossil Tool Materials" Worksheet

Troubleshooting Tips

1. The food preparation for this lesson requires a significant amount of time. The edible fossil cake tends to bind well with cake mix rather than all cookies. Sprinkle the "fossils" into the mix and gently mix them in. This will make a "fossil dig" that can both be cut and taken apart easily by the students' tools.

Safety Issues

Be aware of student food allergies when choosing ingredients, as well as diabetics. For more information, visit the American Diabetes Association home page, http://www.diabetes.org/home.jsp, and the American Academy of Allergy Asthma and Immunology home page, http://www.aaaai.org/. There are many helpful links for educators.

Additional Resources

http://www.ucmp.berkeley.edu/help/timeform.html > helpful list of geologic time periods from the University of California Museum of Paleontology

Name: ______________________________ Date: ________________

Fossil Grid

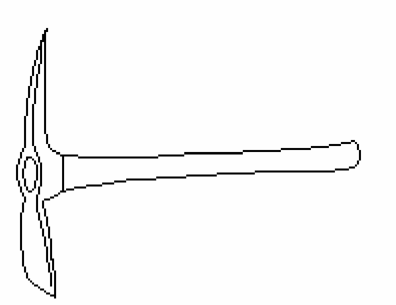
Where did you find each fossil? Draw in each fossil that you found in your part of the grid.

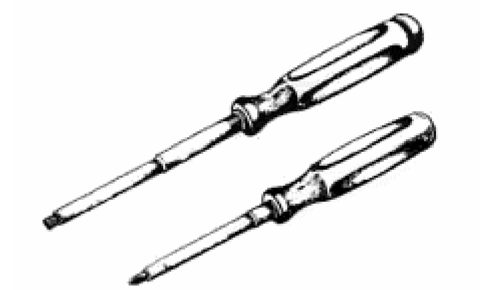
Name: ______________________ Date: _____________

Fossil Tool Materials

Material	Will you use it?	Why will you use it?
Popsicle Stick		
Toothpicks		
Straws		
Tape		
Plastic Cutlery		

Fossil Tools

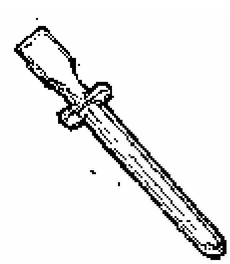


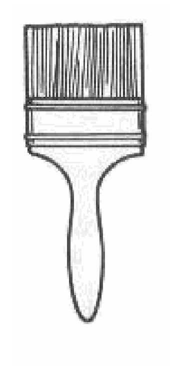


Ice Pick

Small Pick

Screwdrivers

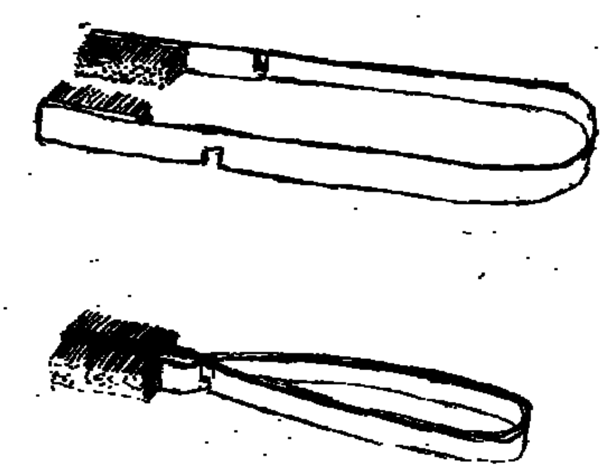


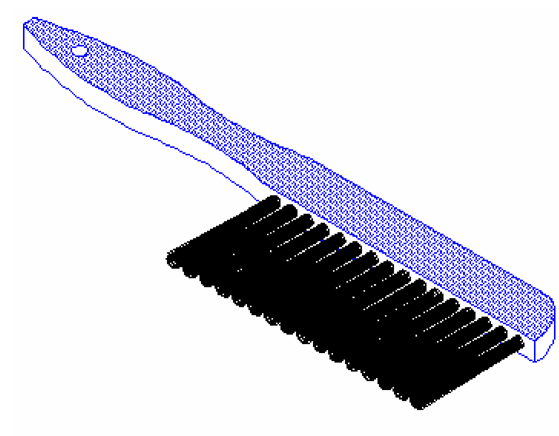


Small Chisel

Whisk Broom

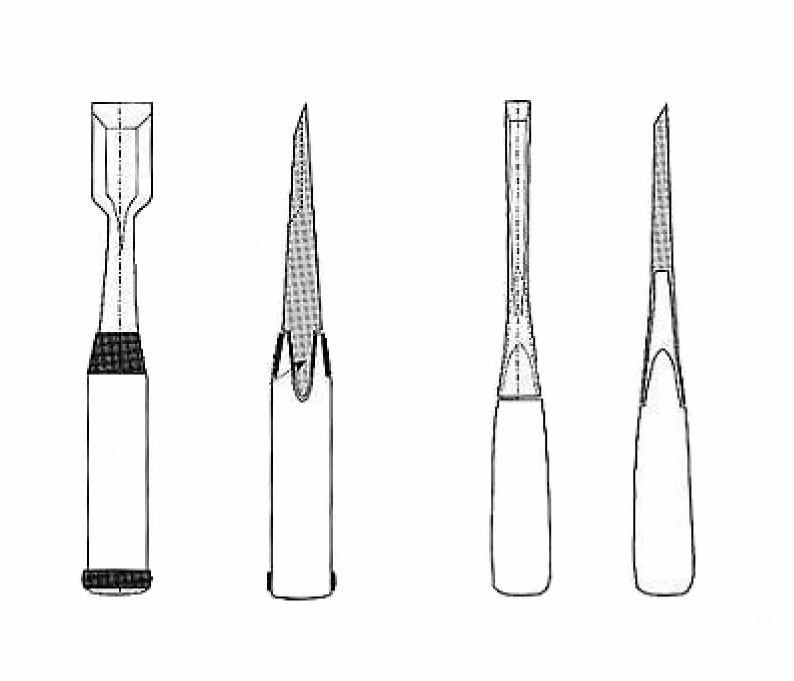
Chip Brush





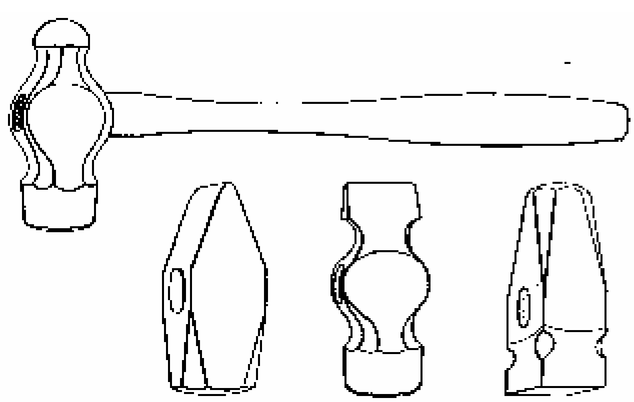
Working Toothbrush

Drafting Brush



Dental Picks

Chisels



Small Brush

Hammer and Heads

Figure 1: Bat Fossil

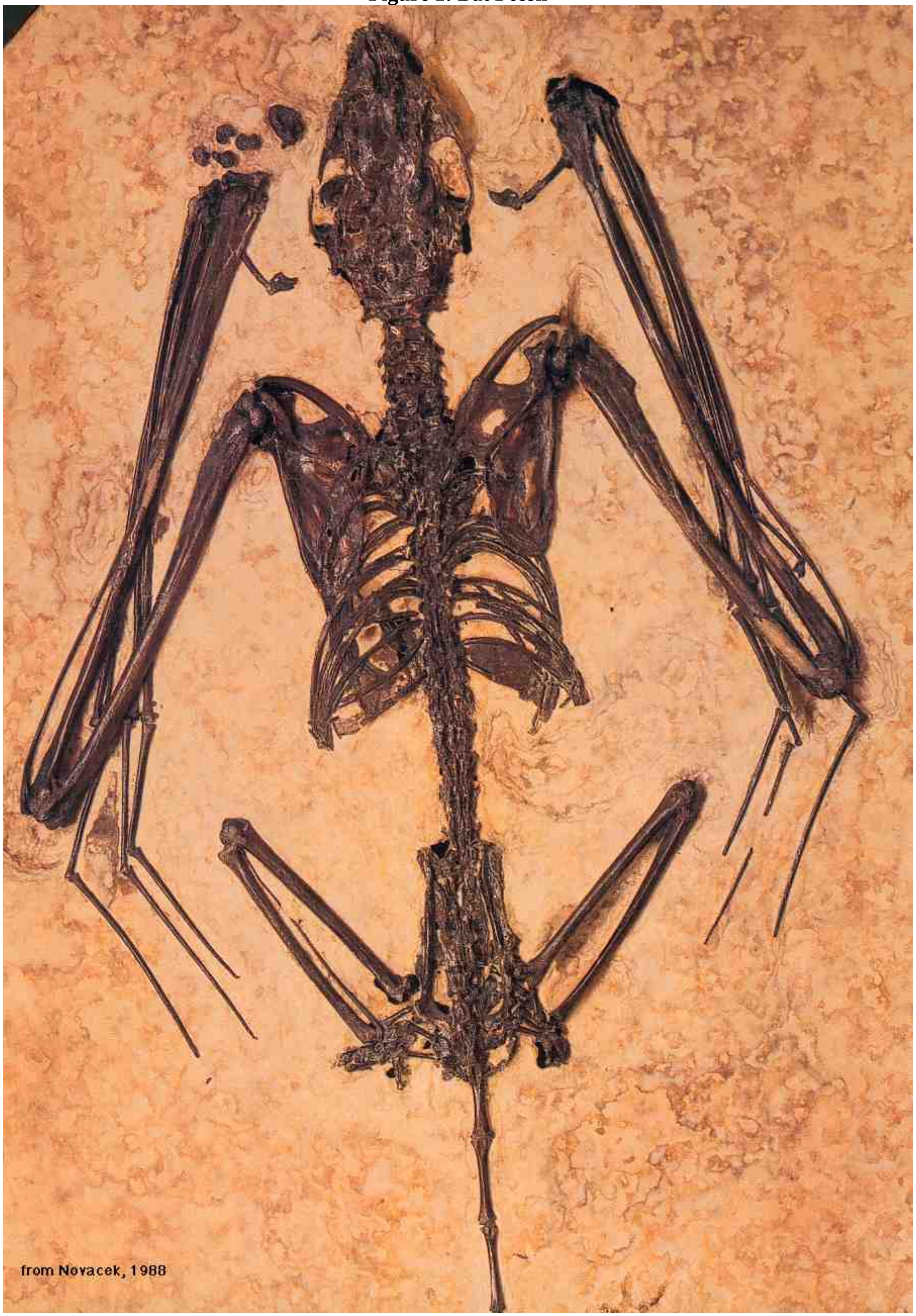


Figure 2: Cockroach Fossil

Figure 3: Fish Fossil

Figure 4: Leaf Fossil

Figure 5: Shark Fossil

Figure 6: Cicada Fossil

Figure 7: Fern Fossil

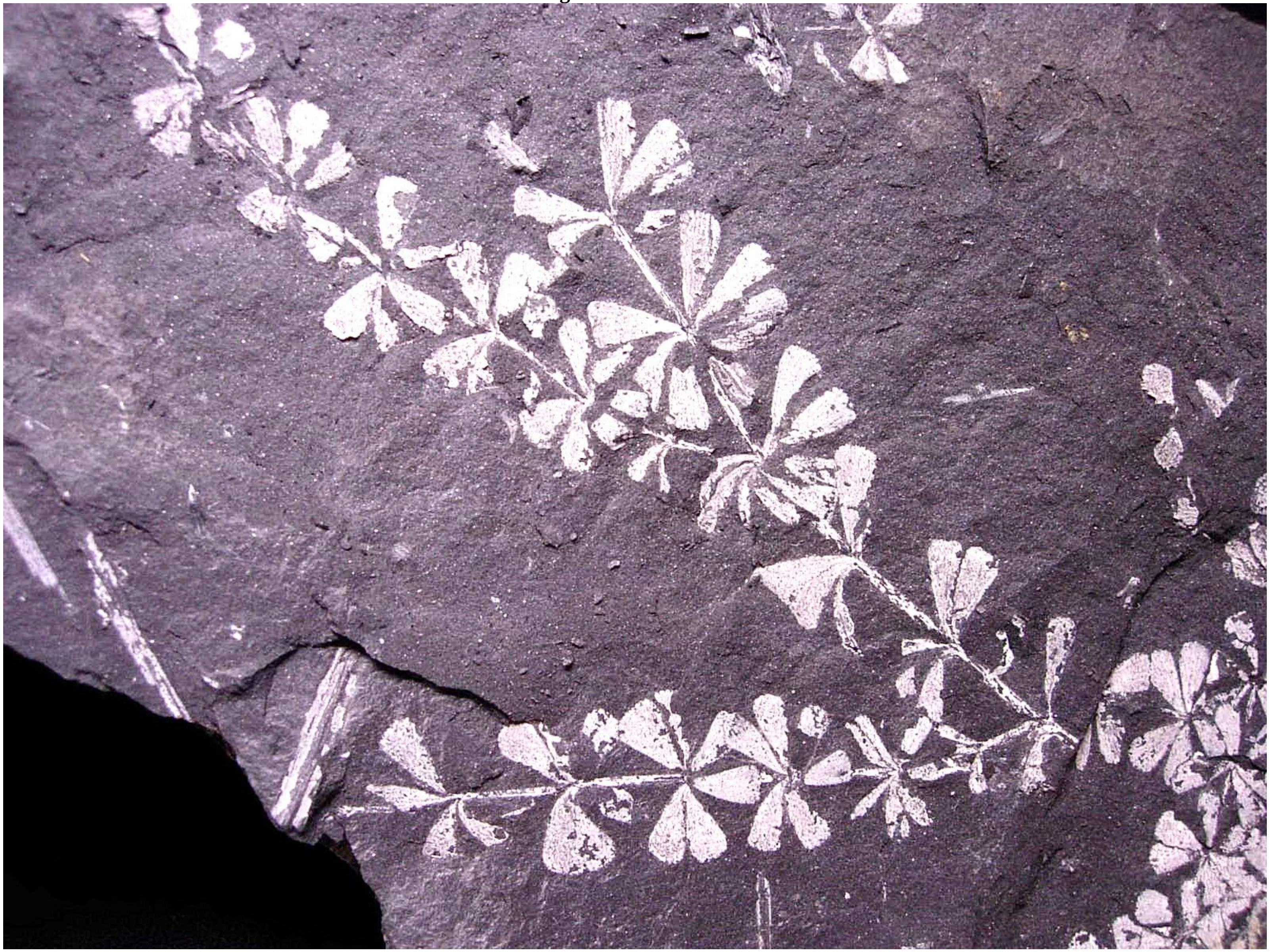


Figure 8: Gingko Fossil

Figure 9: Psittacosaurus (Chinese Dragon) Fossil

Figure 10: Shell Fossils

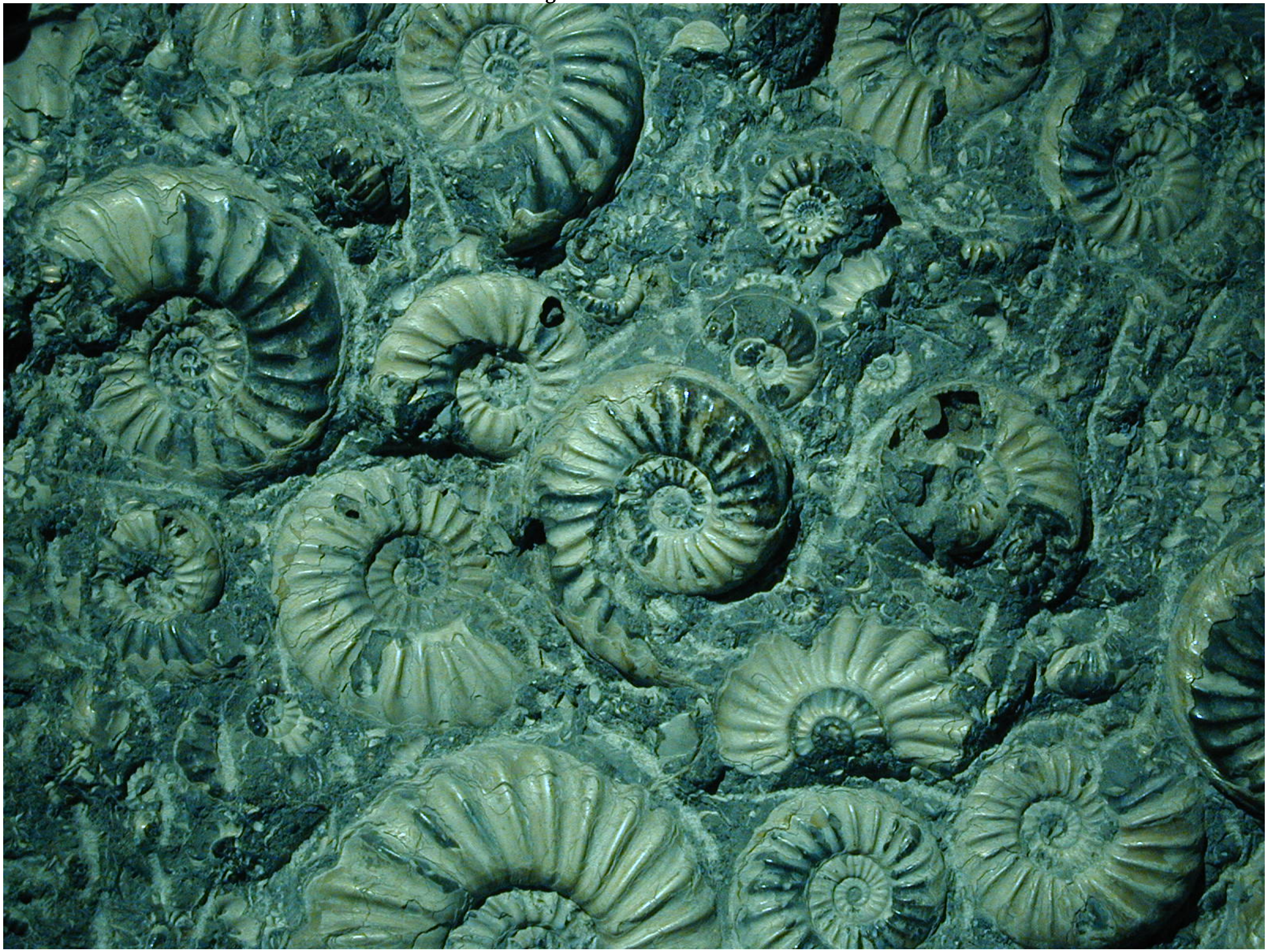


Figure 11: Turtle Fossil

2.C.1 Human Body Parts as Tools

Investigating how parts of the human body are used in similar ways as tools.

Grade Level	2
Sessions	1 at 50 minutes
Seasonality	None
Instructional Mode(s)	Whole class/small groups
Team Size	Individual
WPS Benchmarks	02.SC.IS.01; 02.SC.TE.05
MA Frameworks	K-2.TE.1.5; K-2.TE.2.1; K-2.TE.2.2
Key Words	Tool, Grasp, Human Being

Summary

This lesson introduces children to the idea of parts of the human body as tools that can be used to complete various tasks. The students also learn how animals use parts of their bodies in similar ways to humans. They then design a human being for a specific task.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 2

1. **02.SC.IS.01** Ask questions about objects, organisms, and events in the environment
2. **02.SC.TE.05** Describe how human beings use parts of the body as tools (e.g., teeth for cutting, hands for grasping and catching), and compare their use with the ways in which animals use those parts of their bodies.

Additional Learning Objectives

1. Students will understand that animals and humans have body parts that can be used for specific tasks.
2. Students will learn similarities and differences between humans and other animals.
3. Students will work with other members of a group to problem-solve and engineer a human being to complete a specific task.

Required Background Knowledge

None

Essential Questions

1. What part of the human body do you use in a similar way as a tool? What tool is it like?
2. How many more parts of the human body can you think of that you use like a tool? In addition, what tools are those parts like?
3. For what activity have you chosen to design a new human? How will your design help a human perform this activity?

Introduction / Motivation

The instructor can introduce students to how certain parts of the body can act as tools for performing certain tasks. The instructor can ask students what parts of the body can be used for what tasks. Students can also be introduced to parts of other animals' bodies that also perform those tasks.

Procedure

Part 1: (50 minutes)

1. Discuss with students how parts of the human body can be used as tools (teeth for cutting, hands for grasping, etc.). Also, discuss how animals also use their bodies in similar ways.
2. The students will work individually in this lesson.
3. Introduce the challenge of designing a human being that each student engineers to perform a specific task. Assign students a task, or allow them to choose a task for themselves. Some optional tasks are:
    - Climbing a mountain
    - Swimming to the bottom of the ocean/deep sea diving
    - Playing baseball/soccer/football
    - Running a marathon
    - Building a house
    - Firefighting

4. Allow the students to work in teams, and talk amongst themselves about the tasks and what tools a human would need to perform it successfully.
5. Hand out a blueprint to each student (attached) and have each student design a human being with those tools as body parts. It may also be motivational for the students to come up with a name for their new person and to color the design in.
6. When the blueprints are completed, have each student share his or her design with the rest of the class.

Materials List

Materials per Student	Amount	Location
Human Blueprint	1	Attached

Vocabulary with Definitions

1. *Tool* – A thing that you use to make the work of a task easier
2. *Grasp* –To hold a thing with a hand or claw
3. *Human Being* – A person

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Observe students at work.
2. Collect student worksheets.
3. Determine whether students understand the concepts involved by noting several things on each worksheet and during the short presentation:
   a. Did the student draw a human body?
   b. Did the student label the new parts of the body?
   c. Did the student explain to the class his or her new design (i.e. the new parts and their purposes)?

Lesson Extensions

1. (Engineering) Show students pictures of mechanical tools that perform tasks similar to body parts (a steam shovel for biting like a mouth, a robotic arm for grasping, etc.) and discuss the similarities and differences.
2. (Engineering) Have students build a model of the human being out of simple materials. Have them list the materials used and for what reasons.

Attachments

1. Human Blueprint

Troubleshooting Tips

1. It may be helpful to draw an example of a modified human being in front of the class to point students in the correct direction. One example for this would be a mountain climber, replacing his hands with hooks, feet with claws, etc.
2. A "word bank" may be helpful. During the initial conversation with the class about parts of the human body that are used in the same way as tools, list on a white or blackboard the body parts and the tools they are similar to, when a student says them. For example:

Body Part	Tool/Machine
Hand/Arm	Wrench, Crane, Lever, Screwdriver, Forklift, Utensils, Paddle
Leg	Elevator, Spring
Foot	Wheel, Ski, Propeller
Torso/Back	Frame, Hinge
Brain	Computer
Teeth/Mouth	Scissors, Saw, Utensils

Safety Issues

None

Additional Resources

None

Human Blueprint

Name: ______________________________________ Date: ________________

For what activity are you designing your human? ______________________________

Draw your human in the space below. Please label the parts of your human.

2.C.2 Ramps/Motion

Investigating motion using the Engineering Design Process

Grade Level	2
Sessions	1 - 50 minutes
Seasonality	None
Instructional Mode(s)	Small Groups
Team Size	3-4 students
WPS Benchmarks	02.SC.TE.03; 02.SC.TE.04; 02.SC.IS.01; 02.SC.IS.02; 02.SC.IS.03; 02.SC.IS.04; 02.SC.IS.05; 02.SC.IS.06;
MA Frameworks	K-2.TE.04
Key Words	Structure, Build, Shelter, Engineering Design Process

Summary

This lesson introduces children to the idea of “motion” as well as a basic version of Newton’s Laws. Students are allowed to explore motion through creating a simple track system to overcome several obstacles. Additional objectives include the strengthening of teamwork and manipulative skills, and the provision of a context in which students use the Engineering Design Process.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 2

1. **02.SC.IS.01** Ask questions about objects, organisms, and events in the environment.
2. **02.SC.IS.02** Tell about why and what would happen if?
3. **02.SC.IS.03** Make predictions based on observed patterns.
4. **02.SC.IS.04** Name and use simple equipment and tools to gather data and extend the senses.
5. **02.SC.IS.05** Record observations and data with pictures, numbers, or written statements.
6. **02.SC.IS.06** Discuss observation with others.
7. **02.SC.TE.03** Identify and describe the safe and proper use of tools and materials (e.g. glue, scissors, tape, ruler, paper, toothpicks, straws, spools) to construct simple structure.

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

Additional Learning Objectives

1. Students will understand that objects require a force on them to make them move, and that objects will move until something stops them
2. Students will learn different ways objects can begin moving and what each way can be used for.
3. Students will work with other members of a group to problem-solve, design, and create a track which guides an object across several obstacles.

Required Background Knowledge

None

Essential Questions

1. How do objects move?
2. How do objects stop moving?
3. What are ways that objects can begin moving?
4. What are the first steps in the Engineering Design Process?

Introduction / Motivation

The instructor can introduce students to the concepts of motion and how a force, like pushing, pulling, dropping, throwing, etc. creates motion and that an object in the way stops motion, and that an object will not go without being moved. The instructor can demonstrate dropping a ball, rolling a ball, letting a ball roll downhill, and having a ball jump off a ramp. The instructor can also ask what things move and what causes them to move (i.e. rollercoaster, car, boat, etc).

Procedure

Part 1: (50 minutes)

1. Discuss the idea of motion again with the students. Introduce gravity and discuss how objects fall when they do not have anything underneath them. Also, discuss how ramps can be used to direct motion upwards.
2. Place the students into small groups (3-4 students)

3. Introduce the challenge of getting an object from one point to another using the track without touching or pushing the object. Show them how the track guides the object, and give them a specific starting point and ending point.
4. Allow the students to work in teams, and experiment with the challenge.
5. When completed, introduce obstacles between the two points. Vary the width and height of the obstacles to require that some be gone over and some be gone around.
6. Hand out blueprints (attached) and have the students design a track shape to overcome the obstacles.
7. Have each group build and test their track one at a time.
8. Discuss with the students what worked, what did not, and why.

Materials List

Materials per class	**Amount**	**Location**
Foam rubber pipe insulation, cut in half lengthwise	12 feet total length	Hardware store
Tape (for connecting track)	1 roll	Hardware store
Obstacles of various sizes and shapes (desks, chairs, etc.)	At least 1, no limit.	Classroom

Materials per Student	**Amount**	**Location**
Ball or marble sized to fit type of track	1	Toy or sporting goods store
Blueprint sheets	1	Attached

Vocabulary with Definitions

1. *Motion* – The word for when an object is moving
2. *Gravity* – A force that causes objects to fall
3. *Ramp* – A simple machine, which allows moving, objects to change direction up or down

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Observe student groups at work.

2. Collect student worksheets.
3. Determine whether students understood the Engineering Design Process.
4. Determine whether students understand the concepts involved.

Lesson Extensions

1. (Engineering) Discuss with students various real-life vehicles, how they move, and handle obstacles. Introduce students to other ways objects can move (i.e. engines)
2. (Engineering) If using toy cars, introduce students to wheels, axles, and how they roll when put in motion. Discuss how real life vehicles use them.
3. (Engineering) Have the students design a complete rollercoaster around the classroom. See if they can get the marble to come back to it's starting point.

Attachments

1. Track Blueprint

Troubleshooting Tips

1. If time does not allow testing each student's ramp, have the students decide as a group the best way around each obstacle.

Safety Issues

None

Additional Resources

FOSS Kit # WX742-5015

Finish

Start

Name________

Track Blueprint

2.C.3 Balancing Crane

The Engineering Design Process in the classroom

Grade Level	2
Sessions	1 – 40 minutes 2 – 30 minutes
Seasonality	None
Instructional Mode(s)	Whole class, groups of 4–5 students, individual
Team Size	None
WPS Benchmarks	02.SC.IS.03; 02.SC.IS.04; 02.SC.IS.05; 02.SC.IS.06; 02.SC.TE.03; 02.SC.TE.04
MA Frameworks	K-2.TE.1.3; K-2.TE.2.1
Key Words	Counterweight, Crane, Fulcrum, Balance, Balance Point, Lever, Predict, System, Weight

Summary

This lesson works in conjunction with the Balance and Motion, and Simple Machines lessons. In this activity, each student will experiment with balance and motion. To begin, the students will mimic a demonstration, initially performed by the teacher, with rulers about center of gravity and balance. Next, the teacher will demonstrate how a construction crane is a real life engineering application of balance. Then the students will use small levers to understand balance hands-on, graduating to the larger crane to solve a problem based on observations and predictions. The students will have the task of moving an object from one pod to another using the crane, requiring them to predict how to solve the problem and give an explanation based on solid evidence. The students will learn how to predict and test, as well as proper tool use and material properties. This lesson focuses on the functionality of a design.

Session 1: Balance

Summary of Session

The teacher will demonstrate the concept of balance using a yardstick, and challenge the students to prove that there is a balance point to simple objects, thereby making their own definition for balance.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 2

Students will…

1. **02.SC.IS.03** Make predictions based on observed patterns.
2. **02.SC.IS.04** Name and use simple equipment and tools to gather data and extend the senses.
3. **02.SC.IS.05** Record observations and data with pictures, numbers, or written statements.
4. **02.SC.IS.06** Discuss observation with others.
5. **02.SC.TE.03** Identify and describe the safe and proper use of tools and materials (e.g. glue, scissors, tape, ruler, paper, toothpicks, straws, spools) to construct simple structure.
6. **02.SC.TE.04** Identify tools and simple machines used for a specific purpose, e.g., ramp, wheel, pulley, lever.

Additional Learning Objectives

Students will make connections between balance and gravity, identifying simple ways to find the balance point of certain objects.

Required Background Knowledge

For the students…

1. The students should have some idea of what makes something balanced. Fine motor skills and an awareness of balance are not required, but helpful.

For the teacher…

1. The center of gravity is the balancing point of an object. The demonstration of finding the balance point of a yardstick is based on friction. When you support the yardstick at the very ends with two forward pointing fingers, both fingers support

equal halves of the weight. As you slide your fingers together, one is moving faster toward the center than the other is. The faster moving finger leaves more of the yardstick behind it, effectively supporting more weight. This will cause the yardstick to press down more on the faster moving finger because of gravity, and the slower moving finger now moves faster than the other does. Both fingers trade moving faster and supporting more weight until you bring them to the center of the yardstick, because more weight makes more friction on the supportive finger. You will always bring your two fingers to the center (balance point) of the yardstick as long as you move them at a slow enough pace and start at equidistant positions.

Essential Questions

1. What makes an object balanced?
2. What did you predict about how to balance your ruler and can you explain why?
3. Can you come up with rules to follow to find the balance point of an object?

Introduction / Motivation

The students' motivation for this exercise is that they will have time to experiment hands-on how to find the balance point of the rulers and make their own definition for what balance is.

Procedure

Part 1

1. The teacher will introduce the general concept of balance, including vocabulary such as the balance, balance point, weight, counterweight, crane, fulcrum, lever, predict, and system.
2. The teacher will demonstrate how to find the balance point of a yardstick by slowly sliding his or her forward pointing finger from the ends of a yardstick to the center.
3. Ask the students to think why this always works with a yardstick (a symmetrical object).
4. Next, the teacher will start with two different finger positions, such as one finger at the end and the other ¼ of the way toward the center.

5. Ask the students to think about what causes this similarity in results.

Part 2

1. Give each of the students a 12-inch ruler, and ask them to predict where the balance point will be.
2. They will find the balance point of it by experimenting and testing their predictions using the same steps as in Part One, finally coming up with a definition of balance for themselves.

Materials

Materials per class	Amount	Location
Lever/Crane Kit	One	Lesson Kit

Materials per student	Amount	Location
12-inch Ruler	One per student	School Supply

Vocabulary with Definitions

1. *Balance Point/Fulcrum* – where a lever balances
2. *Counterweight* – the opposite weight that makes both sides equal
3. *Gravity* – gravitational attraction of the Earth's mass for bodies at or near its surface
4. *Predict* – to say what will happen based on what you know or think
5. *Weight* – a measure of how much gravity is pulling on something

Assessment / Evaluation of Students

1. Can the students successfully balance their rulers, and explain why? If they cannot balance the rulers, can the students explain why not?
2. Can the students define balance?

Lesson Extensions

1. Introduce the concept of friction and how it is a force which both allows objects to stay in one place and slows down moving objects.

Attachments

None

Troubleshooting Tips

If the students cannot replicate the teacher’s yardstick demonstration with their rulers, they can try to change the start point of their fingers, slide their fingers slower, use a heavier ruler, or use the teacher’s yardstick.

Safety Issues

None

Additional Resources

Activity #2. Retrieved November 17, 2005, from the Power to Learn Web site: http://www.powertolearn.com/spotlights/discovery/fun_experiments.shtml

Session 2: Problem Introduction, Prediction, and Testing

Summary of Session

The teacher will refresh the students understanding of balance, including specific vocabulary included in balancing objects. The teacher will include how engineers use balance in structures and machines they design. For reference, machines such as crane or drawbridge, and a structure would be a bridge or a balcony. The teacher should explain that engineers use balance to solve real life problems, and that the students will use a simple machine to move an object from one “pod” or place to another using balance. The students will observe relationships between weights on either end of the crane, and predict and recognize patterns as they place them on a crane.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 2

Students will…

1. **02.SC.IS.03** Make predictions based on observed patterns.
2. **02.SC.IS.04** Name and use simple equipment and tools to gather data and extend the senses.
3. **02.SC.TE.03** Identify and describe the safe and proper use of tools and materials to construct a simple structure.
4. **02.SC.TE.04** Identify tools and simple machines used for a specific purpose.

Additional Learning Objectives

Students will make connections between balance and real-life engineering, such as a large crane that uses weights to balance, as well as a drawbridge.

Required Background Knowledge

For the students:

1. The students should have some idea of what makes something balanced. Fine motor skills and an awareness of balance are not required, but helpful.

For the teacher:

1. A drawbridge or a crane is a lever where the fulcrum is not always in the middle; the length between the center of a lever (fulcrum) and the ends are the

"resistance arm" and "effort arm." The resistance arm is the side of the lever where the load you want to move is. The effort arm is the side of the lever where the effort is applied. In a crane, the effort arm is long end that extends from the fulcrum to the load. The resistance arm is the short arm (with lots of weight) which is used to balance the crane.

Essential Questions

1. What makes an object balanced?
2. What things do you know about that use balance to work?
3. How will you move the specified objects using your knowledge of balance?
4. What steps will you take to balance objects on the crane?
5. What can you predict if this object's weight is changed?

Introduction / Motivation

The students get to decide for themselves how they will move the crane with different weights to complete the challenge.

Procedure

Part 1 (for the Teacher to demonstrate)

1. Assemble the large crane, naming the fulcrum of the crane. (Pictorial instructions are provided in the kit)
2. Balance the crane with no weight. (A cross is provided to mark the dry balance point)
3. With the crane in this balance position, rotate the crane around the fulcrum, demonstrating that the crane can move/rotate in its balance position.
4. Place 2 screws in the basket. The crane should tip toward the basket side. Move the fulcrum of the crane toward the basket, so that it balances again. (All available fulcrum positions are numbered)
5. To use the crane, place a bolt* (moved bolt noted with a *) on the floor. Remove one bolt from the basket. The magnet end will drop to the floor. Rotate the crane to "catch" the bolt* on the magnet. Place enough bolts into the basket to rebalance the crane.

6. Rotate the crane to a new position. Remove bolts from the basket to drop the magnet to the floor.
7. Remove the bolt* from the magnet, and place bolts in the basket to rebalance the crane.
8. The teacher may demonstrate this procedure again.

Part 2 (for the students to do at their desks)

1. Ask the students to take out their 12-inch ruler.
2. Provide each student with a fulcrum (small gray plastic prism) and handful of weights.
3. Ask the students to balance the ruler on the fulcrum block.
4. Allow the students to experiment with different fulcrum positions and weights.

Part 3

1. Now that the students have hands-on experience with their levers, they may use the large crane to complete the challenge of moving bolts from one pod to another.
2. Ask the students what they will do to complete the challenge, and then what they predict will happen and why, based on their observations of the teacher's demonstration and their hands-on experience with 12-inch levers. Specifically, where will they choose to be the fulcrum, how much weight they want to move, how much counterweight they will need, and why.

Materials

Materials per class	Amount	Location
Lever/Crane Kit	One	Lesson Kit

Materials per student	Amount	Location
12-inch Ruler	One	School Supply
"Balancing Crane" Worksheet	One	PIEE/WPI Graduate Fellows

Vocabulary with Definitions

1. *Balance Point/Fulcrum* – where a lever balances

2. *Counterweight* – the opposite weight that makes both sides equal
3. *Crane* – A machine for hoisting and moving objects by means of a swinging arm
4. *Gravity* – gravitational attraction of the Earth's mass for bodies at or near its surface
5. *Lever* – a simple machine that tries to move a weight through space
6. *Predict* – to say what will happen based on what you know or think
7. *Weight* – a measure of how much gravity is pulling on something

Assessment / Evaluation of Students

1. Can the students determine the proper placement of weights to balance the lever arm on top of the crane?
2. The students will identify the crane by saying: It has a base. It has arms. It has a balance point. (Name it. Hold it. Explain it. Demonstrate it.)

Lesson Extensions

Magnetism and the Compass

Attachments

1. Balancing Crane worksheet

Troubleshooting Tips

The balance and crane lesson will result in trial and error, which is very common in the Engineering Design Process. It is not expected that all students will have the fine motor skills to operate the crane, which is why the teacher can help position it based on the students’ directions.

Safety Issues

1. When the students work with levers at their desks, make sure that they do not end up making catapults and launching weights across the room by directing them to slowly weight both ends.
2. The crane will be about the same height as the students, and when they swing the arm around to aim for the pods, make sure they keep a safe distance from the weighted ends, and that no heavy weights drop on their toes.

Additional Resources

None

Name: ______________________________ Date ___________

Balancing Crane

What parts of a crane can you draw?

What parts of a crane can you label?

2.C.5. Pulleys and “The Amazing Mine”

The Engineering Design Process in the classroom

Grade Level	2
Sessions	1 – 30 minutes 2 – 30 minutes
Seasonality	None
Instructional Mode(s)	Whole class, groups of 4–5 students, individual
Team Size	None
WPS Benchmarks	02.SC.IS.01; 02.SC.IS.02; 02.SC.IS.03; 02.SC.IS.06; 02.SC.TE.02; 02.SC.TE.04;
MA Frameworks	K-2.TE.1.2; K-2.TE.2.1
Key Words	Simple Machine, Pulley, Wheel, Rope

Summary

This lesson works in conjunction with the Balance and Motion, and Simple Machines lessons. In this activity, each student will be given an opportunity to experiment with a simple pulley. Each student should discover that pulleys do make lifting easier. The students should then discuss with the teacher places where people use pulleys for lifting. The teacher should then read “The Amazing Mine” story, which illustrates the uses of pulleys, levers and ramps to make work easier. The students should predict how the miner will use the simple machines.

Session 1: Balance

Summary of Session

This session will introduce the students to the concept of a pulley.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 2

Students will…

02.SC.IS.01 Ask questions about objects, organisms, and events in the environment.
02.SC.IS.02 Tell about why and what would happen if?
02.SC.IS.03 Make predictions based on observed patters.
02.SC.IS.06 Discuss observations with others.
02.SC.TE.04 Identify tools and simple machines used for a specific purpose.

Additional Learning Objectives

Students will apply their knowledge of simple machines to real-world examples.

Required Background Knowledge

For the students…

None

For the teacher…

Pulleys functions by reducing the total work done, to increase the power of the work.

For example: in a 2x pulley (the pulley system provided in the kit), each 1 ft pull of the rope, only moves the pulley ½ ft.

Pulleys are used for many activities. Sailor use pulleys to pull in the boom and sail. The Egyptians used pulleys to pull the large stone blocks up the sides of the pyramids. Cranes use pulleys to lift heavy loads up into the air.

Essential Questions

1. Does a pulley make work easier or harder?
2. How do people use pulleys to make work easier?

Introduction / Motivation

The students' motivation for this exercise is that they will have time to experiment hands-on how to discover that a pulley makes work easier.

Procedure

1. Set up pulley assembly by securing the loop to the ceiling, or other high place, such as a doorframe.
2. Fill the bucket with nuts and bolts for weight.
3. Allow the students to attempt to lift the bucket by grabbing all of the ropes and lifting up (without using the pulley). Then the students should try to lift the weight by pulling on the free end of the rope.
4. Ask the students, which was easier. If they think it was easier without the pulley ask them to try again
5. After each student has attempted the experiment, discuss how pulleys are used.

Materials

Materials per class	Amount	Location
Pulley Kit	One	

Vocabulary with Definitions

1. Pulley – A simple machine, which uses wheels and rope to make work easier

Assessment / Evaluation of Students

1. Do the students recognize that a pulley makes work easier?
2. Can the students identify practical uses for pulleys?

Lesson Extensions

None

Attachments

None

Troubleshooting Tips

1. Ask the students to talk about their findings. Their shared experience with simple machines will help cement the idea that simple machines make work easier.

Safety Issues

None

Additional Resources

Session 2: "The Amazing Mine" Story

Summary of Session

In this Session, the students will listen to story about practical uses for simple machines

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 2

Students will…

02.SC.IS.01 Ask questions about objects, organisms, and events in the environment.
02.SC.IS.02 Tell about why and what would happen if?
02.SC.IS.03 Make predictions based on observed patters.
02.SC.IS.06 Discuss observations with others.
02.SC.TE.02 Identify and explain some possible uses of natural materials and human materials.
02.SC.TE.04 Identify tools and simple machines used for a specific purpose.

Additional Learning Objectives

Students will begin to use their imaginations to consider additional scenarios where they might use levers, ramps, and pulleys.

Required Background Knowledge

None

Essential Questions

6. How can the Miner move his gold over a ledge?
7. How can the Miner move his gold up a mine shaft?
8. How can the Miner move the heavy boulder?

Introduction / Motivation

This is a simple story, and the students should be encouraged to make predictions.

Procedure

3. Read "The Amazing Mine" story, stopping periodically to ask the students to predict how the miner might solve the latest problem.

Materials

Materials per class	Amount	Location
"The Amazing Mine" Story	One	

Vocabulary with Definitions

None

Assessment / Evaluation of Students

3. Can the students make reasonable predictions how the miner might solve the problems?
4. Are the students active listeners during the story?

Lesson Extensions

The students may choose to write/illustrate their own stories, in which the main character uses simple machines.

Attachments

None

Troubleshooting Tips

1. Students may enjoy reading the story more than once.
2. Depending on the students comfort with the concept of simple machines, ask the students to think about why each modification to the simple machines used in the store makes the work even easier.

Safety Issues

None

Additional Resources

None

2.D.1 Towers

Engineering Design Process in the classroom

Grade Level	2
Sessions	1 – 30 minutes 2 – 30 minutes
Seasonality	None
Instructional Mode(s)	Whole class
Team Size	None
WPS Benchmarks	02.SC.IS.01; 02.SC.IS.03; 02.SC.IS.04; 02.SC.IS.05; 02.SC.IS.06; 02.SC.TE.01
MA Frameworks	K-2.TE.1.1; K-2.TE.1.2; K-2.TE.1.3; K-2.TE.2.1
Key Words	Manmade, Natural, Stable, Tower

Summary

In this lesson, students will construct a tower from natural and manmade materials. Students will use the engineering method to plan their tower, identify which natural or manmade materials best suit their purpose, identity what makes a tower stable, construct a tower, and complete a written, self-evaluation. The lesson is meant to focus on both structures and the uses of natural and manmade materials.

Session 1: Problem Introduction, Prediction, and Testing

Summary of Session

The teacher will cover natural and manmade materials, highlighting materials that are used in construction. Several existing towers will be shown to the students, and the students will be asked to identify features of the towers. The students will design their towers in a blueprint and be presented with the challenge of building their own towers.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 2

Students will…

1. **02.SC.IS.01** Ask questions about objects, organisms, and events in the environment.
2. **02.SC.IS.03** Make predictions based on observed patterns.
3. **02.SC.IS.04** Name and use simple equipment and tools to gather data and extend the senses.
4. **02.SC.IS.05** Record observations and data with pictures, numbers or written statements.
5. **02.SC.IS.06** Discuss observations with others.
6. **02.SC.TE.01** Identify and describe the characteristics of natural materials and human made materials.

Additional Learning Objectives

1. Students will make connections between balance and real-life engineering, such as in building structures.

Required Background Knowledge

For the students:

1. The students should have some idea of what makes something balanced, as well as some background in constructing structures. Fine motor skills and an awareness of balance are not required, but helpful.

For the teacher:

1. Towers are not limited to manmade structures. Towers can also be natural like those seen in many landscapes. Students should be encouraged to note the similarities between these structures.

Essential Questions

3. What makes an object balanced?
4. How does a tower stay upright?
5. Where do natural materials come from?
6. What kinds of materials do engineers use to build structures?

Introduction / Motivation

If students are studying other cultures in social studies, towers in other countries could lead into this lesson. The pictures provided at the end of this lesson are of towers from France, China, Pakistan, and the USA.

Procedure

Part 1

1. Discuss with the students natural and manmade materials, and have the students define what a natural material is (it grows, it comes from nature/the earth).
2. Ask the students to name some natural and manmade materials, which might be used for construction. If students have trouble try and relate back to social studies, i.e. some Native Americans used poles (wood) and buffalo skins to make their homes.

   The Eifel Tower is made of steel.

   The Washington Monument is made of granite.

   Other construction materials are brick, wood, plastic (vinyl siding), and glass
3. Show the students the sample materials
4. If time allows, the students may wish to handle the materials (The “glass” is actually plastic for safety reasons).
5. Provide the students with the materials list and ask them to identify what materials they will use.

6. Provide the students with the blueprint worksheet and ask them to draw their proposed tower.

Part 2

5. Ask the students to take out their blueprints and materials list.
6. Pass out the materials based on the materials listed on their worksheets. Students may also require tape and scissors.
7. Allow the students to build their models (25 – 30 minutes).
8. Once the students have completed their towers, have them write about their tower. Suggested sentences are:

    What materials did you use? (2)

    What do you like about your tower? (1)

    What would you change about your tower? (1)

Materials

Materials per class	Amount	Location
Tape	Undefined	Classroom supply

Materials per class	Amount	Location
Soda Straws	15 per student	Craft Supply Store
Popsicle Sticks	15 per student	Craft Supply Store
Pipe Cleaners	5 per student	Craft Supply Store
Cardboard Base (~6 in sqr)	1 per student	Recycled
Soda Cans	2 per student	Recycled
String	3 feet per student	Craft Supply Store

Vocabulary with Definitions

2. *Natural* – Made from material, which exists without being created by people
3. *Manmade* – Materials created by chemical reactions or refinement
4. *Tower* – Freestanding structure
5. *Blueprint*– A drawing of an object you plan to build. A map of how something will be constructed.

Assessment / Evaluation of Students

3. Are the towers wide at the base, but still taller than they are wide? If not, then are the towers steady?

4. Can the students distinguish between natural and manmade?
5. Do the students use their “Blueprint” and “Materials” worksheets?

Lesson Extensions

1. Students may wish to continue with the engineering process and test their towers. Using and fan, water mister, and moving the base, the teacher can simulate high winds, rain and an earthquake. Students can then write about what they observer. Since their towers maybe damaged, students should be allowed to rebuild, since the students will feel proud of the physical tower.

Attachments

1. “Blueprint” Worksheet
2. “Materials” Worksheet

Troubleshooting Tips

1. Showing the students a tower model that has been made prior to lesson presentation will give them a general idea of how to use materials, such as how to tape cans and build bracing to make a strong tower.
2. Some students may have trouble with fine motor skills, or conceptualizing their tower. Teacher assistance may help the students begin to design their own tower. Students may also be overwhelmed by the list of materials. Try to select specific materials, and ask what they might use that material for. “What might you use the soda can for?”

Safety Issues

None

Additional Resources

1. Google, or other search engine on the internet, for “Towers” will provide the students with pictures of many different towers from around the world.

TOWER DESIGN

Name: ___________________________________ **Date:** _______________

Material	**Manmade or Natural?**	**Why are you using this material for your tower?**
Popsicle Sticks	Manmade Natural	
Lightweight cardboard	Manmade Natural	
String	Manmade Natural	
Aluminum Cans	Manmade Natural	
Clear Tape	Manmade Natural	
Plastic Drinking Straws	Manmade Natural	

My Tower	Name:

Figure 12: Bank of China Tower, Hong Kong, China

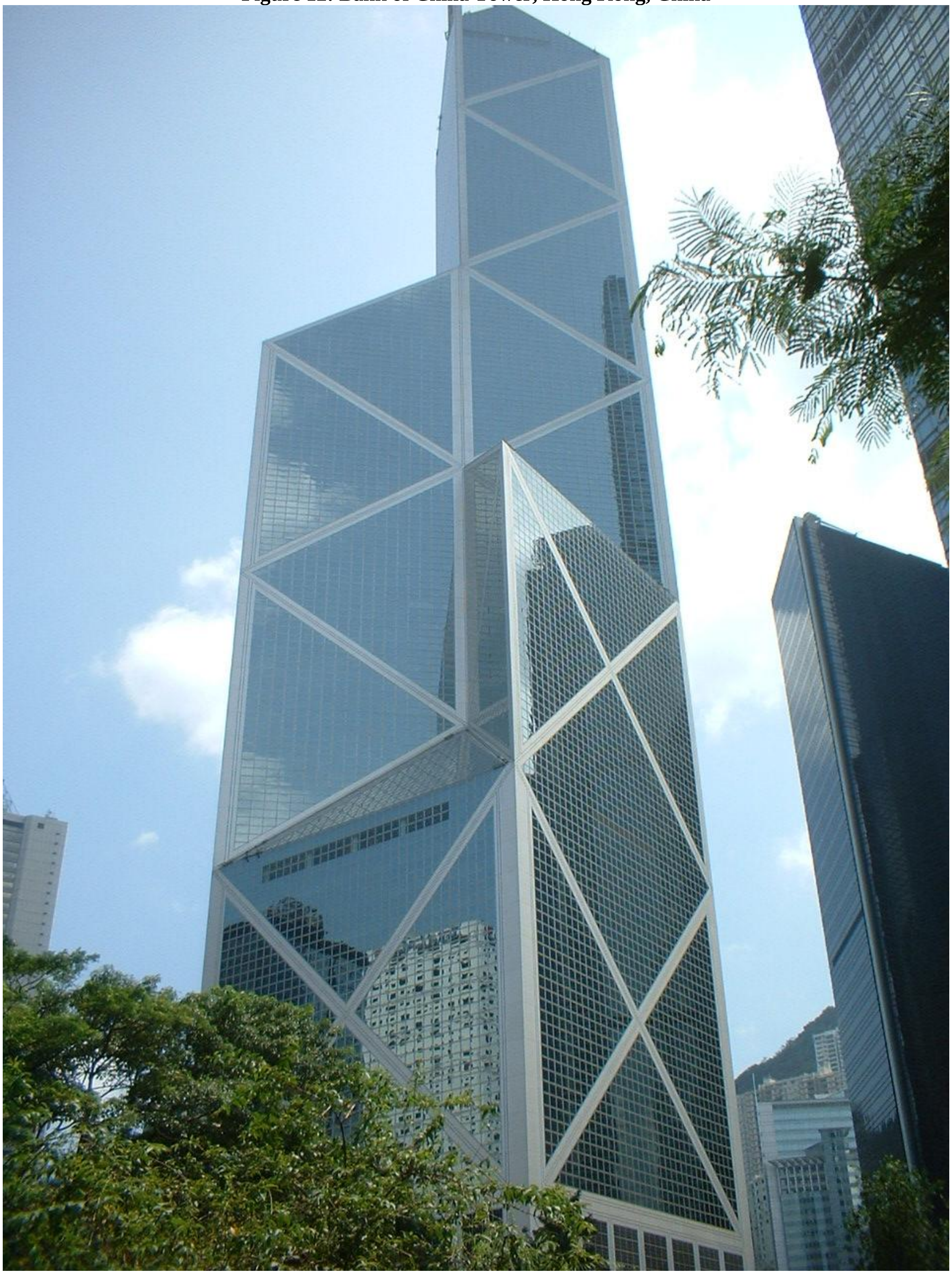
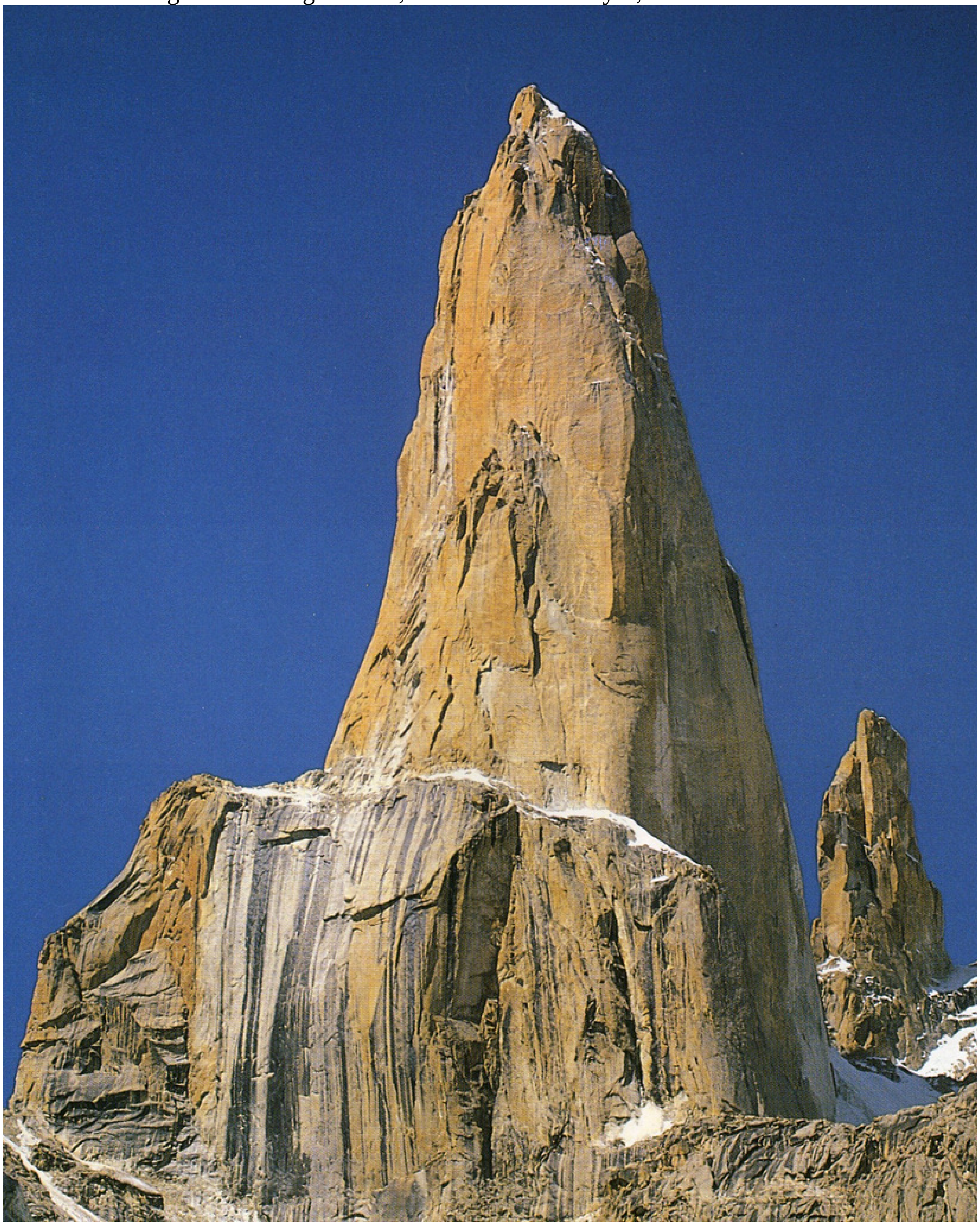


Figure 13: Eiffel Tower, Paris, France

Figure 14: Goodman Hill Fire Lookout Tower, Pierce County, Washington, USA

Figure 15: Washington Monument, Washington, D.C., USA

Figure 16: Trango Tower, Karakoram Himalayas, Northern Pakistan



Appendix L: Third Grade Lessons

3.C.1 Phases of the Moon 405

3.A.1 Sparky's Engineer

Exploring various types engineering

Grade Level	3
Sessions	(1): 1 at 50 minutes
Seasonality	Suggested as introduction to Technology/Engineering
Instructional Mode(s)	Whole class, Individual
Team Size	N/A
WPS Benchmarks	None
MA Frameworks	None
Key Words	Aeronautical Engineer, Biomedical Engineer, Chemical Engineer, Civil Engineer, Electrical Engineer, Engineer, Fire Protection Engineer, Mechanical Engineer, Software Engineer

Summary

The children's book Sparky's Engineer introduces students to a variety of engineering professions. A "Know, Want to know, Learned" (KWL) chart introduces the lesson. A worksheet with writing prompts concludes the lesson by allowing students to explain their knowledge of one particular type of engineering.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

This lesson does not address individual WPS Benchmarks; rather, it introduces students to various types of engineering and prepares them to learn about the Engineering Design Process (EDP).

2001 Massachusetts Frameworks for Grade 3

This lesson does not address individual MA Frameworks; rather, it introduces students to various types of engineering and prepares them to learn about the Engineering Design Process (EDP).

Additional Learning Objectives

1. Students will learn to identify various types of engineering (mechanical, fire protection, biomedical, etc.).
2. Students will learn to describe the functions of various types of engineers (design software, design buildings, etc.).

3. Students will recognize that (a) engineering, as a profession, is accessible to them, and that (b) engineers are a diverse group of people.

Required Background Knowledge

None

Essential Questions

1. What is an engineer?
2. What is a(n):
    a. Aeronautical Engineer
    b. Biomedical Engineer
    c. Chemical Engineer
    d. Civil Engineer
    e. Electrical Engineer
    f. Fire Protection Engineer
    g. Mechanical Engineer
    h. Software Engineer?
3. What type of job does each engineer do?
4. What perception of engineering does one have before reading Sparky's Engineer? After?

Introduction / Motivation

The instructor might begin the lesson with a KWL chart: "What do we **Know**, What do we **Want** to know, What did we **Learn**" (see Appendix A: Instructor's Notes). (S)he might ask students whether or not more than one type of engineer exists (5 minutes).

Procedure

1. Read Sparky's Engineer to the class using the Teacher's Edition.
2. Lead students through the attached worksheet (see Sparky's Engineer).
3. If time permits, students may complete additional writing prompts (see Lesson Extensions) or share worksheet responses with the class.

Materials List

Materials per class	Amount	Location
Sparky's Engineer: Teacher's Edition Children's Book	One	Worcester Polytechnic Institute

Materials per student	Amount	Location
Sparky's Engineer Worksheet	One	End of lesson plan – print or photocopy

Vocabulary with Definitions

1. *Aeronautical Engineer* – designs machines that fly such as airplanes and spaceships.
2. *Biomedical Engineer* – designs tools used by doctors, nurses and technicians; the tools assist the sick, injured, or disabled and include wheelchairs, medicine, stitches and prosthetics.
3. *Chemical Engineer* – designs chemicals and chemical products through chemical processes; products may include air filters, rocket fuel, and non-freezing pipes.
4. *Civil Engineer* – designs tunnels, roads, buildings, bridges, and dams using various materials such as soil, rocks, and concrete.
5. *Electrical Engineer* – designs electrical circuits found in items such as radios, televisions and computers.
6. *Engineer* – uses ideas from science and math to help people do work faster and better; helps people stay healthy, safe, and comfortable; uses tools to draw, build, and invent.
7. *Fire Protection Engineer* – designs systems to help prevent and respond to fire in various structures.
8. *Mechanical Engineer* – designs machines and devices that have moving parts such as automobiles and various other types of machines.
9. *Software Engineer* – designs computer programs.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Note class participation during reading of Sparky's Engineer.
2. Read entries in Engineering Journals; determine whether students understand a type of engineering and can articulate the reasons for selecting the given type.

Lesson Extensions

1. The instructor might use this lesson as an introduction to the Technology/Engineering and the Engineering Design Process.
2. Ask students to respond to additional writing prompts such as:
    a. Would you like to be an engineer? Why/why not?
    b. Has your perception of engineering changed since reading Sparky's Engineer?
    c. Describe three facts that you learned while reading Sparky's Engineer.

Attachments

1. Sparky's Engineer Worksheet

Troubleshooting Tips

None

Safety Issues

None

Additional Resources

None

Appendix A: Instructor's Notes

The following is an example of a KWL chart:

KWL Chart

What do we **Know**?	What do we **Want** to know?	What did we **Learn**?

Sparky's Engineer

Name: ______________________ Date: _________________

1. What is your favorite type of engineer from <u>Sparky's Engineer?</u>

____

2. What does this type of engineer do?

____

____

____

____

3. If you could be an engineer, what kind of engineer would you like to be? Why?

____

____

____

____

4. If you have time, draw a picture of something that your favorite type of engineer might design. Use the back of this worksheet.

3.B.1 Tree House

Model tree house construction and selection of appropriate materials and tools

Grade Level	3
Sessions	(5): 1 at 35 minutes, 4 at 50-80 minutes
Seasonality	Recommended for autumn
Instructional Mode(s)	Whole Class, Small Groups
Team Size	2-4 students
WPS Benchmarks	03.SC.TE.01, 03.SC.TE.02, 03.SC.TE.03, 03.SC.TE.04, 03.SC.TE.05, 03.SC.IS.03
MA Frameworks	3-5.TE.1.1, 3-5.TE.1.2, 3-5.TE.2.1, 3-5.TE.2.2, 3-5.TE.2.3
Key Words	Engineering Design Process, Material, Model, Structure, Tool, Tree House

Summary

The five parts of this lesson introduce children to the idea of "structure". They provide an opportunity for students to design and construct a model tree house, and to select and use appropriate materials and tools. Additional objectives include the strengthening of teamwork and manipulative skills and the provision of a context in which students use the Engineering Design Process.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.01 Identify materials used to accomplish a design task based on a specific property, e.g., weight, strength, hardness, and flexibility.
2. 03.SC.TE.02 Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.
3. 03.SC.TE.03 Identify a problem that reflects the need for shelter, storage, or convenience.
4. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
5. 03.SC.TE.05 Develop a knowledge and understanding of the metric measurement system.
6. 03.SC.IS.03 Keep accurate records while conducting simple investigations or experiments.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.1.1 Identify materials used to accomplish a design task based on a specific property, i.e., weight, strength, hardness, and flexibility.
2. 3-5.TE.1.2 Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.
3. 3-5.TE.2.1 Identify a problem that reflects the need for shelter, storage, or convenience.
4. 3-5.TE.2.2 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
5. 3-5.TE.2.3 Identify relevant design features (e.g., size, shape, weight) for building a prototype of a solution to a given problem.

Additional Learning Objectives

1. Students will learn that materials can be manipulated to make use of their inherent properties.
2. Students will improve fine-motor skills through construction of functional structures.
3. Students will work with other members of a group to problem-solve, design, and create a model structure.

Required Background Knowledge

None

Essential Questions

1. What is a structure (see Vocabulary with Definitions)?
2. What properties or characteristics are important when selecting a material for a specific purpose?
3. How does one apply the Engineering Design Process to a particular design challenge?

Introduction / Motivation

The instructor might begin the lesson by asking students to recall various engineering professions, explained in the children's book Sparky's Engineer. Students may share their knowledge of tree houses in general, and more specifically, of the types of materials appropriate for building a tree house. A visible "KWL" chart, or a "What do we **Know**, What do we **Want** to know, What did we **Learn**" chart (see Appendix A: Instructor's Notes), may help students conceptualize the idea of a model tree house.

Procedure

The instructor will:

Part 1: (35 minutes)

1. Lead students through the "K" and "W" portions of a KWL chart.
2. Read the children's book Tree House aloud to students.
3. Encourage student involvement throughout the reading by asking them to relate previous knowledge to the idea of building a model tree house.
4. Complete the "L" portion of a KWL chart.

Part 2: (50 – 80 minutes)

1. Divide students into pairs or small groups (2 to 4 students).
2. Show students the materials and tools available (see Materials List) for tree house design and construction.
3. Provide each student with a worksheet (see Tree House Design).
4. Explain the "Engineering Design Process" (see Appendix A: The Engineering Design Process).
5. Lead students through the Tree House Design worksheet, questions 1 and 2.
6. Consider bringing students outdoors to look at trees, focusing on those suitable for building a tree house.

Part 3: (50 – 80 minutes)

1. Ask students to reform previous groups.

2. Ask students to look at previous work on the Tree House Design worksheets; they should recall ideas about structure design and materials.
3. Allow students time to complete question 3; they should focus on *why* each selected material is the best for a given part of their model.
4. Provide each group with a large sheet of paper and lead students through question 4.

Part 4: (50 – 80 minutes)

1. Ask students to reform previous groups.
2. Ask students to look at previous work on the Tree House Design worksheets; they should recall ideas about structure design and materials.
3. Allow student groups/pairs time to construct their models.

Part 5: (50-80 minutes)

1. After all teams have built models, allow students to test the models using the water test, the wind test, and the drop test (see Appendix B: Instructor's Notes).
   a. Consider conducting the tests group-by-group, in front of the class, so that all students can observe the results of the tests.
2. Ask students to verbally describe the results of each test.
3. Ask students to complete question 5.
7. After testing, allow students to revise their models, or simply write about how they might revise the models (question 6).
8. Allow students time to measure various parts of their tree houses in centimeters and to complete the worksheet titled The Metric System.

Materials List

See attached prototype letter to parents to ask for assistance in collecting materials.

Materials per class	**Amount**	**Location**
Spray bottle with water	One	Gardening supply store, grocery store
Fan	One	Classroom, home
Meter stick	One	Classroom, office supply store

Lightweight cardboard	As needed	Recycle bin (cereal boxes, etc.)
String	One roll	Craft store
Plastic wrap	One box	Grocery store
Aluminum foil	One box	Grocery store
Popsicle sticks	100-300	Craft store
Clear tape	Two rolls	Craft store, drugstore, grocery store

Materials per student	**Amount**	**Location**
Ruler – inches/centimeters	One per group	Classroom
Glue	One bottle per group	Classroom
Scissors	One pair per group	Classroom
Tree House Design worksheet	One	End of lesson plan – print or photocopy
The Metric System worksheet	One	End of lesson plan – print or photocopy

Vocabulary with Definitions

1. *Civil Engineer* – designs tunnels, roads, buildings, bridges, and dams using various materials such as soil, rocks, and concrete.
2. *Material* – the substance used to make another product; it can be described by its properties.
3. *Model* – a small object, usually built to scale, that represents in detail another, often larger object.
4. *Structure* – an object made up of a number of parts that are held or put together in a particular way.
5. *Tool* – an object used to do work or to make work easier.
6. *Tree house* – a house built among the branches of a mature tree.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Observe student groups at work; assess group work skills, understanding of materials selection, and understanding of the engineering design process.
2. Collect student worksheets; assess understanding of materials selection, engineering design process.

3. Listen to oral responses and class discussions.

Lesson Extensions

1. Read The Indian in the Cupboard by Lynne Reid Banks: main characters build model Native American structures (longhouse, igloo, etc.).
2. Allow students to construct another model structure, such as a tent or doghouse.

Attachments

1. Appendix A: The Engineering Design Process
2. Appendix B: Instructor's Notes
3. Tree House Design
4. The Metric System

Troubleshooting Tips

1. Consider grouping students with different talents and interests together to facilitate peer-learning.
2. Circulate through the classroom during all sessions. Leading questions, such as *Why would you select that particular material…?*, seem to help students focus on construction of a working model.
3. Allowing student groups to manage themselves as much as possible, especially in the areas of dividing tasks, selecting materials, physically constructing the model, and managing their time.

Safety Issues

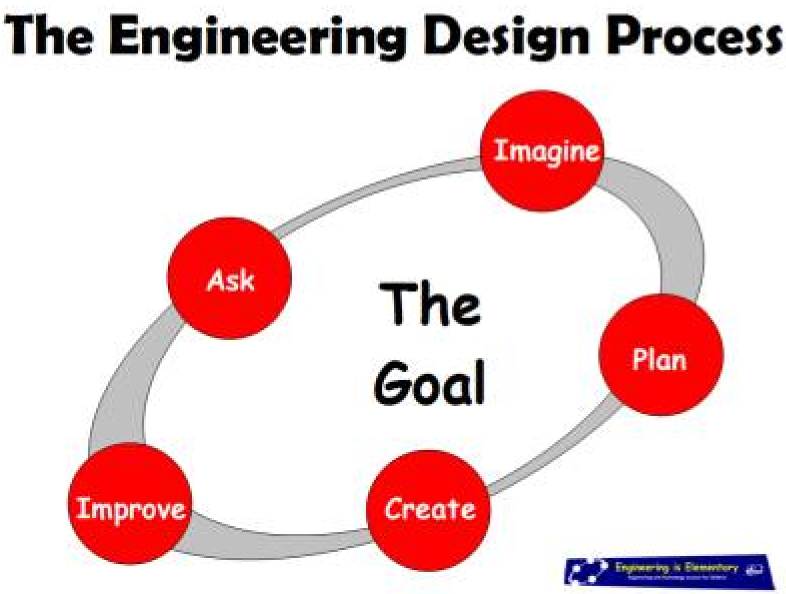
1. Scissors should be used with caution.
2. The edges of aluminum foil and plastic wrap boxes are quite sharp; the instructor should be responsible for passing out these materials.
3. Use caution when spraying the water in the "Water Test"; ensure that the water is sufficiently far away from the electric fan to preclude electrical problems.

Additional Resources

1. The Engineering Design Process for Children: http://www.mos.org/doc/1559 (accessed 7 October 2005).

Appendix A: The Engineering Design Process

“The Engineering Design Process for Children” and associated text comes directly from: http://www.mos.org/doc/1559 (accessed 2 February 2006).



“The Engineering Design Process is a series of steps that engineers use to guide them as they solve problems. Many variations of the model exist. While having a guide is useful for novices who are learning about engineering, it is important to note that practicing engineers do not adhere to a rigid step-by-step interpretation of the process. Rather there are as many variations of the model as there are engineers. Because our curriculum project focuses on young children, we have created a simple process that depicts fewer steps than other renditions and that uses terminology that children can understand. The engineering design process is cyclical and can begin at any step. In real life, engineers often work on just one or two steps and then pass along their work to another team.”

“A few questions can guide students through each of the steps:

“ASK

- What do I want to do?

- What is the problem?
- What have others done?

“IMAGINE

- What could be some solutions?
- Brainstorm ideas.
- Pick one to start with that you think will work the best.

“PLAN

- Draw a diagram of your idea.
- Make lists of materials you will need to make it.
- Decide how it works. How will you test it?

“CREATE

- Build a prototype.
- Test it.
- Talk about what works, what doesn't, and what could work better.

“IMPROVE

- Talk about how you could improve your product.
- Draw new designs.
- Make your product the best it can be!”

Appendix B: Instructor's Notes

KWL Chart

What do we **Know**?	What do we **Want** to know?	What did we **Learn**?

Create the Water Test: Simulates Rain

1. Fill a plastic spray bottle (see Materials List) with water.
2. Spread paper towels on a small desk or table at the front of the classroom.
3. Allow students to spray their model tree houses (suggested: 15 squirts per model).
4. Students should first describe verbally, and then use their worksheets (question 5) to note the effects of water on their models.

Create the Wind Test: Simulates Wind

1. Locate a small electric fan (see Materials List) and place it on a desk or table, away from the water test. ***Water and electricity should never mix***.
2. Invite student groups to the front of the classroom and allow them to hold their models in front of fan for a pre-selected amount of time (suggested: 5 seconds).
3. Students should first describe verbally, and then use their worksheets (question 5) to note the effects of wind on their models.

Create the Drop Test: Tests Strength and Flexibility

1. Tape a meter stick (see Materials List) vertically against one of the classroom walls. The bottom of the stick should be on the floor.
2. Explain to students that they will hold their model tree houses level with the top of the meter stick, and will then drop the models, allowing them to fall to the ground.
3. When student groups return to their seats, they should quietly write their observations in the chart found in question 5 of their worksheets.

Dear Parents,

As part of our Technology/Engineering curriculum, students are designing and constructing model tree houses. Students are working with materials to identify those most appropriate for model building.

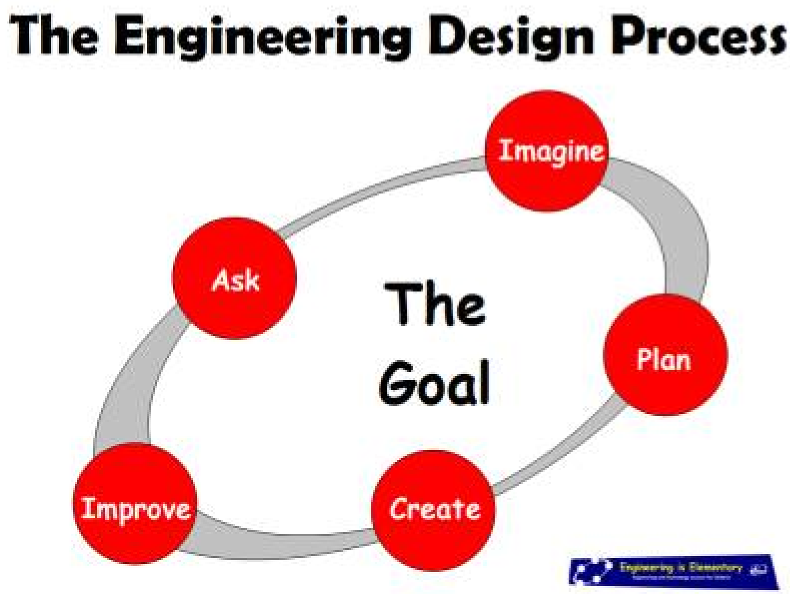
We ask that you please save a small number of boxes made from lightweight paperboard (cereal, toys, tissues, etc.) and send them to school with your child this week.

Thank you for you support!

Sincerely,

Tree House Design

Name: ______________________ Date: _________________



The Engineering Design Process for Children: http://www.mos.org/doc/1559 (accessed 7 October 2005)

1. **Ask –**

What structure do I want to build? ____

____

____

____

Aluminum Foil Lightweight Cardboard Glue String
Plastic Wrap Popsicle Sticks Clear Tape

2. **Imagine** –

Imagine that you are a civil engineer. For what purpose would you use your tree house?

____

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____

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____

How will your tree house protect you from the rain? What materials will you use to build the model?_______________________________________

____

____

____

____

Aluminum Foil Lightweight Cardboard Glue String
Plastic Wrap Popsicle Sticks Clear Tape

How will your tree house protect you from the wind? What materials will you use to build the model? ____

____

____

____

____

____

How will your tree house stay in a tree? What materials will you use to build the model?

____

____

____

____

____

____

Read the list of materials below. Think about which materials you would like to use. Beside the materials that you **will** use, write **why** you will use them.

Material	Why will you use the material to construct your tree house?
Aluminum Foil	
Lightweight cardboard	
String	
Plastic Wrap	
Popsicle Sticks	
Clear Tape	
Glue	

3. **Plan –**

On a separate sheet of paper, draw a picture of the model tree house that you would like to create. Label the parts of the tree house (wall, window, door, roof, floor, etc.). Beside each part, write which material you will use to make that part of the model. Use the chart of materials above when you plan.

4. **Create –**

Collect the materials that you need and then construct your model. Test your model with the Water Test, the Wind Test and the Drop Test. Can you think of other tests?

The Test	**What happened?**
Water Test: 15 Squirts!	

The Test	What happened?
Drop Test: 1 Meter!	
Wind Test: 5 Seconds!	

5. **Improve –**

What can you do to your tree house model to make it better?

___

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___

___

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___

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The Metric System

Name: ______________________ Date: __________________

The Metric System – In many parts of the world, people use a system for measuring called the “Metric System”. The metric system uses meters, centimeters (cm), and millimeters (mm) to describe the length of an object. Use the metric side of your ruler, marked with centimeters (cm) to answer the following questions.

1. How **tall** is the tallest part of your model tree house? ____________ centimeters
2. How **wide** is your model tree house? ____________ centimeters
3. How **long** is your model tree house? ____________ centimeters
4. What is the **perimeter** of your model tree house? ____________ centimeters

3.C.1 Materials to Build

Discussing and experiencing the properties of various materials

Grade Level	3
Sessions	(1): 1 at 20-45 minutes
Seasonality	None
Instructional Mode(s)	Whole Class
Team Size	N/A
WPS Benchmarks	03.SC.TE.01, 03.SC.TE.04, 03.SC.PS.02
MA Frameworks	3-5.TE.1.1, 3-5.TE.2.2, 3-5.PS.1.1
Key Words	Flexibility, Hardness, Material, Property, Strength, Texture, Weight

Summary

This lesson introduces students to materials and their properties; students will have the opportunity to manipulate a variety of materials and to discuss their respective properties.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.01 Identify materials used to accomplish a design task based on a specific property, e.g., weight, strength, hardness, and flexibility.
2. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagram, graphic organizers, and lists.
3. 03.SC.PS.02 Gather a variety of solid objects. Collect data on properties of these objects such as origin (man-made or natural), weight (heavy, medium, light), length, odor, color, hardness, and flexibility.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.1.1 Identify materials used to accomplish a design task based on a specific property, i.e., weight, strength, hardness, and flexibility.
2. 3-5.TE.2.2 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
3. 3-5.PS.1.1 Differentiate between properties of objects (e.g., size, shape, weight) and properties of materials (e.g., color, texture, hardness).

Additional Learning Objectives

1. Students will be introduced to the vocabulary appropriate to discussing “properties” of materials.
2. Students will consider the suitability of various materials with respect to the engineering concepts of “design” and “structure”.

Required Background Knowledge

None

Essential Questions

1. What are some important properties of materials?
2. How can various materials be described by their texture, weight, strength, hardness, and flexibility?
3. How can the properties of a material be taken into account when one designs a structure?

Introduction / Motivation

The instructor may discuss with students the meanings of the words *material*, *property*, *texture*, *weight*, *strength*, *hardness*, and *flexibility* (see Vocabulary with Definitions). (S)he may then ask students to explain or write the terms.

Procedure

The instructor will:

1. Use a collection of assorted materials (see Materials List) to show students a variety of materials.
2. Allow students to handle and manipulate each material.
3. Discuss each material using the following terms:
    a. Texture
    b. Weight
    c. Strength
    d. Hardness
    e. Flexibility

4. Ask students to use the attached worksheet (see "Materials to Build") to list materials one might use to build each of five structures.

Materials List

Materials per Class	Amount	Location
Leather Scraps	As appropriate	Craft store, home, furniture store, equestrian center
Rocks	As appropriate	Outdoors
Pieces of Brick, Baked Clay	As appropriate	Outdoors
Metal Scraps (wire, smooth sheets, nails/screws/bolts, copper, etc.)	As appropriate	Home goods store, home, hardware store
Pieces of Concrete	As appropriate	Outdoors
Smooth Seaglass	As appropriate	Outdoors, craft store, home
Vinyl, Tyvek, Other Construction Materials	As appropriate	Home goods store, home, hardware store
Variety of Plastics (soft, hard, flexible, sturdy, etc.)	As appropriate	Home goods store, home, hardware store
Wood Scraps (natural and treated)	As appropriate	Home goods store, home, hardware store
Cloth Scraps (silk, polyester, rayon, cotton, polar-fleece, wool, nylon, etc.)	As appropriate	Craft store, home
Materials of Your Choice	As appropriate	Varies

Materials per Student	Amount	Location
Materials to Build Worksheet	One	End of lesson, Print or Photocopy

Vocabulary with Definitions

1. *Flexibility* – the ability to be bent repeatedly without breaking.
    a. examples: *flexible* (rubber, cotton, some plastics) versus inflexible (brick, wood, rock, some metals, china, glass)
2. *Hardness* – the ability to resist bending, scratching, or denting.
    b. examples: *hard* (diamond, granite), versus *soft* (soap, cloth)
3. *Material* – a substance that can be used to make things.

4. *Property* – a characteristic or trait.
5. *Strength* – the ability to resist forces or stress.
    c. examples: *strong* (metal, some plastics, rock), versus *weak* (foam, paper, china, glass, and cloth)
6. *Texture* – the appearance and feel of a surface.
    d. examples: *smooth* (metal, porcelain), *rough* (concrete), *grained* (wood), *porous* (brick), *fibrous* (cotton, paper)
7. *Weight* – the amount of mass in an object, or its "heaviness".
    e. examples: *heavy* (brick, rock), versus *light* (foam, wood, plastic)

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Use class discussions to evaluate level of student understanding of the "properties" of various materials.
2. Collect student worksheets; determine whether students understand the appropriate use of various materials. Look for a correlation between a material's "properties" and the design of a proposed structure.

Lesson Extensions

1. Lesson: 3.C.2 Properties of Materials

Attachments

1. Materials to Build

Troubleshooting Tips

1. Select objects made from only one material.
2. Prompt students to use appropriate vocabulary ("texture", "property", etc.).

Safety Issues

1. Do not choose dangerous materials, such as broken glass or other sharp objects, litter, or soiled objects.

Additional Resources

None

Name: ____ Date: ___________________________

	Materials I would use to build…
A wall	
A chair	
A fireplace	
A set of stairs	

3.C.2 Properties of Materials

Exploring the properties of various materials

Grade Level	3
Sessions	(1): 1 at 50-70 minutes
Seasonality	Suggested beginning of school year – basic technology/engineering concepts
Instructional Mode(s)	Whole Class
Team Size	N/A
WPS Benchmarks	03.SC.TE.01, 03.SC.TE.04, 03.SC.PS.02
MA Frameworks	3-5.TE.1.1, 3-5.TE.2.1, 3-5.PS.1.1
Key Words	Flexibility, Hardness, Man-made, Natural, Properties

Summary

This lesson expands students' knowledge of material properties by familiarizing them with different types of materials and their applications in real-world situations.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.01 Identify materials used to accomplish a design task based on a specific property, e.g., weight, strength, hardness, and flexibility.
2. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagram, graphic organizers, and lists.
3. 03.SC.PS.02 Gather a variety of solid objects. Collect data on properties of these objects such as origin (man-made or natural), weight (heavy, medium, light), length, odor, color, hardness, and flexibility.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.1.1 Identify materials used to accomplish a design task based on a specific property, i.e., weight, strength, hardness, and flexibility.
2. 3-5.TE.21 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
3. 3-5.PS.1.1 Differentiate between properties of objects (e.g., size, shape, weight) and properties of materials (e.g., color, texture, hardness).

Additional Learning Objectives

1. Students will differentiate between man-made and natural materials.

2. Students will learn and use vocabulary appropriate to discussing “properties” of materials.
3. Students will improve writing and organizational skills.
4. Students will consider the suitability of various materials with respect to the engineering concepts of “design”, “structure”, and “build”.

Required Background Knowledge

None

Essential Questions

1. What are man-made materials?
2. What are some examples of man-made materials?
3. What are natural materials?
4. What are some examples of natural materials?
5. List some important properties of materials.

Introduction / Motivation

The instructor may begin the lesson by discussing with students the differences between “man-made” and “natural” materials (see Vocabulary with Definitions). Students may give examples from both categories.

Procedure

The instructor will:

1. Ask each student to collect three different “materials”: one from home, one from outdoors, and one from inside their classroom (examples include: wood, plastic, rocks, wool, cloth, and cotton,).
2. Lead students through the attached worksheet (Properties of Materials); they should use the three materials on their desks.
3. If students require prompting, the following instructions/questions may be used:
    a. Write the name of each collected object on the chart.
    b. Is the “material” from which each object is made “man-made” or “natural”?
    c. Is the object heavy, medium, or light in weight?
    d. What shape is the object?
    e. Does the material from which the object is made have an odor?

f. What color(s) do(es) is the material?

g. Is the material flexible? If so, how flexible?

h. Is the material hard, soft, or semi-pliable (see Vocabulary with Definitions)?

4. Lead students through the second worksheet, Materials – Building a House.

Materials List

Materials per student	**Amount**	**Location**
Properties of Materials Worksheet	One	End of lesson plan – print or photocopy
Materials – Building a House Worksheet	One	End of lesson plan – print or photocopy
Material from Home	One	Student's home
Material from Outdoors	One	School playground
Material from Classroom	One	Classroom

Vocabulary with Definitions

1. *Man-Made* – manufactured, created, or constructed by human beings.
2. *Natural* – created without human care.
3. *Pliable* – easily bent or shaped.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Collect student worksheets to determine the level of understanding of materials, their properties, and the correct use of a chart or graphic organizer.
2. Use class discussion to evaluate how well students understand the difference between "man-made" and "natural" materials.

Lesson Extensions

1. Consider using this lesson in conjunction with 3.C.1 – Materials to Build.

Attachments

1. Properties of Materials
2. Materials – Building a House

Troubleshooting Tips

1. The objects that are found in the classroom may be made of several materials or be synthetic, which may be created to look like natural materials. To minimize confusion, suggest that students chose items made of a single, non-synthetic material.

Safety Issues

1. Ensure the students do not choose dangerous materials, such as broken glass, sharp objects, litter, or soiled items.

Additional Resources

None

Materials – Building a House

Name: ___________________________ Date: ____________________

Look carefully at the material that you brought from home. Use the Material Properties Chart. Write a paragraph about the properties of your material. Could your material be used to build a house? Why or Why not?

____

____

____

____

____

____

____

____

____

____

____

Name: ______________________________________ Date: _________________________

Material Properties Worksheet

OBJECT (name)	Man-made or Natural	Weight	Shape
1.			
2.			
3.			

OBJECT	Odor	Color	Flexibility	Hardness
1.				
2.				
3.				

3.C.3 Sound Machine

Construction of a simple sound machine using the Engineering Design Process

Grade Level	3
Sessions	(2): 1 at 35 minutes, 1 at 50-80 minutes
Seasonality	None
Instructional Mode(s)	Whole Class, Small Groups
Team Size	2-4 students
WPS Benchmarks	03.SC.TE.01, 03.SC.TE.02, 03.SC.IS.03, 03.SC.PS.08
MA Frameworks	3-5.TE.1.1, 3-5.TE.1.2, 3-5.PS.1.1
Key Words	Pitch, Sound Machine, Volume

Summary

This lesson introduces students to volume and pitch through the creation of a sound machine. It also allows children to review the Engineering Design Process while strengthening their teamwork and manipulative skills.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.01 Identify materials used to accomplish a design task based on a specific property, e.g., weight, strength, hardness, and flexibility.
2. 03.SC.TE.02 Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.
3. 03.SC.IS.03 Keep accurate records while conducting simple investigations or experiments.
4. 03.SC.PS.08 Design and construct a simple sound-producing device that demonstrates how to change the properties of volume and pitch (e.g., home-made instruments).

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.1.1 Identify materials used to accomplish a design task based on a specific property, i.e, weight, strength, hardness, and flexibility.
2. 3-5.TE.1.2 Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.

3. 3-5.PS.1.1 Recognize that sound is produced by vibrating objects and requires a medium through which to travel. Relate the rate of vibration to the pitch of sound.

Additional Learning Objectives

1. Students will become familiar with materials used to make a sound machine with variable volume.
2. Students will learn the concepts of “volume” and “pitch.”
3. Students will work with other members of a group to problem-solve, design, and model a sound machine.

Required Background Knowledge

1. The instructor may wish to teach 3.C.1 Materials to Build and 3.C.2 Properties of Materials before teaching the present lesson.

Essential Questions

1. What is a sound machine?
2. What is volume?
3. How can the volume of a sound machine be changed?
4. What is pitch?
5. How can the pitch of a sound machine be changed?
6. What materials can be used to make simple homemade instruments?
7. How is the Engineering Design Process used when designing a sound machine?

Introduction / Motivation

The instructor might begin the lesson by bringing in an instrument of his or her own. (S)he might also review the Engineering Design Process (see Appendix B: Instructor’s Notes).

Procedure

The Instructor will:

Part 1: (35 minutes)

1. Explain to the students the difference between “volume” and “pitch” (See Vocabulary with Definitions).
2. Divide students into pairs or small groups (2-4 students).

3. Show students the materials available (see Materials List) for sound machine design and construction. Each group need not use all materials.
4. Explain to the students that they will make a sound machine capable of changing volume and pitch.
5. Provide each student with a Sound Machine Design worksheet.
6. Lead students through questions 1, 2 and 3 on the Sound Machine Design worksheet. Before the students provide written responses, encourage them to discuss their ideas with each other.
7. Consider showing the students pictures of various instruments from different cultures.
8. Provide each group with a single, medium-sized sheet of paper and lead students through question 4.

Part 2: (50 – 80 minutes)

1. Ask students to reform previous groups.
2. Ask students to look at their previous work on the Sound Machine Design worksheet. They should recall ideas about the sound machine and the materials that they planned to use.
3. Allow groups time to construct and try their model sound machines (See Appendix A" Instructor's Notes).
4. Ask each group to change the volume and pitch of their sound machine.
5. Discuss with the students which instrument has the highest pitch and which has the lowest pitch.
6. Ask students to finish questions 4 and 5.

Materials List

Materials per class	**Amount**	**Location**
Dried Kidney Beans	A few bags	Grocery Store
Paper Plates	One Package	Grocery Store
Rubber Bands	One Package	Convenience Store
Popsicle Sticks	10-20	Craft store
Small Round Cardboard Boxes	~10	Craft store
Staples	One Stapler	Classroom
Wax Paper	One roll	Grocery store

Materials per student	Amount	Location
Sound Machine Design Worksheet	One	End of lesson plan – print or photocopy
Medium Sized-Sheet of Paper	One per group	Classroom

Vocabulary with Definitions

1. *Pitch* – The property of sound that varies with variation in the frequency of vibration; the ‘highness’ or ‘lowness’ of sound.
2. *Sound Machine* – Any instrument that can make a noise when played.
3. *Volume* – The loudness of a sound.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Observe student groups at work and collect student worksheets to determine whether students understand the appropriate use of materials and tools when making a sound machine.
2. Determine whether students understand the Engineering Design Process by reviewing their worksheets.

Lesson Extensions

1. Ask students to measure various parts of their sound machine in inches and centimeters. See WPS Benchmark “03.SC.TE.05 Develop a knowledge and understanding of the metric measurement system.”
2. Have the students graph the differing volumes and pitches.

Attachments

1. Appendix A: Instructor’s Notes
2. Appendix B: The Engineering Design Process
3. Sound Machine Design

Troubleshooting Tips

1. Students may not choose the correct materials; therefore, the sound machine will not produce any sound (See Appendix A: Instructor’s Notes).

Safety Issues

1. Scissors are sharp and students should use caution.
2. Students should use extreme caution if/when using the stapler. If possible, and adult helper should perform this task for them.

Additional Resources

None

Appendix A: Instructor's Notes

At least three different types of sound machines may be made using the given materials:

1. Maracas

   Materials: Kidney Beans, Paper Plates, Popsicle Sticks and Staples

2. Drums

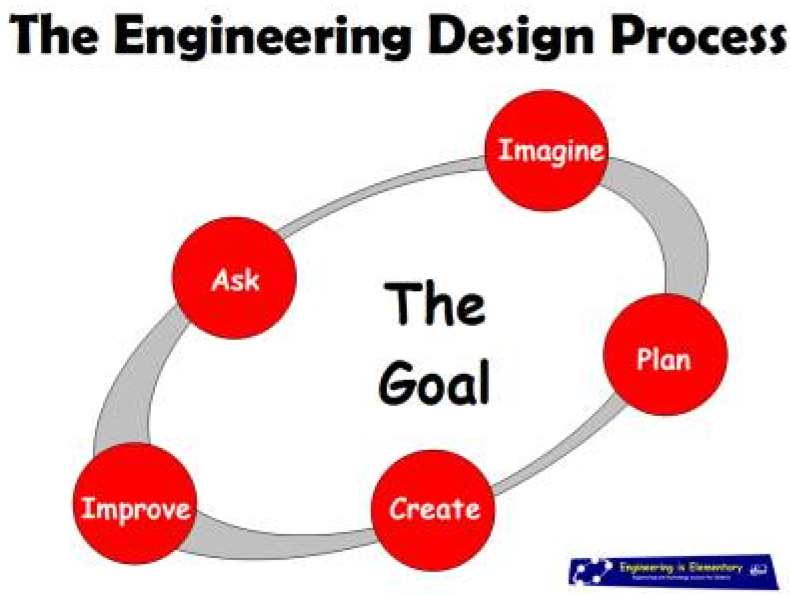
   Materials: Small Round Cardboard Box, Rubber Bands, Wax Paper and Popsicle Sticks

3. String Instrument

   Materials: Pieces of Cardboard and Rubber Bands

Appendix B: The Engineering Design Process

"The Engineering Design Process for Children" and associated text comes directly from: http://www.mos.org/doc/1559 (accessed 2 February 2006).



"The Engineering Design Process is a series of steps that engineers use to guide them as they solve problems. Many variations of the model exist. While having a guide is useful for novices who are learning about engineering, it is important to note that practicing engineers do not adhere to a rigid step-by-step interpretation of the process. Rather there are as many variations of the model as there are engineers. Because our curriculum project focuses on young children, we have created a simple process that depicts fewer steps than other renditions and that uses terminology that children can understand. The engineering design process is cyclical and can begin at any step. In real life, engineers often work on just one or two steps and then pass along their work to another team."

"A few questions can guide students through each of the steps:

"ASK

- What do I want to do?
- What is the problem?
- What have others done?

“IMAGINE

- What could be some solutions?
- Brainstorm ideas.
- Pick one to start with that you think will work the best.

“PLAN

- Draw a diagram of your idea.
- Make lists of materials you will need to make it.
- Decide how it works. How will you test it?

“CREATE

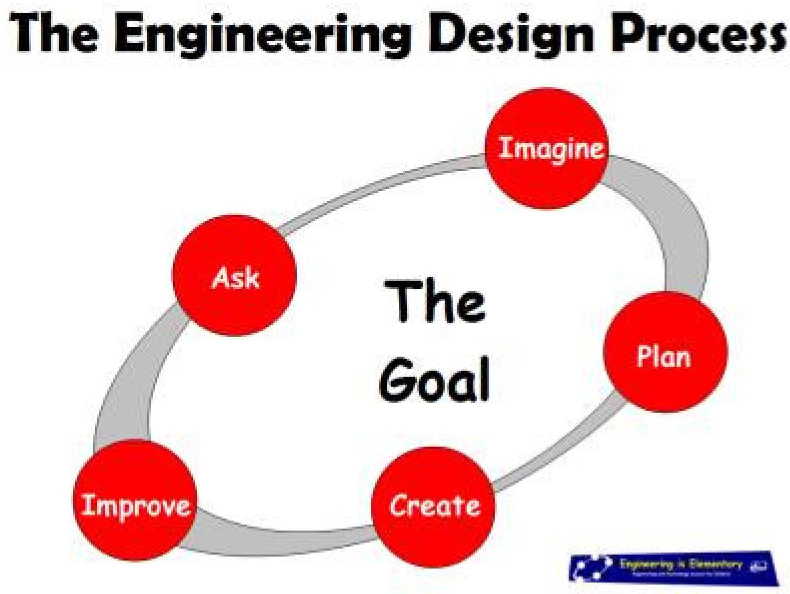
- Build a prototype.
- Test it.
- Talk about what works, what doesn't, and what could work better.

“IMPROVE

- Talk about how you could improve your product.
- Draw new designs.
- Make your product the best it can be!”

Sound Machine Design

Name: ______________________ Date: _________________



The Engineering Design Process for Children: http://www.mos.org/doc/1559 (accessed 7 October 2005)

1. **Ask –**

What type of sound machine do I want to construct that will be able to change volume?

___

___

___

2. **Imagine** –

Look at the list of materials below. Place a check in the box beside the materials that you will use to create your sound machine.

Kidney Beans	
Paper Plates	
Rubber Bands	
Wax Paper	
Popsicle Sticks	
Pieces of Cardboard	
Small Round Cardboard Box	
Staples	
Tape	
Glue	

Why did you pick these materials? ____

____

____

____

____

____

____

Which material(s) will allow the sound machine to change volume?________________

____

____

____

____

How can you change the pitch of the sound machine?____________________________

____

____

____

____

3. **Plan –**

On a separate sheet of paper, draw a picture of the sound machine that you plan to make. Beside each part, write which material you will use to make that part. Use the list above as a guide.

4. **Create –**

Collect the materials that you need and then construct your model. Test your model by changing the volume and pitch.

5. **Improve –**

If you could not change the volume of your model, how can you improve your model so that it will change volume?

____

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If your model did change volume, how can you improve your model to make it better?

____

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3.C.4 Minerals: Observe and Identify

A hands-on introduction to the properties of minerals

Grade Level	3
Sessions	(1): 1 at 40-60 minutes
Seasonality	None
Instructional Mode(s)	Whole Class, Small Groups
Team Size	2-4 students
WPS Benchmarks	03.SC.TE.01, 03.SC.TE.04, 03.SC.IS.01, 03.SC.IS.02, 03.SC.IS.03, 03.SC.IS.06, 03.SC.ES.01, 03.SC.ES.03
MA Frameworks	3-5.TE.1.1, 3-5.TE.2.2, 3-5.ES.0.1, 3-5.ES.0.2
Key Words	Cleavage, Color, Hardness, Luster, Mineral, Property, Rock, Streak

Summary

This lesson provides students with the opportunity to observe various properties of minerals and to record their observations in a notebook.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.01 Identify materials used to accomplish a design task based on a specific property, e.g., weight, strength, hardness, and flexibility.
2. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
3. 03.SC.IS.01 Ask questions and make predictions that can be tested.
4. 03.SC.IS.02 Select and use appropriate tools and technology (e.g., calculators, computers, balances, scales, meter sticks, graduated cylinders) in order to extend observations.
5. 03.SC.IS.03 Keep accurate records while conducting simple investigations or experiments.
6. 03.SC.IS.06 Record data and communicate findings to others using graphs, charts, maps, models, oral and written reports.
7. 03.SC.ES.01 Give a simple explanation of what a mineral is and some examples (i.e., quartz, mica).
8. 03.SC.ES.03 Identify the physical properties of minerals (hardness, color, luster, cleavage, and streak), and explain how minerals can be tested for these different physical properties

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.1.1 Identify materials used to accomplish a design task based on a specific property, e.g., weight, strength, hardness, and flexibility.
2. 3-5.TE.2.2 Describe different ways in which a problem can be represented, e.g., sketches, diagram, graphic organizers, and lists.
3. 3-5.ES.1 Give a simple explanation of what a mineral is and some examples, e.g., quartz, mica.
4. 3-5.ES.2 Identify the physical properties of minerals (hardness, color, luster, cleavage, and streak), and explain how minerals can be tested for these different physical properties.

Additional Learning Objectives

1. Students will improve writing and organizational skills by keeping a journal.

Required Background Knowledge

None

Essential Questions

1. What is a mineral?
2. What are some properties of minerals?
3. What are some tests geologists use to identify minerals?

Introduction / Motivation

Explain to students that they will be learning about the "properties" of minerals and will make their own "Rock Discovery" notebooks. Ask students what they already know about rocks and minerals. As a class, discuss the differences between a rock and a mineral (see Vocabulary with Definitions).

Procedure

The instructor will:

1. Provide students with an observation notebook (See Appendix A: Instructor's Notes)

2. Ask them to write their names on the front of their "notebooks" (worksheet) and to start a table of contents on the inside of the first page of the worksheet.
3. Define "mineral" in a visible location and explain the different properties used to identify minerals: luster, hardness, cleavage, and streak (see Vocabulary with Definitions and Appendix A: Identifying Minerals).
4. Allow students to examine various examples of minerals.
5. Lead students through the attached worksheet.

Materials List

Materials per Class	Amount	Location
Rock Collection	One	Science store, internet
Streak Stone	One per group	Science store, internet

Materials per Student	Amount	Location
Rock and Mineral Journal: Minerals Worksheet	-One copy of instructions -One copy of cover page -One single-sided copy of observation sheet -Two double-sided copies of observation sheet	End of lesson plan – print or photocopy
Blank Sheet of Paper	One	Classroom
Magnifying Glass	One	Classroom

Vocabulary with Definitions

1. *Cleavage* – The pattern that results when a mineral is broken.
2. *Hardness* – The ability of a mineral to scratch another material or to be scratched by another material.
3. *Luster* – The way light reflects off the surface of a mineral (dull, waxy, greasy, oily, pearly, silky, glassy, resinous, metallic).

4. *Mineral* – A naturally occurring inorganic substance that has specific characteristics (coal, calcite, diamond, quartz, gold, carbon, salt).
5. *Rock* – A lump or mass of hard consolidated mineral matter (e.g. granite, limestone, slate).
6. *Streak* – The color of a mineral's powder; tested by scratching the mineral across a streak plate.
7. *Streak Plate*: A porcelain plate used to test the streak of a mineral.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Observe student groups at work.
2. Collect student worksheets/journal to determine: (a) whether or not students understand the different "properties" used to identify minerals, and (b) the correct way to make accurate observations.
3. Ask students to explain how they used each "test" while observing their minerals.

Lesson Extensions

1. As a class, ask students to graph the various properties of minerals and to note observed trends.

Attachments

1. Rock and Mineral Journal: Minerals
2. Appendix A: Instructor's Notes
3. Appendix B: Identifying Minerals

Troubleshooting Tips

None

Safety Issues

1. A test for "cleavage" was intentionally left out of this lesson because it is not safe to conduct such a test in the classroom. The instructor may discuss this important test orally.

Additional Resources

1. Good background on the differences between rocks and minerals. http://www.rocks-and-minerals.com/ (accessed 5 January 2006).

Name ______________________ Date _________________

Rock and Mineral Journal: Minerals

Part 1:

1. Write your name on the cover of the notebook and then open to the first page.
2. At the top of the first page write “Table of Contents”.
3. On the next page, write the number “2” in the top right corner.
4. Wait for your teacher’s instructions before moving to the next part.

Part 2:

1. Once you receive your mineral, **observe** it carefully and try to find some of the properties that your teacher described.
2. Write the name of your mineral, draw a picture of it, and write a few sentences about some of its properties in your journal.
3. On each page, mark the page number in the top right corner.
4. After you finish making your observations, write the name of each mineral that you observed in the “Table of Contents”.
5. Write the page number in the “Table of Contents” so that your teacher can find information about that mineral in your notebook.

My Mineral Journal

Name:_____________________________

Name of Mineral: ______________________________

Picture:

Description:______________________________________

____

____

____

____

1. If you scratch the mineral with your fingernail, do pieces of it fall on your desk? If not, what material might be able to take pieces of the rock off?

____

____

____

2. What color is the mineral?

____

3. How well does the mineral reflect light? Would you say its dull, shiny or glassy?

____

____

4. If you hit this mineral with a hammer, how do you think it would break? Would the broken surface of the rock look smooth or rough?

____

____

5. What color powder did the mineral produce on the streak plate?

____

Appendix A: Instructors Notes

The teacher may assemble the notebooks or have students assemble them.

Assembling Notebooks:

1. Fold each page of the notebook in half.
2. Place the cover page of your notebook face down on a flat surface.
3. Place the blank side of the single-sided copy of the observation page on top of the cover page.
4. Place the remaining double-sided observation pages on top of the single-sided copy.
5. Place two to three staples at the center of notebook.

Appendix B: Identifying Minerals

Taken directly from: http://library.thinkquest.org/3639/Identification.html on 5 January 2006.

Cleavage

“Cleavage is the way that a mineral breaks along well defined planes of weakness. The planes are between layers of atoms or other places where the atomic bonding is the weakest. Most cleavage surfaces are not always perfectly smooth like crystal faces, although they are very consistent and reflect light evenly. Cleavage is described as perfect, distinct, indistinct, or none.

Color

“The color of a mineral is a useful identification feature. Although it helps to identify minerals, color identification can trick you. Many minerals, like quartz, occur in a lot of different colors, and many minerals are boring white or even colorless.

Fracture

“If you hit a mineral with a geological hammer, it breaks, leaving the surfaces rough and uneven. This is called fracture. Cleavage surfaces are usually flat and exactly the same. Fractures are not the same each time. Common fracture terms are uneven, shell-like, jagged, and splintery.

Hardness

“Hardness is also a way to identify a mineral or rock. Hardness is the measurement of how resistant the mineral is to being scratched. On the Mohs’ scale, the softest mineral is talc to the hardest mineral, diamond. The chart was created by Friedrich Mohs. Minerals with higher numbers will scratch those with lower numbers. You can also scratch minerals with household objects. For example: any mineral scratched by a coin has a hardness less than 3 1/2.

Mohs' Scale of Hardness

1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Orthoclase
7	Quartz
8	Topaz
9	Corundum
10	Diamond

Specific Gravity (S.G.)

"Comparing the weight of a mineral with the weight of an equal volume of water gives a mineral's specific gravity. This is shown in numbers. An S.G. of 2 1/2 shows a mineral weighs 2 1/2 times as much as water.

Transparency

"Transparency refers to the way light passes through a mineral sample. It varies, depending on the way the mineral atoms are bonded together. Mineral samples that you can see through are transparent. If you can not see through it, the mineral sample is translucent. When no light can pass through the mineral, even when it is cut very thin, it is opaque.

Streak

"The color of a mineral's powder is called streak. You can see the streak of a mineral by rubbing the rock across the surface of an unglazed porcelain tile. If the mineral is very hard, crush a small amount of it off with a geological hammer, or rub it against a hard surface. Streak is more reliable in identification than the color of the mineral because it is more consistent.

Luster

“Luster defines the way light is reflected off a mineral's exterior. The kind and intensity of luster vary according to the nature of the mineral surface and the amount of light exorbed. Well-recognized words used to describe luster are dull, metallic, pearly, glassy, greasy, and silky.”

3.C.5 Rocks: Observing Properties

A hands-on introduction to rocks and their properties

Grade Level	3
Sessions	(1): 1 at 40-60 minutes
Seasonality	Recommended before teaching life sciences' plant unit
Instructional Mode(s)	Whole Class, Individual
Team Size	2-4 students
WPS Benchmarks	03.SC.TE.01, 03.SC.TE.04, 03.SC.IS.01, 03.SC.IS.02, 03.SC.IS.03, 03.SC.IS.05, 03.SC.IS.06, 03.SC.ES.02, 03.SC.ES.05
MA Frameworks	3-5.TE.1.1, 3-5.ES.0.3
Key Words	Diagram, Igneous, Metamorphic, Properties, Rock, Sedimentary

Summary

This lesson allows students to study various types of rocks. After students have discussed "rocks" and "minerals", they will observe and record observations about rocks using a "Rock Journal."

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.01 Identify materials used to accomplish a design task based on a specific property, e.g., weight, strength, hardness, and flexibility
2. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagram, graphic organizers, and lists.
3. 03.SC.IS.01 Ask questions and make predictions that can be tested.
4. 03.SC.IS.02 Select and use appropriate tools and technology (e.g., calculators, computers, balances, scales, meter sticks, graduated cylinders) in order to extend observations.
5. 03.SC.IS.03 Keep accurate records while conducting simple investigations or experiments.
6. 03.SC.IS.05 Recognize simple patterns in data and use data to create a reasonable explanation for the results of an investigation or experiment.
7. 03.SC.IS.06 Record data and communicate findings to others using graphs, charts, maps, models, oral and written reports.

8. 03.SC.ES.02 Identify the three categories of rocks (metamorphic, igneous, and sedimentary) based on how they are formed, and explain the natural and physical processes that create these rocks.
9. 03.SC.ES.05 Examine rocks collected from the schoolyard or a field trip location, or brought in from home. Sort rocks into igneous, metamorphic, or sedimentary based on their physical properties.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.1.1 Identify Materials used to accomplish a design task based on a specific property, i.e. weight, strength, hardness, and flexibility.
2. 3-5.ES.0.3 Identify the three categories of rocks (metamorphic, igneous, and sedimentary) based on how they are formed, and explain the natural and physical processes that create these rocks.

Additional Learning Objectives

1. Students will improve writing and organizational skills by keeping a notebook and organizing a rock collection.

Required Background Knowledge

1. A basic understanding of minerals (see lesson 3.C.4 Minerals: Observe and Identify).

Essential Questions

1. What is a rock?
2. What are the differences between rocks and minerals?
3. What is an igneous rock?
4. What is a sedimentary rock?
5. What is a metamorphic rock?
6. What processes make these different types of rocks?
7. What properties are used to identify some of these rocks?

Introduction / Motivation

Explain to students that they will learn about rocks and their properties. Consider asking students what they already know about rocks. Students may explain the difference between rocks and minerals (See Vocabulary with Definitions).

Procedure

The instructor will:

1. *For homework, ask students to bring in three rocks from home in preparation for this lesson.*
2. Explain the three different types of rocks: igneous, metamorphic and sedimentary (see Vocabulary with Definitions).
3. Provide students with an observation notebook (See Appendix A: Instructor's Notes).
4. Ask students to write their names on the front of the "notebook" (worksheet) and to start a "Table of Contents" on the inside of the first page of the worksheet.
5. Ask students to observe the properties of the three rocks and minerals they have brought to class (see Appendix B: Identifying Rocks). Students should record these observations in their journals.
6. Ask students to identify as "igneous", "metamorphic", or "sedimentary", the rocks they brought from home.

Materials List

Materials per Class	**Amount**	**Location**
Rock Collection	One	Science store, internet

Materials per Student	**Amount**	**Location**
Rock and Mineral Journal: Rocks Worksheet	-One copy of instructions -One copy of cover page -One single-sided copy of observation sheet	End of lesson plan – print or photocopy

	-Two double-sided copies of observation sheet	
Magnifying Glass	One	Classroom

Vocabulary with Definitions

1. *Gravity* – The natural force of attraction exerted by the Earth upon objects at or near its surface.
2. *Igneous* – Rocks formed from magma that has solidified beneath the Earth's surface.
3. *Luster* – Describes the way light reflects off the surface of a mineral (e.g. dull, waxy, greasy, oily, pearly, silky, glassy, resinous, metallic).
4. *Magma* – Molten rock.
5. *Metamorphic* – Rock formed when igneous or sedimentary rocks have been subjected to heat and pressure, usually from the Earth's crust.
6. *Mineral* – A naturally occurring, inorganic substance that has specific identifiable characteristics (e.g. coal, calcite, diamond, quartz, gold, carbon, salt).
7. *Rock* – A lump or mass of hard consolidated mineral matter (e.g. granite, limestone, slate).
8. *Sedimentary* – Rock formed from layers of material that have accumulated and hardened over time.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Observe students at work and ensure that they can identify the three types of rock (metamorphic, igneous, sedimentary).
2. Collect student worksheets (notebook) and ensure that students identified the properties that helped them identify their rocks.
3. Ask students to describe the difference processes that form each rock type.

Lesson Extensions

1. As a class, ask students to graph the various properties of their rocks and observe trends.

2. Teach lesson 3.C.6 Creating a Rock and Mineral Collection.

Attachments

1. Appendix A: Identifying Rocks
2. Appendix B: The Engineering Design Process
3. Rock and Mineral Journal: Rocks

Troubleshooting Tips

1. To be determined

Safety Issues

1. If students staple their own worksheets, they should use great caution not to injure their fingers.

Additional Resources

1. Good background on the differences between rocks and minerals: http://www.rocks-and-minerals.com/ (accessed 5 January 2006).

Name ______________________ Date _________________

Rock and Mineral Journal: Rocks

1. Once you receive your rock, **observe** it closely. Look for the properties that your class discussed.
    a. Does the rock have layers?
    b. Does the rock appear to be made of grains that were cemented together?
    c. Do the grains appear to be different sizes?
    d. How heavy is your rock compared to the others that you have?
    e. Does the rock appear to have many holes?
2. Try to identify the type of rock that you have.
3. Draw a picture of the rock and write a few sentences about some of its properties in your journal.
4. As you move to the next page, be sure to mark your page number in the top right corner.

My Rock Journal

Name:____________________________

Name of Rock:______________________________

Type of Rock:______________________________

Picture:

Description:______________________________

1. What are some of the physical properties of this rock (color, texture, hardness)?

2. How can you tell what kind of rock this is?

3. If you were to build or make something using many of these rocks, what would you build or make? What properties make this rock suitable for what you would build?

Appendix A: Instructors Notes

The teacher may assemble the notebooks or have students assemble them.

Assembling Notebooks:

1. Fold each page of the notebook in half.
2. Place the cover page of your notebook face down on a flat surface.
3. Place the blank side of the single-sided copy of the observation page on top of the cover page.
4. Place the remaining double-sided observation pages on top of the single-sided copy.
5. Place two to three staples at the center of notebook.

Appendix B: Identifying Rocks Taken directly from: http://www.minsocam.org/MSA/K12/rkcycle/typeofrock.html (5 January 2006).

What Type of Rock do I Have?

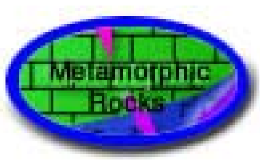
How to tell an igneous rock from a sedimentary rock from a metamorphic rock.

Igneous rocks are recognized by:

- the interlocking texture of the grains
- the presence of vesicules (holes) in extrusive igneous rocks
- may be dark-colored and heavy
- may display two grain sizes, one much larger than the other

Sedimentary rocks are recognized by:

- grains cemented together
- the presence of fossils
- light-colored and light weight
- may display interlocking grains but is very light weight

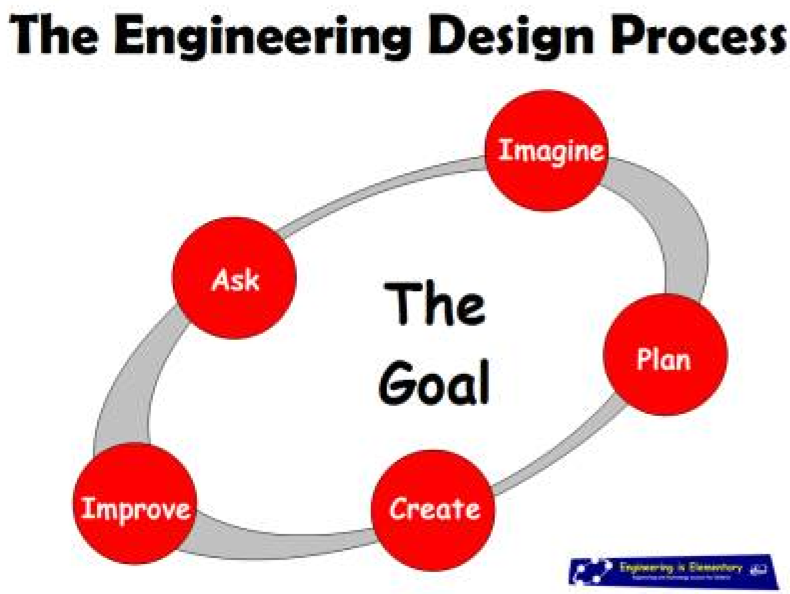


Metamorphic rocks are recognized by:

- the interlocking texture of large grains
- foliation (layering)
- banded light and dark colors
- "ching" sound instead of a "chunk" sound when tapped

Appendix C: The Engineering Design Process

"The Engineering Design Process for Children" and associated text comes directly from: http://www.mos.org/doc/1559 (accessed 7 February 2006).



"The Engineering Design Process is a series of steps that engineers use to guide them as they solve problems. Many variations of the model exist. While having a guide is useful for novices who are learning about engineering, it is important to note that practicing engineers do not adhere to a rigid step-by-step interpretation of the process. Rather there are as many variations of the model as there are engineers. Because our curriculum project focuses on young children, we have created a simple process that depicts fewer steps than other renditions and that uses terminology that children can understand. The engineering design process is cyclical and can begin at any step. In real life, engineers often work on just one or two steps and then pass along their work to another team."

"A few questions can guide students through each of the steps:

"ASK

- What do I want to do?
- What is the problem?
- What have others done?

“IMAGINE

- What could be some solutions?
- Brainstorm ideas.
- Pick one to start with that you think will work the best.

“PLAN

- Draw a diagram of your idea.
- Make lists of materials you will need to make it.
- Decide how it works. How will you test it?

“CREATE

- Build a prototype.
- Test it.
- Talk about what works, what doesn't, and what could work better.

“IMPROVE

- Talk about how you could improve your product.
- Draw new designs.
- Make your product the best it can be!"

3.C.6 Making a Rock and Mineral Collection

A hands-on introduction to building an organized rock and mineral collection

Grade Level	3
Sessions	(1): 1 at 60 minutes
Seasonality	None
Instructional Mode(s)	Whole Class, Small Groups
Team Size	2-4 students
WPS Benchmarks	03.SC.TE.01, 03.SC.TE.03, 03.SC.TE.04, 03.SC.IS.01, 03.SC.IS.02, 03.SC.ES.03, 03.SC.ES.04, 03.SC.ES.05
MA Frameworks	3-5.TE.1.1, 3-5.TE.2.1, 3-5.ES.0.1, 3-5.ES.0.2, 3-5.ES.0.3
Key Words	Collection, Mineral, Rock

Summary

This lesson will extend students' understanding of rocks and minerals; students will create a rock collection and design an enclosure for these rocks using classroom materials.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.01 Identify materials used to accomplish a design task based on a specific property, e.g., weight, strength, hardness, and flexibility.
2. 03.SC.TE.03 Identify a problem that reflects the need for shelter, storage, or convenience.
3. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
4. 03.SC.IS.01 Ask questions and make predictions that can be tested.
5. 03.SC.IS.02 Select and use appropriate tools and technology (e.g., calculators, computers, balances, scales, meter sticks, graduated cylinders) in order to extend observations.
6. 03.SC.ES.03 Identify the physical properties of minerals (hardness, color, luster, cleavage, and streak), and explain how minerals can be tested for these different physical properties.
7. 03.SC.ES.04 Acquire a collection of minerals that includes a) duplicates of the same mineral, somewhat different in appearance (size, shape, exact color) and b) samples of minerals that look similar but are actually different. Examine minerals using a hand lens. Look for and record similarities and differences such as heaviness, color, texture,

crystal shapes, luster, surface patterns, etc. Sort as accurately as possible. Report total number of different minerals present, and how many duplicates, if any, of each type.

8. 03.SC.ES.05 Examine rocks collected from the schoolyard or a field trip location, or brought in from home. Sort rocks into igneous, metamorphic, or sedimentary based on their physical properties.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.1.1 Identify Materials used to accomplish a design task based on a specific property, i.e. weight, strength, hardness, and flexibility.
2. 3-5.TE.2.1 Identify a problem that reflects the need for shelter, storage, or convenience.
3. 3.5.ES.0.1 Give a simple explanation of what a mineral is and some examples, e.g., quartz, mica.
4. 3-5.ES.0.2 Identify the physical properties of minerals (hardness, color, luster, cleavage, and streak), and explain how minerals can be tested for these different physical properties.
5. 3-5.ES.0.3 Identify the three categories of rocks (metamorphic, igneous, and sedimentary) based on how they are formed, and explain the natural and physical processes that create these rocks.

Additional Learning Objectives

1. Students will improve organizational skills by creating and arranging a rock and mineral collection.

Required Background Knowledge

1. A solid understanding of rocks and minerals, and their respective identification (see lessons 3.C.4 Minerals: Observe and Identify and 3.C.5 Rocks: Observing Properties).

Essential Questions

1. What are some properties of rocks?
2. What are some properties of minerals?
3. What are the differences between rocks and minerals?

4. How can various rocks and minerals be organized?

Introduction / Motivation

Explain to students that they will create collections of rocks and minerals and will design an enclosure to organize these rocks and minerals. The instructor may wish to ask students why creating an organized collection of rocks is important and how they might approach the task.

Procedure

The instructor will:

1. *Ask students to bring to class three to five rocks from home for homework.*
2. Break students into pairs or small groups.
3. Remind students of the simplified Engineering Design Process (see Appendix A: The Engineering Design Process and the worksheet, Rock and Mineral Collection) and encourage them to use it as they think about how to organize and store their rock and mineral collections.
4. Ask students to organize the three to five rocks that they have brought from home, drawing on their knowledge from lessons 3.C.4 and 3.C.5 (ex. color, hardness, luster, cleavage, streak, texture, etc.).
5. After students have organized their rocks, ask them to design a container to store their rocks in an organized fashion using cardboard boxes or egg cartons (see worksheet, Rock and Mineral Collection)
6. Have students build their container.

Materials List

Materials per Class	**Amount**	**Location**
Stapler	One	Classroom
Tape	One	Classroom
Small/Large Lightweight Cardboard Boxes	Assorted	Recycle bin
Popsicle Sticks	Large Quantity	Craft Store
Egg Cartons	Assorted	Recycle bin

Materials per Student	**Amount**	**Location**
Rocks	Three to five	Student's home
Glue	One per Group	Classroom

Magnifying Glass	One per Group	Classroom

Vocabulary with Definitions

1. *Cleavage* – The pattern that results when a mineral is broken.
2. *Hardness* – The ability of a mineral to scratch another material or be scratched by another material.
3. *Igneous* – Rocks formed from magma that has solidified beneath the Earth's surface.
4. *Luster* – Describes the way light reflects off the surface of a mineral (ex. dull, waxy, greasy, oily, pearly, silky, glassy, resinous, metallic).
5. *Magma* – Molten rock.
6. *Metamorphic* – Rock formed when igneous or sedimentary rocks have been subjected to heat and pressure usually from the Earth's crust.
7. *Mineral* – A naturally occurring, inorganic substance that has specific identifiable characteristics (ex. coal, calcite, diamond, quartz, gold, carbon, salt).
8. *Rock* – A lump or mass of hard consolidated mineral matter (ex. granite, limestone, slate).
9. *Sedimentary* – Rock formed from layers of material that have accumulated and hardened over time.
10. *Streak* – The color of a mineral's powder tested by scratching it across a streaking plate.
11. *Streak Plate*: A porcelain plate used to test the streak of a mineral.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Observe student groups at work and ask students why they chose the materials that they did.
2. Collect students' rock and mineral collections and evaluate the organization of the collection and the durability of the container.
3. Ask students to present their designs to the class and to describe their collections.
4. Ask students to demonstrate their container's durability.

Lesson Extensions

1. Consider teaching lessons <u>3.C.7 Soil: Water Retention</u> and <u>3.C.8 Soil Composition</u>.

Attachments

1. Appendix A: The Engineering Design Process
2. Rock and Mineral Collection

Troubleshooting Tips

1. To be determined

Safety Issues

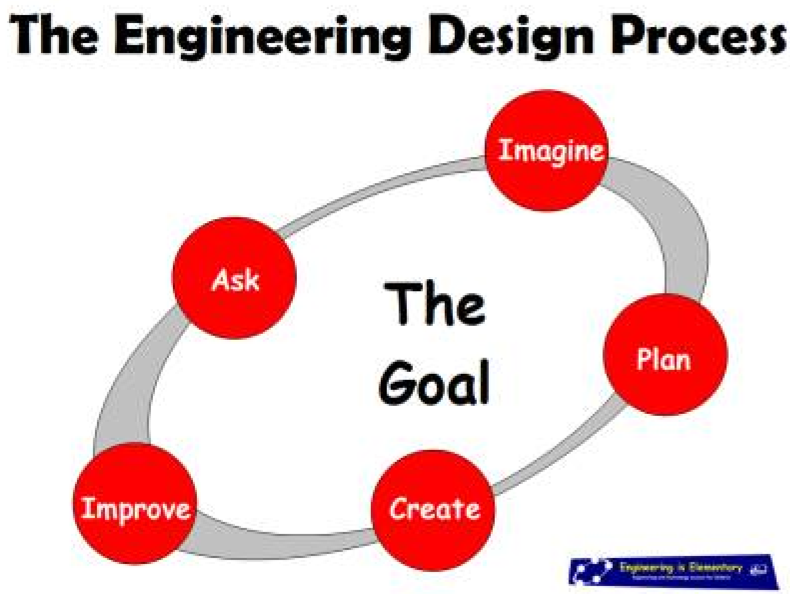
None

Additional Resources

1. Good background on the differences between rocks and minerals http://www.rocks-and-minerals.com/ (accessed 5 January 2006).

Rock and Mineral Collection

Name: ______________________ Date: _________________



The Engineering Design Process for Children: http://www.mos.org/doc/1559 (accessed 7 Februrary 2006)

1. **Ask –**

What do I want to build? ____

____

____

____

2. **Imagine** –

Imagine that you are exploring your backyard for different kinds of rocks and minerals. How would you store them safely as you move around your yard?

____

____

____

____

____

____

____

How would you organize your rocks and minerals in your container? (Hint: Think of some of the properties you used to identify your rocks and minerals.)

____

____

____

____

____

____

Read the list of materials below. Think about which materials you would like to use to construct your container. Beside the materials that you **will** use, write **why** you will use them. If you wish, space is provided for you to choose two additional materials that are not listed on this chart and that you have in your classroom.

Material	**Why will you use the material to construct your rock and mineral container?**
Cardboard Box	
Egg Carton	
Clear Tape	
Popsicle Sticks	
Glue	

3. **Plan –**

On a separate sheet of paper, draw a picture of the rock and mineral container you would like to build. Beside each part, write which material you will use to make that part of the model. Use the chart of materials above when you plan. Be sure to indicate where you will put your rocks and minerals.

4. **Create –**

Collect the materials that you need and then construct your model.

Have you noticed any problems with your design? If so, what were they?

____

____

____

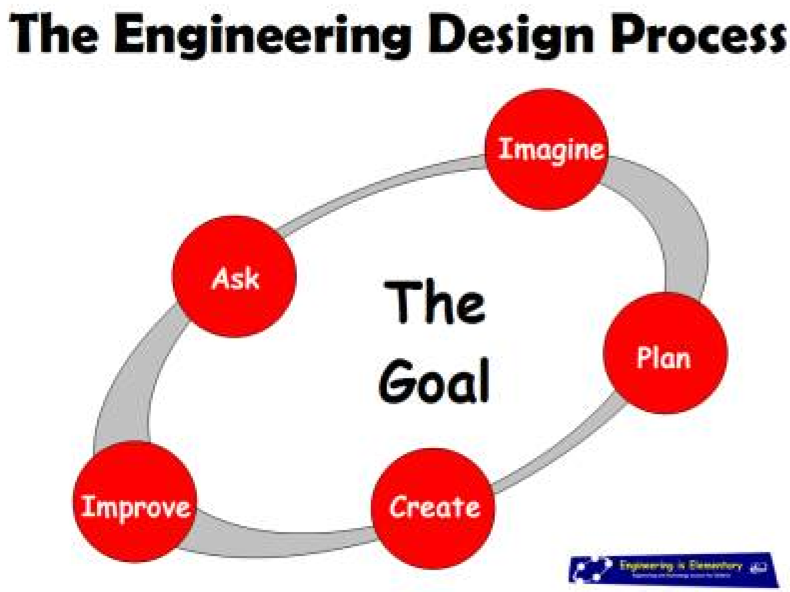
____

5. **Improve –**

What can you do to your rock and mineral container to make it better? How would you fix any problems that you had while you were constructing it?

Appendix A: The Engineering Design Process

"The Engineering Design Process for Children" and associated text comes directly from: http://www.mos.org/doc/1559 (accessed 7 February 2006).



"The Engineering Design Process is a series of steps that engineers use to guide them as they solve problems. Many variations of the model exist. While having a guide is useful for novices who are learning about engineering, it is important to note that practicing engineers do not adhere to a rigid step-by-step interpretation of the process. Rather there are as many variations of the model as there are engineers. Because our curriculum project focuses on young children, we have created a simple process that depicts fewer steps than other renditions and that uses terminology that children can understand. The engineering design process is cyclical and can begin at any step. In real life, engineers often work on just one or two steps and then pass along their work to another team."

"A few questions can guide students through each of the steps:

"ASK

- What do I want to do?
- What is the problem?
- What have others done?

“IMAGINE

- What could be some solutions?
- Brainstorm ideas.
- Pick one to start with that you think will work the best.

“PLAN

- Draw a diagram of your idea.
- Make lists of materials you will need to make it.
- Decide how it works. How will you test it?

“CREATE

- Build a prototype.
- Test it.
- Talk about what works, what doesn't, and what could work better.

“IMPROVE

- Talk about how you could improve your product.
- Draw new designs.
- Make your product the best it can be!”

3.C.7 Soil: Water Retention

A muddy introduction to dirt and its properties

Grade Level	3
Sessions	(1): 1 at 40-60 minutes
Seasonality	None
Instructional Mode(s)	Whole Class, Small Groups
Team Size	2-4 Students
WPS Benchmarks	03.SC.TE.05, 03.SC.IS.01, 03.SC.IS.04 03.SC.ES.06, 03.SC.ES.07, 03.SC.ES.08
MA Frameworks	3-5.TE.2.2, 3-5.TE.2.3, 3-5.ES.0.5
Key Words	Dirt, Metric System, Retain, Soil, Water

Summary

This lesson investigates how different types of soil retain varying amounts of water.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.05 Develop a knowledge and understanding of the metric measurement system.
2. 03.SC.ES.07 Recognize and discuss the different properties of soil, including color, texture (size of particles), the ability to retain water, and the ability to support the growth of plants.
3. 03.SC.ES.08 Design an experiment to find out if different soil samples retain different amounts of water. Explain how the properties of the particles affect the large-scale properties of the soil like water retention and speed of water flow. Discuss how a soil's water retention affects the animals and plants that live in it.
4. 03.SC.IS.01 Ask questions and make predictions that can be tested.
5. 03.SC.IS.04 Conduct multiple trials to test a prediction. Compare the results of an investigation or experiment with the prediction.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.2.2 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.

2. 3-5.TE.2.3 Identify relevant design features (e.g. size, shape, weight) for building a prototype of a solution to a given problem.
3. 3-5.ES.3 Identify the three categories of rocks (metamorphic, igneous, and sedimentary) based on how they are formed, and explain the natural and physical processes that create these rocks.

Additional Learning Objectives

1. Students will learn how to develop a scientific experiment.
2. Students will practice using the metric system.

Required Background Knowledge

1. Basic understanding of the metric system, specifically the units of volume (ex. milliliters).
2. Basic understanding of the composition of soil and how soil is formed (decomposing organisms and weathering of rock).

Essential Questions

1. How is soil formed?
2. What materials comprise soil?
3. Do some soils retain water better than others?
4. How much water do these types of soil retain in milliliters (ml)?
5. What types of soil best support plant life?

Introduction / Motivation

Explain to students that they will design the experiment for today's lesson; the experiment will test how well different types of soil retain water. The instructor may wish to open the discussion by asking students whether they have ever gardened or played with different kinds of dirt.

Procedure

The instructor will:

1. Create groups of approximately four students in each.
2. Provide groups with the following materials:

a. One empty plastic cup
b. 240 ml (one cup) of sand
c. 240 ml of dirt
d. 240 ml of water
e. enough cheesecloth to line the inside of a plastic cup

3. Allow students time to examine the provided materials.
4. Ask students for suggestions about how they might measure the amount of water that varying types of dirt can store.
5. Begin to write several steps of the "Procedure" (see Vocabulary with Definitions) in a visible location. Let students take over the process of creating a "Procedure" in their groups, using the Sand & Soil: Procedure worksheet.
6. Review each group's "Procedure" before proceeding.
7. Ask students to carry out the "Procedure" and to record results on the worksheet Soil & Sand: Results.

Materials List

Materials per Group	**Amount**	**Location**
Cheesecloth	Enough to line one plastic cup	Grocery store
Large, Disposable Plastic Cups	Four	Grocery store
Metric Measuring Cup	One	Home
Sand	240 ml (1 cup)	Backyard, garden supply store
Dirt	240 ml (1 cup)	Backyard, garden supply store
Paper Towels	Many!	Classroom

Materials per Student	**Amount**	**Location**
Sand & Soil: Procedure Worksheet	One	End of lesson plan – print or photocopy
Sand & Soil: Results Worksheet	One	End of lesson plan – print or photocopy

Vocabulary with Definitions

1. *Civil Engineer* – designs tunnels, roads, buildings, bridges, and dams using various materials such as soil, rocks, and concrete.
2. *Metric System* – a system of measurement based on powers of ten; the unit of measurement for volume is the liter (L) and one thousand milliliters equal one liter.
3. *Procedure* – the sequence of steps taken in an experiment, similar to the directions in a recipe for cooking.
4. *Sand* – loose particles of broken rock.
5. *Soil* – a mixture of sand and decaying plant and animal material.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

5. Observe student groups at work to ensure that the metric system is used properly.
6. Collect student worksheets to ensure that students make and record accurate observations.
7. Listen to oral responses and class discussions and note whether students understand that soil is a mixture of sand and decaying plant and animal material.

Lesson Extensions

None

Attachments

1. <u>Sand & Soil: Procedure</u>
2. <u>Sand & Soil: Results</u>

Troubleshooting Tips

1. To be determined

Safety Issues

None

Additional Resources

None

Sand & Soil: Procedure

Name ______________________ Date _________________

Directions: Pretend that you are a civil engineer. As a civil engineer, you have been asked to determine whether *sand* or *dirt* can hold more water. Engineers and scientists usually write a set of directions, called a *Procedure*, to organize the steps of an experiment. Here are some questions to help you write your procedure.

1. If you pour water into a cup, how will you know when the dirt can not absorb anymore water?

____

____

____

2. If you pour exactly 100 ml of water into a cup, and the dirt absorbed (soaked up) 60 ml of water, how much water was not absorbed?

____

3. If you had a way to cut a hole into the bottom of a cup to drain water, how would that help you decide whether *sand* or *dirt* can hold more water?

____

____

____

Use the space below to write a list of steps that you will follow in your experiment. Remember that you may use only the materials you have been given (plastic cups, cheesecloth, sand, dirt, water, and measuring cups).

Procedure:

1. ____

____

2. ____

____

3. ____

____

4. ____

____

5. ____

____

6. ____

____

7. ____

____

8. ____

____

Sand & Soil: Results

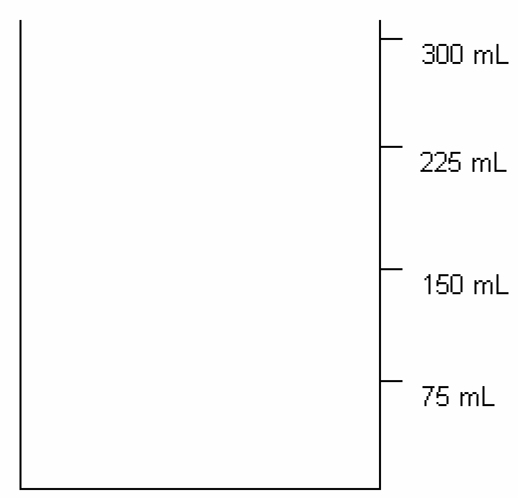
Name ______________________ Date _________________

Directions: Now that you have written your **Procedure**, follow each step to measure how much water 200 ml of sand will retain and how much water 200 ml of dirt will retain. Using the metric markings on your measuring cup, measure (approximately) how much water has they absorbed.

How much water dripped out of the sand into your measuring cup?
_________ milliliters (ml)

How much water did the sand absorb?
_________ milliliters (ml)

Use the cup pictured below to create a diagram, color in what the water look like in your measuring cup.



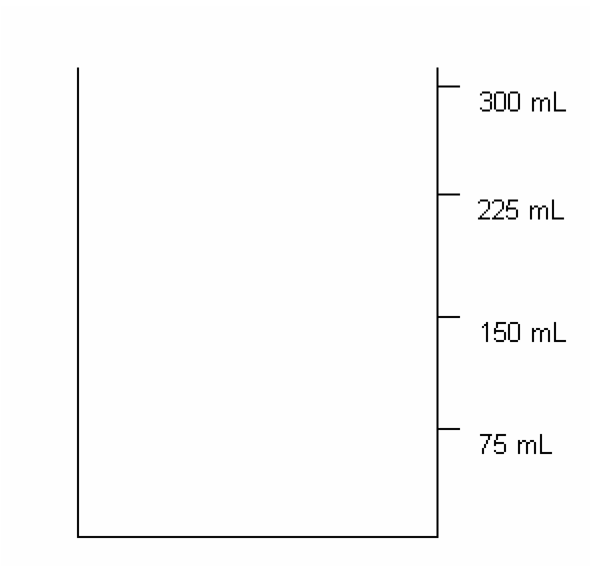
How much water dripped out of the dirt into your measuring cup?

__________ milliliters (ml)

How much water did the sand absorb?

__________ milliliters (ml)

Use the cup pictured below to create a diagram, color in what the water look like in your measuring cup.



Which material holds more water (dirt or sand)?

____

Plants need water to survive. What materials are best for growing a plant? (Remember that too much water can be bad for a plant!)

____

____

Why are the materials that you chose the best for growing a plant?

____

____

____

____

____

3.C.8 Soil Composition

An interactive introduction to the composition of soil

Grade Level	3
Sessions	(1): 1 at 40-60 minutes
Seasonality	None
Instructional Mode(s)	Whole Class, Small Groups
Team Size	4 students
WPS Benchmarks	03.SC.TE.05, 03.SC.IS.01, 03.SC.IS.04, 03.ES.SC.09
MA Frameworks	3-5.ES.0.4
Key Words	Igneous, Metamorphic, Rocks, Sedimentary

Summary

The objective of this lesson is to extend students' understanding of the composition of soil with a hands-on activity. Students will examine a variety of soil samples with a hand lens and will then create their own soil mixtures of organic and inorganic materials.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.05 Develop a knowledge and understanding of the metric measurement system.
2. 03.SC.ES.09 Observe sand with a hand lens. Note how particles resemble minerals. Observe topsoil with a hand lens. Look for fragments of organisms. Note differences in color, texture, odor, and clumping due to organic components vs. pure sand. Mix topsoil and sand together in various proportions to represent samples of types of soils.
3. 03.SC.IS.01 Ask questions and make predictions that can be tested.
4. 03.SC.IS.04 Conduct multiple trials to test a prediction. Compare the results of an investigation or experiment with the prediction.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.ES.0.4 Explain and give examples of the ways in which soil is formed (the weathering of rock by water and wind and from decomposition of plant and animal remains).

Additional Learning Objectives

1. Students will gain experience with the metric system.
2. Students will learn about the composition of soil as background for studying plants and plant growth.

Required Background Knowledge

None

Essential Questions

1. What types of materials comprise soil?
2. How do various mixtures of soil and sand appear?

Introduction / Motivation

Explain to students that they will examine various types of soil and will then create their own soil. The instructor may wish to open the discussion by asking students what they already know about different kinds of soil, and if applicable, what they remember from the lesson 3.C.7 Soil – Water Retention.

Procedure

The instructor will:

1. Create groups of students with approximately four children in each.
2. Provide students with four different samples of sand and soil (see Materials List). Assign a number to each sample so students can identify them on their worksheets (see Appendix A: Teachers Notes)
3. Ask students to spread a small amount of one soil sample on a large piece of paper and to separate the various components with a toothpick.
4. Ask students to observe each soil sample with a magnifying glass and to record the sample's properties on the worksheet titled Soil Explorer: Part 1.
5. Provide students with samples of topsoil and sand and ask them to mix the two according to the direction on the second worksheet (see Soil Explorer: Part 2).
6. Lead students through the worksheet, Soil Explorer: Part 2.

Materials List

Materials per Class	Amount	Location
Various Samples of Soil (ex. sandy, silty, loam, clay)	One cup of each soil type per group	Backyard, garden shop

Materials per Student	Amount	Location
Soil Explorer: Part 1 Worksheet	One	End of lesson plan – print or photocopy
Soil Explorer: Part 2 Worksheet	One	End of lesson plan – print or photocopy
White Construction Paper	One sheet	Classroom
Magnifying Glass	One	Classroom, science supply store
Toothpicks	Two	End of lesson plan – print or photocopy

Vocabulary with Definitions

1. *Clay* – a fine grain soil that is pliable when moist but hardens as it is heated.
2. *Compost* – decomposed organic material.
3. *Loam* – a soil containing clay, sand, silt and organic matter.
4. *Metric System* – a system of measurement based on powers of ten.
5. *Sand* – loose particles of broken rock.
6. *Silt* – particles of rock slightly larger than clay but smaller than sand.
7. *Soil* – a mixture of minerals, organic material, and decaying life forms.
8. *Topsoil* – the upper layer of soil; plant roots are typically found here.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Observe student groups at work to determine whether students understand that a mixture of sand and organic material make up soil.
2. Collect student worksheets and assess student understanding of the metric system.

Lesson Extensions

1. Allow students to use various-sized screens to separate the pieces of dirt and rock in their soil samples.

Attachments

1. Appendix A: Teachers Notes
2. Soil Explorer: Part 1
3. Soil Explorer: Part 2

Troubleshooting Tips

1. In preparing for the lesson, ensure that selected soil samples have plenty of organic material for students to observe. Add leaves, sticks or other organic materials as necessary to supplement soils and to enrich the students' investigation.

Safety Issues

None

Additional Resources

None

Appendix A: Teacher's Notes

With respect to the soil samples used in this lesson, a good variety of samples is recommended. Select mixtures such as: sand, silt, loam, peat, topsoil, and soil from various locations (backyard, park, etc.). Soils from different locations will allow students to see some of the many different kinds of soil on Earth.

Provide each student or group of students with four samples of various types of soil. Large plastic cups work well for passing these samples to students. The cups can be reused for the different soil types and for mixing the sand and dirt together. Allowing students to mix their own soil shows them how soil forms naturally, as well as its composition.

Emphasize the importance of the metric system and ensure that students are aware of the units they are using to describe the different amounts of dirt.

Soil Explorer: Part 1

Name ______________________ Date _________________

Directions: Pretend that you are a civil engineer who is studying the soil found at a construction site. Look at the four different soil samples that you have been given. **Observe** the different properties of your soil sample. Next, **observe** the different materials and organisms in the sample.

Soil Sample: number___________

This soil looks…

____

____

____

Are there any minerals in this soil? Is it sandy?

____

____

Are there any decaying (rotting) organisms, such as plants or insects, in this soil?

____

____

____

Soil Sample: number __________

This soil looks…

____

____

____

Are there any minerals in this soil? Is it sandy?

____

____

Are there any decaying (rotting) organisms, such as plants or insects, in this soil?

____

____

____

Soil Sample: number____________

This soil looks…

____

____

____

Are there any minerals in this soil? Is it sandy?

____

____

Are there any decaying (rotting) organisms, such as plants or insects, in this soil?

____

____

____

Soil Sample: number____________

This soil looks…

____

____

____

Are there any minerals in this soil? Is it sandy?

____

____

Are there any decaying (rotting) organisms, such as plants or insects, in this soil?

____

____

____

Soil Explorer: Part 2

Name ______________________ Date _________________

Directions: Pretend that you are a civil engineer who wants to create three different types of soil. Use a measuring cup marked with **milliliters** and mix different amounts of soil and sand. **Record** the different properties of your new mixtures, and record the different materials and organisms you find.

Part One

Make a mixture of:

- 40 milliliters (ml) of sand
- 10 milliliters (ml) of topsoil

What does this soil look like?

____

____

____

____

Is the soil very rough or smooth?

____

____

Where do you think you might find soil like this outdoors?

____

____

____

____

Part Two

Make a mixture of:

- 30 milliliters (ml) of sand
- 20 milliliters (ml) of topsoil

What does this soil look like?

Is the soil very rough or smooth?

Where do you think you would find soil like this?

Part Three

Make a mixture of:

- 20 milliliters (ml) of sand
- 20 milliliters (ml) of topsoil

What does this soil look like?

Is the soil very rough or smooth?

Where do you think you would find soil like this?

3.D.1 Plant Structures

Sketching basic plant structures

Grade Level	3
Sessions	(1): 1 at 50 minutes
Seasonality	Spring
Instructional Mode(s)	Whole Class, Individual
Team Size	N/A
WPS Benchmarks	03.SC.TE.04, 03.SC.LS.07
MA Frameworks	3-5.TE.2.1, 3-5.LS.0.3
Key Words	Bark, Flower, Leaf, Plant, Root, Seed, Sketch, Stem, Structure, Wood

Summary

Sketches are commonly used to quickly capture information on paper. After learning to identify various plant structures and their respective functions, students will demonstrate their knowledge by sketching each plant structure and describing its function.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2. 03.SC.LS.04 Identify the structures in plants (leaves, roots, flowers, stem, bark, wood) that are responsible for food production, support, water transport, reproduction, growth, and protection.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.21 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2. 3-5.LS.21 Identify the structures in plants (leaves, roots, flowers, stem, bark, wood) that are responsible for food production, support, water transport, reproduction, growth, and protection.

Additional Learning Objectives

None

Required Background Knowledge

None

Essential Questions

1. What is a sketch (see Vocabulary with Definitions)?
2. Why is a sketch useful?
3. How can a sketch show various plant structures?
4. What are the functions of various plant structures?

Introduction / Motivation

The instructor might bring to class a variety of vegetables, flowers, and woody plants (see Materials List) so that students can examine various plant "structures" (see Vocabulary with Definitions).

Procedure

The instructor will:

1. Lead a class discussion about plant structures, using a variety of plants to illustrate leaves, roots, flowers, stems, bark, and wood (see Materials List).
2. Allow small groups of students to study the example vegetables, flowers, and woody plants.
3. Lead students through the attached worksheet (see Sketching Plant Structures).
4. Ask students to write a short description of the function of each plant structure.

Materials List

Materials per Class	**Amount**	**Location**
Leaves (ex. lettuce, spinach, cabbage)	Varies	Grocery store
Roots (ex. carrot, potato, turnip, beet)	Varies	Grocery store
Flowers (ex. broccoli, cauliflower, cut flowers)	Varies	Grocery store
Stems (ex. celery, white carnations, cut flowers)	Varies	Grocery store

Bark (ex. from trees, mulch)	Varies	Outdoors
Wood (ex. pencils, chairs, sticks, blocks, logs)	Varies	Classroom, outdoors

Materials per student	**Amount**	**Location**
Sketching Plant Structures Worksheet	One	End of lesson plan – print or photocopy

Vocabulary with Definitions

1. *Bark* – the tough outer covering of trees that protects the inside of trees, creates new plant cells, and transports fluids.
2. Flower – the showy, usually colorful part of a plant that is used for producing and receiving pollen.
3. *Leaf* – a usually flat, green, plant structure used in photosynthesis and transpiration (breathing).
4. *Root* – a plant structure that provides stability to a plant, collects water and nutrients from the soil, and is usually found below the ground.
5. *Seed* – a plant structure that contains the *embryo*, or tiny, developing plant.
6. *Sketch* – a brief outline or overview drawing.
7. *Stem* – a thin part of a plant that connect various structures (leaves, flowers, roots) to each other and functions in the transport of water and nutrients.
8. *Structure* – the arrangement of various plant tissues.
9. *Vegetable* – the edible part of a plant, such as the root, leaf, stem, flower, or bud, other than the seed-bearing embryo (fruit).
10. *Wood* – the layer of plant tissue just below the bark that provides structure to a plant and transports water.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Collect student worksheets to determine whether students understand the use and creation of a "sketch".
2. Collect student worksheets to determine the level of understanding of various plant "structures" and their respective functions.

Lesson Extensions

1. Place white carnations or roses into vases of water; add several drops of food coloring. The veins in the flower's petals will change color once the flower's stem draws water from the vase into the petals.
2. Help students to grow plants from seed; explain each stage of new growth.

Attachments

1. Sketching Plant Structures

Troubleshooting Tips

None

Safety Issues

None

Additional Resources

None

Sketching Plant Structures

Name: ______________________ Date: _________________

Complete the chart below. Look carefully at the example plants that your teacher gives you. Make a **sketch** of each special plant **structure**. Color your sketches. Beside each sketch, describe the function of each structure.

Plant Structure	My Sketch	Function
Bark		______________________________ ______________________________ ______________________________ ______________________________ ______________________________
Flower		______________________________ ______________________________ ______________________________ ______________________________ ______________________________

Plant Structure	My Sketch	Function
Leaf		
Root		

Plant Structure	My Sketch	Function
Seed		
Stem		

Plant Structure	My Sketch	Function
Wood		______ ______ ______ ______ ______

3.D.2 Plant Life Cycles

Creating a diagram of the generic plant life cycle

Grade Level	3
Sessions	(1): 1 at 50 minutes
Seasonality	Spring
Instructional Mode(s)	Whole Class
Team Size	N/A
WPS Benchmarks	03.SC.TE.04, 03.SC.LS.07
MA Frameworks	3-5.TE.2.1, 3-5.LS.0.3
Key Words	Diagram, Fruit, Germinate, Life Cycle, Plant

Summary

Students will learn to construct a diagram that demonstrates how plants change in a predictable pattern called a *life cycle*. A diagram is a useful way to convey various types of information and will show the distinct stages through which a generic plant passes.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2. 03.SC.LS.07 Recognize that plants and animals go through life cycles that include birth, growth, development, reproduction and death.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.21 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2. 3-5.LS.03 Recognize that plants and animals go through predictable life cycles that include birth, growth, development, reproduction, and death.

Additional Learning Objectives

1. Students will work independently to solve the problem of representing a plant life cycle graphically.

Required Background Knowledge

1. Students should be familiar with the idea that plants undergo a life cycle that includes the following stages: seed, plant, flower, fruit, seed and death.

Essential Questions

1. What is a diagram?
2. Why is a diagram useful?
3. What are the various stages of a plant's life cycle?
4. How can a diagram show different the stages of a plant's life cycle?

Introduction / Motivation

The instructor might begin by asking students to discuss, as a class, the definitions of "plant" and "diagram" (see Vocabulary with Definitions). Students may wish to comment on whether or not animals need plants to survive, and if so, why.

Procedure

The instructor will:

1. In a visible location, create a diagram of the generic "plant life cycle". The plant life cycle usually includes the following events:
    - Seeds germinate
    - Roots and stem appear
    - Leaves appear
    - Flowers appear
    - Flowers produce pollen
    - Flowers receive pollen
    - Plants produce fruit that contains seeds
    - Seeds disperse
2. Ask students to use the attached worksheet to create a diagram of the "plant life cycle." Students may draw and color directly on the worksheet, or may use the worksheet as a guide, creating their Plant Life Cycle Diagram on a larger separate sheet of paper.

Materials List

Materials per student	Amount	Location
Plant Life Cycle Worksheet	One	End of lesson plan – print or photocopy

Vocabulary with Definitions

1. *Diagram* – a symbolic representation of information that shows and explains relationships.
2. *Fruit* – the seed-bearing part of a plant.
3. *Germinate* – to begin to grow.
4. *Life cycle* – the series of repetitive events experienced by an organism as it grows, develops, reproduces, and dies.
5. *Plant* – a photosynthetic organism that reproduces itself, usually by producing fruit and seeds.
6. *Vegetable* – the edible part of a plant, such as the root, leaf, stem, flower, or bud, other than the seed-bearing embryo (fruit).

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Collect student worksheets to gauge student understanding of the use, function, and proper construction of a "diagram".
2. Collect student worksheets to determine how well students can graphically represent the "plant life cycle".

Lesson Extensions

1. Allow students to use magnifying glasses to examine the inside of dried beans that have been soaked for several days in water. Each seed should show a tiny root as the seed begins to germinate (see Vocabulary with Definitions).
2. Use lesson 3.D.3 Corn and Bean Plant Life Cycles to teach students specifically about corn and bean plants.

Attachments

1. The Plant Life Cycle

Troubleshooting Tips

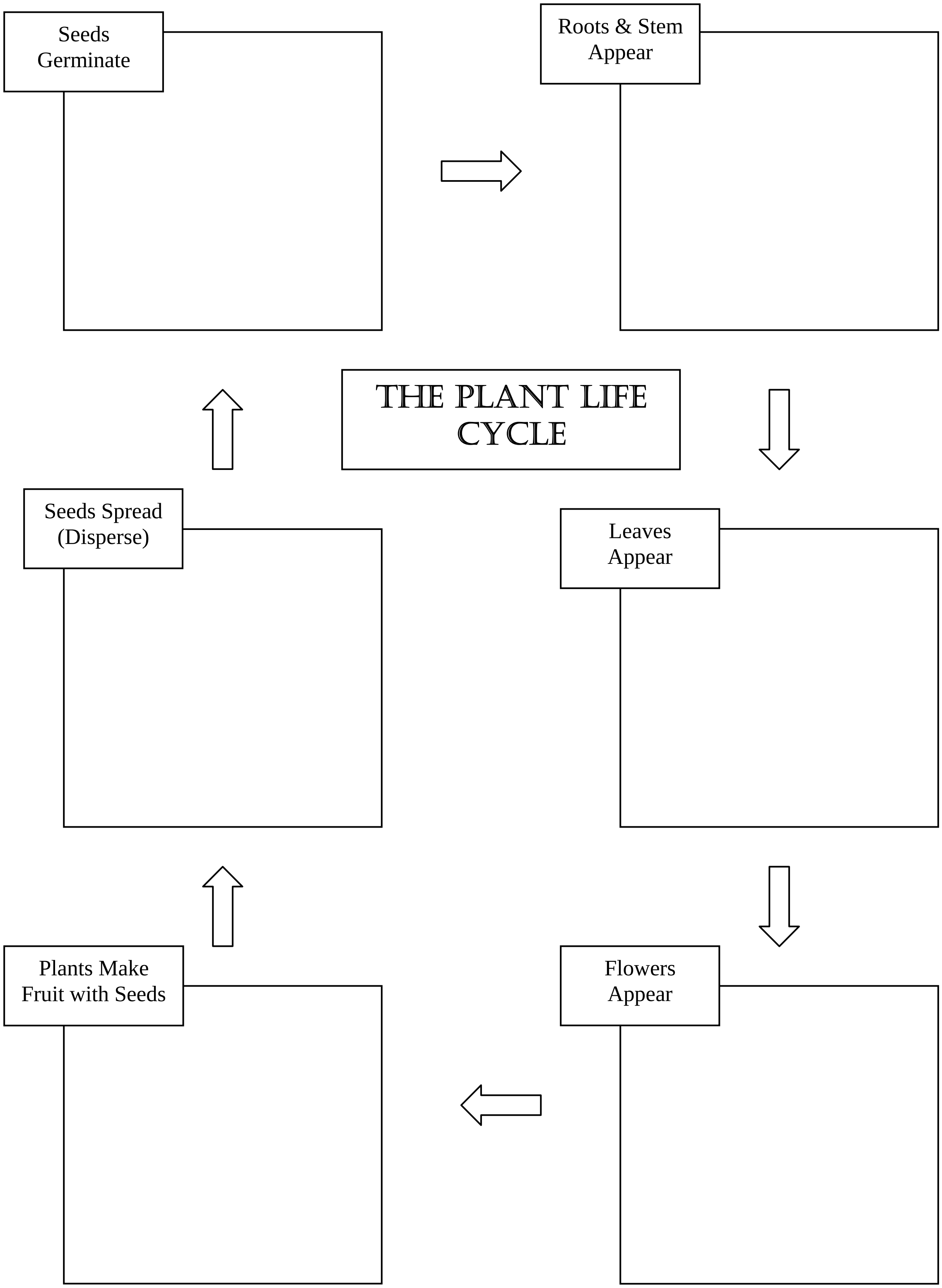
None

Safety Issues

None

Additional Resources

1. Life cycle of a plant graphically represented. http://www.arboretum.fullerton.edu/grow/primer/cycle.asp (27 January 2006).


Seeds Germinate
Roots & Stem Appear
THE PLANT LIFE CYCLE
Leaves Appear
Flowers Appear
Plants Make Fruit with Seeds
Seeds Spread (Disperse)

3.D.3 Corn and Bean Life Cycles

Creating a diagram of corn and bean plant life cycles

Grade Level	3
Sessions	(1): 1 at 50 minutes
Seasonality	Spring
Instructional Mode(s)	Whole Class
Team Size	N/A
WPS Benchmarks	03.SC.TE.04, 03.SC.LS.07, 03.SC.LS.09
MA Frameworks	3-5.TE.2.1, 3-5.LS.0.3
Key Words	Bean Plant, Corn Plant, Diagram, Life Cycle

Summary

Students will learn to construct a diagram that demonstrates how corn and bean plants change in a predictable pattern called a *life cycle*. A diagram is a useful way to convey various types of information. The diagram will show the distinct stages through which the plants pass.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2. 03.SC.LS.07 Recognize that plants and animals go through life cycles that include birth, growth, development, reproduction and death.
3. 03.SC.LS.09 Describe the major stages that characterize the life cycle of the bean and corn plants.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.2.1 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2. 3-5.LS.03 Recognize that plants and animals go through predictable life cycles that include birth, growth, development, reproduction, and death.

Additional Learning Objectives

1. Students will examine structures of bean and corn seeds with hand lenses.

2. Students will work independently to solve the problem of representing corn and bean plant life cycles graphically.

Required Background Knowledge

1. Students should be familiar with the idea that corn and bean plants undergo life cycles that include the following stages: seed, plant, flower, fruit, seed and death.

Essential Questions

1. What is a diagram?
2. Why is a diagram useful?
3. What are the stages in the life cycles of corn and bean plants?
4. How can a diagram show different the stages of corn and bean plants' life cycle?

Introduction / Motivation

The instructor might open a class discussion about corn and beans by asking students how people use various parts of the plants. In some parts of the world, corn husks are used for cooking just as paper muffin liners are used in the United States. Husks are also used to make brooms and other parts of the corn plant are ground to make feed for livestock. Bean plants, bean pods and bean seeds are eaten by livestock.

Procedure

The instructor will:

1. Provide students with magnifying glasses.
2. Allow students to examine fresh bean pods, dried beans, fresh corn-on-the-cob, and dried corn kernels (see Materials List).
3. Review with students the idea of a "plant life cycle" (see lesson 3.D.2: Plant Life Cycles). Ensure that students thoroughly understand the following steps:
    - Seeds germinate
    - Roots and stem appear
    - Leaves appear
    - Flowers appear (corn flowers are called "tassels")
    - Flowers produce pollen

- Flowers receive pollen
- Plants produce fruit that contains seeds
- Seeds disperse

4. Lead students through the attached worksheet (see Corn and Bean Plant Life Cycles).

Materials List

Materials per class	Amount	Location
Fresh Bean Pods	Varies	Grocery store
Dried Beans (kidney, lima, vanilla, coffee, etc.)	Varies	Grocery store
Corn-on-the-Cob, Fresh	Several ears	Grocery store, farm stand
Corn Kernels	Varies	Grocery store

Materials per student	Amount	Location
Corn and Bean Plant Life Cycles Worksheet	One	End of lesson plan – print or photocopy
Magnifying Glasses	One	Classroom

Vocabulary with Definitions

1. *Bean Plants* – a large family of plants with edible seeds and pods; example beans include: kidney, lima, soy, coffee, pinto, and vanilla.
2. *Corn Plants* – tall cereal grasses that produce edible kernels, or seeds; first cultivated in Central America.
3. *Diagram* – a symbolic representation of information that shows and explains relationships.
4. *Fruit* – the seed-bearing part of a plant.
5. *Germinate* – to begin to grow.
6. *Life cycle* – the series of repetitive events experienced by an organism as it grows, develops, reproduces, and dies.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Use completed student worksheets to determine whether students understand the use, function, and proper construction of a "diagram"
2. Observe individual students; discuss with them the parts of bean and corn plants that they examine with magnifying glasses.

Lesson Extensions

1. Allow students to use magnifying glasses to examine the inside of dried beans that have been soaked for a number of days in water. Each seed should show a tiny root as the seed begins to germinate (see Vocabulary with Definitions).
2. Grown corn and bean plants from seed in the classroom. Use the attached worksheet (Corn and Bean Plant Life Cycles) as a journal so that students can visually record the growth of their plants.

Attachments

1. Corn and Bean Life Cycles

Troubleshooting Tips

None

Safety Issues

None

Additional Resources

1. National Association of Biology Teachers. Resources, Archives. Information about bean and pea plants. Accessed 18 January 2006 from http://www.nabt.org/sup/resources/askexpert_plants.asp.
2. Iowa Farmer's Today Corn Cam. Good internet links to a variety of websites with information about corn. Accessed 24 February 2006 from http://www.iowafarmertoday.com/corn_cam/.
3. Iowa State University: College of Agriculture. Good variety of information about corn. Accessed 24 February 2006 from http://maize.agron.iastate.edu/.

Corn and Bean Plant Life Cycles

Name: ______________________ Date: _________________

Create a **diagram** that shows each stage in the **life cycle** of a corn *or* bean plant. Draw an illustration in each of the boxes below.

Seeds germinate	
Roots and stem appear	
Leaves appear	
Flowers appear	

Flowers produce pollen	
Flowers receive pollen	
Plant produces fruit that contains seeds	
Seeds disperse	

3.D.4 Growing Plants

Designing a container for live plants using the Engineering Design Process

Grade Level	3
Sessions	(4): 2 at 35 minutes, 1 at 40-80 minutes, 1 at 5-15 minutes
Seasonality	Spring
Instructional Mode(s)	Whole Class, Small Groups
Team Size	2-4 Students
WPS Benchmarks	03.SC.TE.01, 03.SC.TE.02, 03.SC.TE.03, 03.SC.TE.05, 03.SC.IS.01, 03.SC.IS.02, 03.SC.IS.03, 03.SC.IS.04, 03.SC.IS.05, 03.SC.IS.06, 03.SC.LS.07, 03.SC.LS.08
MA Frameworks	3-5.TE.1.1, 3-5.TE.1.2, 3-5.TE.2.1, 3-5.TE.2.2, 3-5.TE.2.3, 3-5.LS.0.3, 3-5.LS.0.9
Key Words	Container, Engineering Design Process, Graph, Grow, Metric System, Plant

Summary

This lesson provides students with the opportunity to design, construct, and test a container for growing plants. Students will apply their knowledge of the Engineering Design Process and will observe the various stages of the plant life cycle. After making observations, students will also record information in an organized manner and will practice sketching various plant structures.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.01 Identify materials used to accomplish a design task based on a specific property, e.g., weight, strength, hardness, and flexibility.
2. 03.SC.TE.02 Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.
3. 03.SC.TE.03 Identify a problem that reflects the need for shelter, storage, or convenience.
4. 03.SC.TE.05 Develop a knowledge and understanding of the metric measurement system.
5. 03.SC.IS.01 Ask questions and make predictions that can be tested.

6. 03.SC.IS.02 Select and use appropriate tools and technology (e.g., calculators, computers, balances, scales, meter sticks, graduated cylinders) in order to extend observations.
7. 03.SC.IS.03 Keep accurate records while conducting simple investigations or experiments.
8. 03.SC.IS.04 Conduct multiple trials to test a prediction. Compare the results of an investigation or experiment with the prediction.
9. 03.SC.IS.05 Recognize simple patterns in data and use data to create a reasonable explanation for the results of an investigation or experiment.
10. 03.SC.IS.06 Record data and communicate findings to others using graphs, charts, maps, models, oral and written reports.
11. 03.SC.LS.07 Recognize that plants and animals go through life cycles that include birth, growth, development, reproduction and death.
12. 03.SC.LS.08 Grow plants from seeds. Document the complete life cycle of the plant. Emphasize emergence of structures and the functions of these structures. Record changes in height over time. Graph the data.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.1.1 Identify materials used to accomplish a design task based on a specific property, i.e., weight, strength, hardness, and flexibility.
2. 3-5.TE.1.2 Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.
3. 3-5.TE.2.1 Identify a problem that reflects the need for shelter, storage, or convenience.
4. 3-5.TE.2.2 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
5. 3-5.TE.2.3 Identify relevant design features (e.g., size, shape, weight) for building a prototype of a solution to a given problem.
6. 3-5.LS.03 Recognize that plants and animals go through predictable life cycles that include birth, growth, development, reproduction, and death.

7. 3-5.LS.09 Recognize plant behaviors, such as the way seedlings' stems grow toward light and their roots grow downward in response to gravity. Recognize that many plants and animals can survive harsh environments because of seasonal behaviors, e.g., in winter, some trees shed leaves, some animals hibernate, and other animals migrate.

Additional Learning Objectives

1. Students will strengthen observation skills.
2. Students will apply their knowledge of the metric system and the Engineering Design Process.
3. Students will strengthen manipulative skills.

Required Background Knowledge

1. Students should be familiar with a variety of plant structures (see lesson 3.D.1. Plant Structures).
2. Students should have a good understanding of the generic plant life cycle (see lesson 3.D.2 Plant Life Cycles).

Essential Questions

1. What do plants need in order to grow?
2. What type of container is best for growing plants?
3. How can the Engineering Design Process be used to design a plant container?
4. How can plant growth be measured and graphed in the metric system?

Introduction / Motivation

The instructor may wish to begin the lesson by discussing the basic necessities of plants. Students should understand that plants require sunlight, water, nutrients, and air. It is important to note that too much or too little of each of these required items can be harmful to a plant. For example, too much water or too much sunlight will kill some varieties of plants.

Procedure

The instructor will:

Part 1: (35 minutes)

1. Provide each student with a Design My Own Plant Container worksheet.
2. Lead students though questions 1 and 2. They may wish to discuss their ideas with a partner or within groups. Encourage students to feel confident in unique ideas. There is no incorrect container design.
3. Show students the materials available for container design (see Materials List – Materials per Student).
4. Ask students to complete the chart on page 3 of their worksheets. Note that if students plan to use “potting soil”, they should write the “amount” that they will use as a metric measurement. It may be helpful to allow students to look at a set of metric measuring cups.

Part 2: (35 minutes)

1. Ask students to revisit the Design My Own Plant Container worksheet.
2. Encourage students to look over responses to questions 1 and 2.
3. Provide each student with a single large sheet of white paper.
4. Ask students to complete question 3, taking care to label each part of the diagram and to mark which materials will be used for each part of the Plant Container.

Part 3: (40-80 minutes)

1. Ask each student to write his/her name on a craft stick using a permanent marker.
2. Allow students to collect the materials that they have chosen for their plant container.
3. Provide students with sufficient time to construct their plant containers.
4. Ask each student to plant five marigold seeds in the newly designed plant container. If students plan to use potting soil, they should measure the correct amount of soil by using metric measuring cups.
5. As a class, review a plant’s basic necessities (water, air, nutrients, sunlight).

6. Determine the most appropriate location in the classroom for the marigold seeds to germinate (see Vocabulary with Definitions).
7. Place all plant containers (each containing five planted seeds) in a disposable aluminum baking pan (see Materials List) and leave pan in the elected location. The pan serves to catch drained water and to keep all students' containers together.
8. Remind students on this day and in subsequent days that plants require water; the potting soil should always stay moist (see Troubleshooting Tips).

Part 4: (completed regularly 5-15 minutes each time)

1. Ask students to record observations of their plants using the chart in question 4 of their Design My Own Plant Container worksheet.
2. Once plants have flowered, ask students to complete the worksheet, The Metric System – Plants.

Materials List

Materials per class	**Amount**	**Location**
Indelible Marker (ex. Sharpie®)	Several	Classroom
Disposable Aluminum 9x13" Baking Pan	Two or three	Dollar store, grocery store
Water	Varies	Classroom
Metric Measuring Cups	Several sets	Grocery store, home

Materials per student	**Amount**	**Location**
Scissors	One pair	Classroom
Marigold Seeds	Five	Garden supply store
Craft Stick	One	Craft store
Paper Cups	Varies	Grocery store
Plastic Cups	Varies	Grocery store
Styrofoam Egg Carton	Varies	Recycle bin
Plastic Wrap	Varies	Grocery store
Paper Towels	Varies	Grocery store

Potting Soil	Varies	Garden supply store, Wal-Mart
Metric Ruler	One	Classroom

Vocabulary with Definitions

1. *Germinate* – to begin to grow.
2. *Graph* – a visual representation of information.
3. *Grow* – to increase in size, develop, and mature.
4. *Metric System* – a system of measurement in which length is measure in meters, or increments of meters, and weight is measure in grams, or increments of grams.
5. *Plant* – a photosynthetic organism that reproduces itself, usually by producing fruit and seeds.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Listen to class discussions to determine whether students understand the basic necessities of plants.
2. Collect student worksheets and evaluate whether students are able to correctly utilize the Engineering Design Process to design and create a container for growing a plant.
3. Collect student worksheets to determine whether students are able to correctly measure length and volume in metric units.

Lesson Extensions

1. Demonstrate and/or involve students in composting.
2. As a class, grow sweet potatoes (see Additional Resources and Appendix B: Instructor’s Notes).

Attachments

1. Appendix A: Instructor’s Notes
2. Appendix B: The Engineering Design Process
3. Design My Own Plant Container

Troubleshooting Tips

1. For germinating seeds, potting soil should always feel damp, but not wet. If some students' plants are frequently dry, the students may wish to "improve" their containers, perhaps by placing clear plastic wrap over the tops of their containers and poking several holes for air.
2. The teacher may wish to grow extra plants at home in case several students' plants fail to sprout or do not survive.

Safety Issues

1. Scissors should be used with caution.
2. The edge of the plastic wrap box is quite sharp; the instructor should pass out plastic to students that chose it.

Additional Resources

1. Virginia Department of Agriculture and Consumer Services. Resources for Teachers: Growing Activities for Tomorrow's Consumers. Accessed 31 December 2005 from http://www.vdacs.virginia.gov/teachers/growing.html.

Appendix A: Instructor's Notes

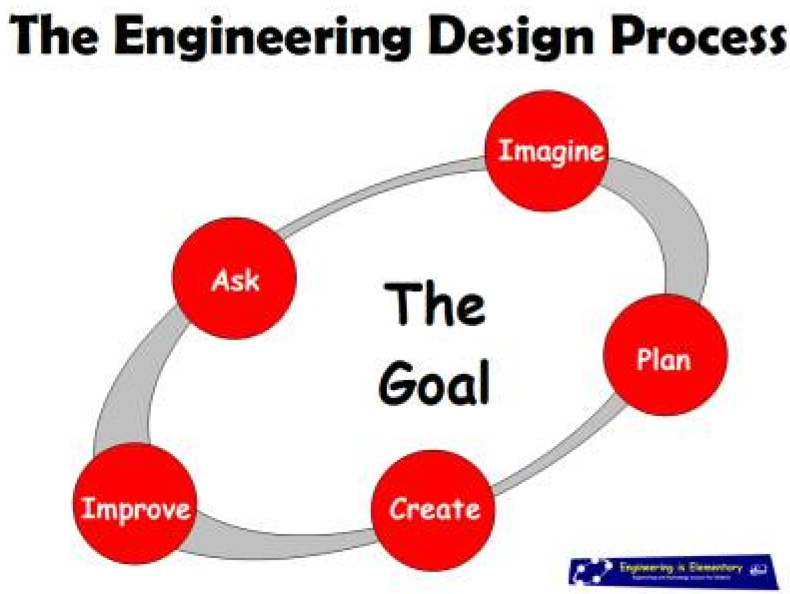
The following excerpt comes from: Forrester, Tina. "Sweet potato vine: Amaze your kids by sprouting a lush vine from this grocery-cart staple". Canadian Gardening. Accessed 31 December 2005 from http://www.canoe.ca/LifewiseHomeYardWeekend00/0513 potato.html.

Growing a Sweet Potato

"To help your kids grow their own vine, choose a firm sweet potato. Some are treated with heat to keep them from sprouting on grocery-store shelves, but most grow roots in a matter of days after being placed in water. Using four toothpicks, have your child suspend the vegetable on the rim of a jar or mug filled with water. Make sure the bottom half - the pointed end - is under water. Place in a sunny spot, and change or add water as needed. In a few days, roots will form below the water. And, two to three weeks later, leaves and stems will sprout from the top. Continue to grow the plant in water or, after a month or two, pot the sweet potato in a houseplant potting mix. Keep the soil moist. The stems are weak, so help your child tie them to strings, wire or a stake. Feed once a month with a balanced water-soluble fertilizer such as 20-20-20. As the vine grows, cut it back a few inches to force the plant to grow bushy. If your kids want to try growing sweet potatoes in your garden, you can have them root 25- to 30-centimetre (10- to 12-inch) cuttings in water, then plant them outside in late May to produce sweet potatoes they can dig and eat in the fall. Plant 30 centimeters (one foot) apart and feed once a month with 5-10-10 fertilizer. Mulch with straw or dry leaves to control weeds, and keep the soil moist. The tubers need approximately 120 days to mature, so let them grow as long as you can. But don't let frost hit them. In case of an early frost, cover the plant overnight with newspaper to keep the vines growing. Late in the season, probe beneath the vines to test the size of the tubers. Be careful not to puncture or bruise them. Store the tubers in a cool, dry place, and wrap them in newspaper to keep them from sprouting."

Appendix B: The Engineering Design Process

"The Engineering Design Process for Children" and associated text comes directly from: http://www.mos.org/doc/1559 (accessed 2 February 2006).



"The Engineering Design Process is a series of steps that engineers use to guide them as they solve problems. Many variations of the model exist. While having a guide is useful for novices who are learning about engineering, it is important to note that practicing engineers do not adhere to a rigid step-by-step interpretation of the process. Rather there are as many variations of the model as there are engineers. Because our curriculum project focuses on young children, we have created a simple process that depicts fewer steps than other renditions and that uses terminology that children can understand. The engineering design process is cyclical and can begin at any step. In real life, engineers often work on just one or two steps and then pass along their work to another team."

"A few questions can guide students through each of the steps:

"ASK

- What do I want to do?

- What is the problem?
- What have others done?

“IMAGINE

- What could be some solutions?
- Brainstorm ideas.
- Pick one to start with that you think will work the best.

“PLAN

- Draw a diagram of your idea.
- Make lists of materials you will need to make it.
- Decide how it works. How will you test it?

“CREATE

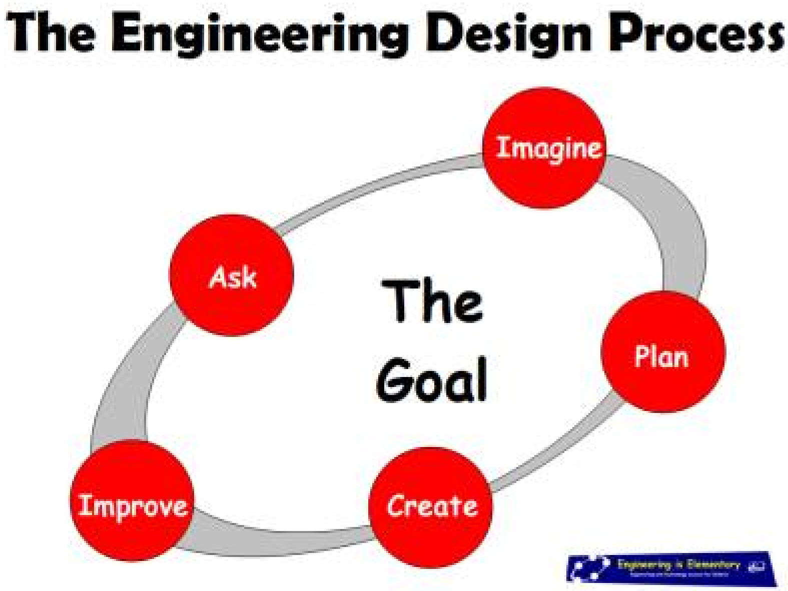
- Build a prototype.
- Test it.
- Talk about what works, what doesn't, and what could work better.

“IMPROVE

- Talk about how you could improve your product.
- Draw new designs.
- Make your product the best it can be!”

Design My Own Plant Container

Name: ______________________ Date: _________________



The Engineering Design Process for Children: http://www.mos.org/doc/1559 (accessed 27 February 2006)

1. **Ask –**

What type of plant container do I want to build? ______________________________

____

____

2. **Imagine** –

Imagine that you are a materials engineer. What is the purpose of your plant container? *Hint: think about what plants need to survive!*

Read the list of materials below. Think about which materials you would like to use. Beside the materials that you **will** use, write the **amount** that you will use and the **reasons** you will use each one.

Material	Amount	Why will you use the material to construct your plant container?
Paper Cup		
Plastic Cup		
Styrofoam Egg Carton		
Plastic Wrap		
Paper Towel		
Potting Soil		

3. **Plan –**

On a separate sheet of paper, draw a picture of the plant container that you would like to create. Label the parts of the container (“pot”, soil, drainage holes, etc.). Beside each part, write which material you will use to make that part of the container. Use the chart of materials above when you plan.

4. **Create –**

Collect the materials that you need and then plant your five marigold seeds. Place a craft stick with your name on it in your plant container. Test your container by observing your plants as they grow. Use the chart on the next page to record your observations.

What happened?	What date did it happen?	What did it look like? Draw a picture.
Roots appear (you *might* not be able to see the roots if you planted your seed in soil)		
A stem appears		
Leaves appear		

What happened?	What date did it happen?	What did it look like? Draw a picture.
A flower appears		
Flowers make seeds		
Seeds disperse or are collected		

5. Improve –

How can you make your plant container better?

The Metric System – Plants

Name: ______________________ Date: _________________

The Metric System – In many parts of the world, people use a system for measuring called the "Metric System". The metric system uses meters, centimeters (cm), and millimeters (mm) to describe the length of an object. Use the metric side of your ruler, marked with centimeters (cm) to answer the following questions.

1. How **tall** did your tallest marigold grow? ____________ centimeters

2. How **tall** is your plant container? ____________ centimeters

3. How **wide** is your widest flower? ____________ centimeters

4. How **wide** is your narrowest flower? ____________ centimeters

Look at a **metric** measuring cup to answer the following questions.

5. **Estimate** how much water, in milliliters (ml), your plant drinks every day.

   ____________ milliliters

6. About how much potting soil did you give your plant?

   ____________ milliliters

3.E.1 Maple Trees – Structure

Creating sketches of maple trees' structures

Grade Level	3
Sessions	(1): 1 at 50 minutes
Seasonality	February or March
Instructional Mode(s)	Whole Class, Individual
Team Size	N/A
WPS Benchmarks	03.SC.TE.04, 03.SC.LS.06
MA Frameworks	3-5.TE.2.1, 3-5.LS.0.2
Key Words	Bark, Fruit, Leaf, Maple, Sketch, Twig

Summary

Students will study important structures of maple trees and will learn to sketch maple bark, fruit, leaves, and twigs. This lesson provides background information useful for continued study of maple trees and the maple sugaring process.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2. 03.SC.LS.06 Study maple trees and go maple sugaring. Identify the structures in the maple tree and their functions.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.21 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2. 3-5.LS.02 Study maple trees and go maple sugaring. Identify the structures in the maple tree and their functions.

Additional Learning Objectives

1. Students will be introduced to the vocabulary appropriate to discussing structures (see Vocabulary with Definitions) of maple trees.
2. Students will create sketches of various maple tree structures.

Required Background Knowledge

None

Essential Questions

1. What is a sketch (see Vocabulary with Definitions)?
2. Why is a sketch a good way to represent information?
3. How can a sketch show various structures of a maple tree?
4. What are the various maple tree structures?

Introduction / Motivation

The instructor might open a class discussion about how people use maple trees. The instructor may then introduce the idea of conveying information through sketches. Sketches are commonly used by scientists and engineers to (a) quickly record information, (b) to capture the essence of an object studied in the field, or (c) to create a working image of a particular thought.

Procedure

The instructor will:

1. Show students pictures or examples of maple trees. This can be done by reading an appropriate science textbook, by reading a children's book about maple sugaring (see Additional Resources), or ideally, by allowing students to examine real maple leaves, bark and twigs.
2. Ask students to use the attached worksheet (see Maple Trees – Sketching Structures) or a large sheet of paper to sketch the important basic structures of maple trees: leaves, twigs, bark, and fruit (see Vocabulary with Definitions).
3. As a class, discuss the function of each structure (see Vocabulary with Definitions). Consider allowing small groups of students to each present one maple structure and its function(s).

Materials List

Materials per class	Amount	Location
Examples of Maple Trees: in books; in pictures; or real leaves/bark/twigs/fruit	Varies	Outdoors, see Additional Resources

Materials per student	Amount	Location
Maple Trees – Sketching Structures Worksheet	One	End of lesson plan – print or photocopy

Vocabulary with Definitions

1. *Bark* – the tough outer covering of trees that protects the inside of trees, creates new plant cells, and transports fluids.
2. *Fruit* – the seed-bearing part of a plant; maple fruit is called "samara".
3. *Leaf* – a usually flat, green, plant structure used in photosynthesis and transpiration (breathing).
4. *Maple* – a type of tree found in northern, temperate regions that (a) looses its leaves during the winter, (b) has hand-shaped leaves, and (c) has winged, paired fruits.
5. *Sketch* – a brief outline or overview drawing.
6. *Structure* – the arrangement of various plant tissues.
7. *Twig* – a small branch that bears buds, leaves, and sometimes the flowers and fruit of a woody plant.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Collect student worksheets to determine whether students understand the use, function, and proper construction of a "sketch".
2. Collect student worksheets to determine the extent to which students understand and can recognize various maple tree structures.

Lesson Extensions

1. Ask students to bring to class maple leaves and fruit.
2. Study the processes of sap collection, sap boiling, and maple syrup production in detail.
3. Bring to class samples of a recipe created with maple syrup.
4. Teach lesson 3.E.2 Maple Trees – Maple Syrup.

Attachments

1. Appendix A: Instructor's Notes
2. Maple Trees – Sketching Structures

Troubleshooting Tips

1. If students have difficulty sketching a maple leaf, they may trace their own hand. Maple leaves are palmate, meaning they have five points; thus, tracing one's hand approximates the structure of a real leaf.

Safety Issues

None

Additional Resources

1. Ehlert, Lois. Red Leaf, Yellow Leaf. 1991.
2. Linton, Marilyn. The Maple Syrup Book. 1983.
3. Mass Maple Association: Watson-Spruce Corner Road, Ashfield MA 01330. Online at http://www.massmaple.org. Via email at info@massmaple.org.

Appendix A: Instructor's Notes

The following information about maple tree identification was taken verbatim from http://www.massmaple.org/treeID.html (accessed 4 January 2005).

Maple Tree Identification

"The commercial production of maple products in North America occurs primarily in the northeastern United States and southeastern Canada. This is the geographic area of greatest abundance of sugar maple (*Acer saccharum*) and black maple (*Acer nigrum*), the two most preferred and most commonly tapped maple species.

"There are thirteen native maple species in North America. While most of these species are probably tapped to some extent, at least by hobbyists, sugar and black maple, along with red maple (*Acer rubrum*), provide most of the commercial sap. A fourth maple species, silver maple (*Acer saccharinum*), is sometimes tapped, particularly in roadside operations, and is often confused with red maple."

The "…sugar, black, red and silver maple…share several characteristics in common. All have leaves of similar shape: a single leaf blade with the characteristic maple shape, 3-5 lobes radiating out like fingers from the palm of a hand (palmately lobed) with notches (called sinuses) between the lobes. Like all maples, the leaves, buds and twigs of all four are attached in pairs opposite each other along the branches. Also, all four produce a fruit called a samara (or double samara), which is a pair of connected, winged seeds.

"Sugar and black maple are very similar species and unquestionably the most preferred species for producing maple products, primarily because of their high sugar content. Sugar maple occurs naturally throughout most of the northeastern United States and southeastern Canada.…

“Identifying a tree as a sugar or black maple…is easily done from the leaves by observing 5-lobed leaves, the paired opposite attachment of the leaves along the stem and the lack of teeth along the leaf margin; from the bark of older trees by observing the long plates that remain attached on one side; from the twigs by observing the opposite arrangement of buds and the relatively long, pointed, brownish terminal bud; and from the seed by observing its horseshoe shape and size. Distinguishing between sugar and black maple is best done by comparing the leaf structure (particularly the number of lobes, droopiness and presence or absence of stipules along base of petiole) and by the degree of bumpiness of the twigs.

“Sugar and black maples are found on a variety of soils and site conditions, but neither tolerates excessively wet or dry sites, and both grow best on moist, deep, well-drained soils. Black maple is more likely to be found along moist river bottoms. Both species can be found growing in pure stands, with each other, or with a wide variety of other hardwood species including American beech, American basswood, yellow birch, black cherry, northern red oak, yellow poplar and black walnut. Both species have been planted extensively as roadside trees which are often tapped as part of a sugaring operation. Plantations of sugar maple have also been established with the intent of developing efficient, productive sugarbushes. Both species are relatively long lived, capable of living well beyond 200 years, with trunk diameters greater than 30 inches and heights greater than 100 feet.

“Sugar and black maple both grow in the shade of other trees (they are shade tolerant), and trees of many different ages (sizes) are often found in a forest. Both species are also found in stands composed of trees that are essentially all the same age (size). Healthy sugar and black maple trees growing in overstocked uneven-aged or even-aged stands can be expected to achieve tapable size in 40 to 60 years, depending on overall site quality. Thinning or release cutting dramatically reduces this age-to-tapable-size.

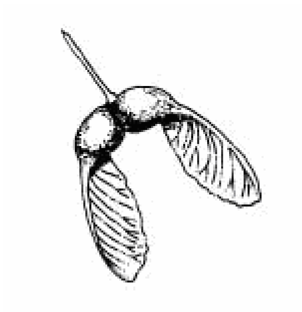
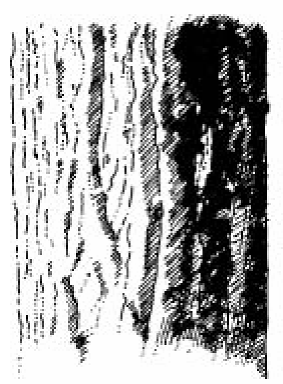
“Sugar and black maple are particularly attractive as sugartrees because of their high sap sugar content and the late date at which they begin growth in the spring. Sugar and black maple have the highest sap sugar content of any of the native maples. While the exact sap sugar content of a tree will vary depending on many factors including genetics, site and weather, sugar and black maples generally average between 2.0 and 2.5 percent sap sugar content. It is not unusual to find many trees in a sugarbush well in excess of 3 percent, and occasionally higher. Genetic research on sugar maple suggests that the sap sugar content of planted seedlings can be increased by controlled breeding. Other things being equal, higher sap sugar content translates to lower costs of production and greater profits.

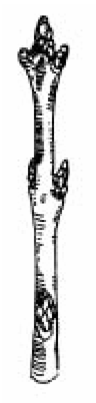
“Black and sugar maples begin growth later in the spring than red or silver maple. As maples begin their growth, chemical changes occur in the sap which make it unsuitable for syrup production. The term "buddy sap" is often applied to late season sap which produces syrup with a very disagreeable flavor and odor. Because sugar and black maple resume growth later than red or silver maple, sap may be collected later in the spring.”

Maple Trees – Sketching Structures

Name: ______________________ Date: __________________

Complete the chart below. In the empty boxes, make your own **sketch** of maple fruit, maple bark, a maple twig, and a maple leaf. Color your sketches.

Maple Tree Structure	Picture	My Sketch
Fruit		
Bark		

Twig		
Leaf		

Images from: http://www.massmaple.org/treeID.html (accessed 21 January 2006).

3.E.2 Maple Trees – Maple Syrup

Designing a receptacle for the collection of maple sap

Grade Level	3
Sessions	(1): 1 at 50 minutes
Seasonality	N/A
Instructional Mode(s)	Whole Class, Small Groups or Individual
Team Size	N/A
WPS Benchmarks	03.SC.TE.03, 03.SC.LS.06
MA Frameworks	3-5.TE.2.1, 3-5.LS.0.2
Key Words	Container, Design, Engineering Design Process, Maple Sap

Summary

Students will use their knowledge of the maple sugaring process to design a container for maple sap collection. The Engineering Design Process (EDP) will provide students with a framework for designing the container.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.03 Identify a problem that reflects the need for shelter, storage, or convenience.
2. 03.SC.LS.06 Study maple trees and go maple sugaring. Identify the structures in the maple tree and their functions.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.21 Identify a problem that reflects the need for shelter, storage, or convenience.
2. 3-5.LS.02 Study maple trees and go maple sugaring. Identify the structures in the maple tree and their functions.

Additional Learning Objectives

1. Students will apply their knowledge of maple sugaring, specifically sap collection and syrup production.

Required Background Knowledge

1. Students should have a solid understanding of:
   a. Maple tree structures and their functions (see lesson 3.E.1 Maple Trees – Structure)
   b. The maple sugaring process, including how/when to tap, how/when to collect sap (see Additional Resources and Appendix A: Teacher's Notes)

Essential Questions

1. What are some methods used to collect sap from a maple tree?
2. What is the EDP?
3. How can the EDP help engineers invent new technologies?
4. How can the need to collect and store sap from maple trees be defined as a "storage problem", in the engineering sense?
5. How does one design a container for the collection of maple sap?

Introduction / Motivation

The instructor may with to refresh the important facts about maple sugaring by reading to students, "How Maple Syrup is Made" (see Appendix A: Instructor's Notes – Maple Sugaring). If students are already familiar with the sugaring process, consider asking students to recall some of the methods used to collect sap from maple trees. These may include buckets or tube systems.

Procedure

The instructor will:

1. Ask students to recall the EDP and how the process was used in the past (see Appendix B: Instructor's Notes – The Engineering Design Process).
2. Lead students through the attached worksheet (see Designing a Container to Collect Maple Syrup).

Materials List

Materials per student	Amount	Location
Designing a Container to Collect Maple Syrup Worksheet	One	End of lesson plan – print or photocopy

Vocabulary with Definitions

1. *Bucket* – the device used to collect flowing sap from a tapped maple tree.
2. *Container* – an object that can be used to hold or carry other objects, such as maple sap.
3. *Design* – to use pictures to plan a new product or idea.
4. *Maple sap* – a watery fluid that circulates within a maple tree, bringing nutrients to various tree structures; sap is boiled to make maple syrup.
5. *Spout* – a hollow plastic, metal or wood piece that fits into a hole drilled into a maple tree; allows sap to flow out of the tree into a collection receptacle.

http://countryjoe.bizland.com/Xmapletap.jpg (accessed 5 January 2006)

6. *Tubing* – a system of flexible, hollow hoses that are strung among a series of maple trees to collect flowing maple sap.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Collect student worksheets to determine whether students understand the EDP.
2. Collect student worksheets to determine the extent to which students can use engineering to solve a problem relating to storage.
3. Observe class discussions to determine whether students understand (a) that maple trees make sap, not syrup and (b) that sap must be collected in containers and boiled before it becomes syrup.

Lesson Extensions

1. Allow students to build prototypes of the containers they have designed. Allow students to test these prototypes with water (instead of sap).
2. Tap a local maple tree and use a covered bucket or adapted milk jug to collect flowing sap in February/March.
3. Use a maple recipe to create a maple treat that can be shared by students (see http://www.massmaple.org for recipe ideas).

Attachments

1. Appendix A: Instructor's Notes – Maple Sugaring
2. Appendix B: Instructor's Notes – The Engineering Design Process
3. Designing a Container to Collect Maple Sap

Troubleshooting Tips

1. The picture below is an example of a clean milk jug being used as a container to collect maple syrup.

http://www.massmaple.org/jug_bucket.jpg (accessed 5 January 2006)

2. If students have difficulty selecting materials to use for their container, or trouble visualizing how the materials might be put together, consider prompting them by asking leading questions such as:
    - What types of materials hold liquids?
    - How much liquid would you like to collect?
    - How will your container attach to a maple tree?

Safety Issues

None

Additional Resources

1. Mass Maple Association: Watson-Spruce Corner Road, Ashfield MA 01330. Online at http://www.massmaple.org. Via email at info@massmaple.org.
2. Mass Maple Association Video: “A Sweet tradition-The Love and Labor of Maple”
3. University of Maine Bulletin #7036: “How to Tap Maple Trees and Make Maple Syrup”. Accessed 5 January 2006 from http://www.umext.maine.edu/onlinepubs /PDFpubs/7036.pdf.
4. Yankee Grocery “Sleepy Mountain Maple Syrup – Maple Sugaring Glossary”. Accessed 5 January 2006 from http://www.yankeegrocery.com/maple_glossary. html.

Appendix A: Instructor's Notes – Maple Sugaring

The following information about maple sugaring was taken verbatim from http://www.massmaple.org (accessed 4 January 2005).

How Maple Syrup is Made

"Pure maple syrup is made by concentrating the slightly sweet sap of the sugar maple tree. The basics needed for making maple syrup therefore are some sugar maple trees and a method of concentrating the sap into syrup. As winter comes to an end, usually in late February or early March, sugarmakers prepare for their annual harvest of the maple trees. The group of maple trees that is used is called sugarbush, or maple orchard. The sugarmaker prepares his sugarbush by clearing access roads in the snow, removing fallen branches, and setting up his buckets or sap tubing systems. Whether they use tubing or buckets, sugarmakers must be sure that all their sap gathering, collecting, evaporating and bottling equipment is absolutely clean and in good condition before the beginning of the season.

"There is no set time when a sugarmaker must tap his trees. He must be aware of the clues of nature to tell him when the time is right. The temperatures are not as extreme as earlier in the winter, the streams run with melting snow, icicles drip faster, the crows can be heard announcing the not-too-distant arrival of spring. Mostly what the sugarmaker is waiting for is the arrival of the time of year known as "sugar weather," when the nights are below freezing and the days are mild. This is the type of weather that makes the sap flow.

"When the sugar farmer feels the time is "right" he will start to tap his trees. Tapping involves going from tree to tree in the sugarbush, drilling holes 7/16 of an inch in diameter, about 3 inches deep, into the wood which carries the sap. If buckets are used to collect the sap, a metal spout or "spile" is tapped snugly into the hole, and a bucket is hung from a hook on the spout. A cover is put on the bucket to keep out rain, snow, and debris. If a plastic tubing system is used to collect the sap, a plastic spout, which is connected to the pipeline system, is tapped into the hole in the tree.

“The maple tree must be a least 10 inches in diameter and in good health before it can be tapped. It usually takes about forty years before a tree will reach tappable size. The hole is usually placed about waist high on the tree, and not near previous tapholes. Larger trees may take as many as three or four taps, but only if they are healthy. The sugarmaker has a feeling of respect for his trees and he knows he must take care of this tree which provides for him. Trees that are in poor health or have been defoliated by insects are often tapped less, or not tapped at all. If proper taping procedures are followed, tapping will not endanger the health and vitality of the tree. A healthy sugar maple can provide sap every year for a hundred years or more.

“Throughout the 4-6 week sugar season, each tap hole will yield approximately ten gallons of sap. This is only a small portion of the tree's total sap production and will not hurt the tree. The average amount of syrup that can be made from this ten gallons of sap is about one quart. These amounts vary greatly from year to year, and depend upon the length of the season, the sweetness of the sap, and many complex conditions of nature, such as weather conditions, soil, tree genetics, and tree health.

“When the trees have been tapped and all the equipment is ready, the sugarmaker is ready for the “first run,” that exciting time of the year when the sap first starts to flow, sap flow requires freezing nights and warm (but not hot) days. These must alternate and be in long enough series to allow the sap to move in the trees. For the first time each season the sap will drip into a bucket or slowly start to flow down the tubing system towards a collection tank. Prolonged periods of either below freezing temperatures or days without freezing nights will stop the sap flow. As a result, sugarhouses often start and stop boiling at different times due to local climatological factors. The gentle geographic progression is a reverse of the fall foliage season. That is the lower elevations and more southern regions of Massachusetts usually start their maple, seasons before the higher elevations and more northerly areas. Prolonged warm spells or cold snaps during the season may halt sap flow for several days, and it may start again when conditions are favorable. As a result, 24 hour work days are often interspersed with two, three or even more days of relative inactivity. This gives the sugarmaker a chance to recover lost sleep, make repairs, clean equipment, and get ready for the next sap "run."

"Maple sap, as it comes from the tree is a clear, slightly sweet liquid. The sugar content rages from one to four percent. A device called a "hydrometer" can be floated in the sap to determine the exact sugar content. Sweeter sap is favored because less water will have to be evaporated to make maple syrup. The sap must be evaporated as soon as possible because the freshest sap makes the best quality syrup. Where the bucket collection method is used, a sap gathering tank is mounted on a sled, wagon, or truck, and is moved through the sugarbush as the sap is gathered. Tractors are most often used, but sometimes teams of horses or even oxen pull the sleds or wagons. The sap is collected from each tree by workers using large gathering pails. These pails are dumped into the gathering tank, which is then taken to a large sap storage tank at the sugarhouse, where it will soon be boiled down into pure maple syrup. If the tubing system is being used, the sap drips from the taphole, through the spout, and into a 5/16 inch diameter section of tubing. This tubing is joined to other trees, and eventually turns into a larger pipeline called a "mainline." The mainline carries the sap downhill to a sap storage tank either at the sugarhouse, or at a low spot where it can be collected easily and transported to the sugarhouse.

"Maple syrup is traditionally made in a building called a "sugarhouse" - the name of the building comes from the time when most sap was actually turned into sugar. Sugarhouses vary in size and shape, each with its own character. Some may be rustic wood buildings out in the woods with poor access and no electricity, full of old tools and memories of grandfather's sugar seasons of the past. Still others might remind you of a modern food processing plant, brightly lit and streamlined. Each sugarhouse will have vent at the top, a cupola - which is opened to allow the steam of the boiling syrup to escape the building. All throughout the maple producing regions, steam rising from the cupola is a signal that maple syrup season is under way.

"Antique or modern, each sugarhouse will contain an evaporator used to boil down the sap into syrup. Evaporators are made up of one or more flat pans which sit on an "arch," a type of firebox. Wood or oil, and sometimes gas or coal is burned at the front end, and the flames are drawn along the underside of the pan, heating and boiling the sap as they travel towards the rear. It commonly takes about one cord of wood or sixty gallons of oil to boil down 800 gallons of sap into maple syrup. Depending on the size of the evaporator and the number of trees tapped, this may represent anywhere from two hours to two whole days of boiling. The basic design of maple syrup evaporators has changed little over the years, although sugarmakers are always tinkering with new designs to make the process faster or more fuel efficient. The size of the evaporator depends on the number of trees a producer has tapped. Most are from two feet wide and six feet long up to six feet wide by twenty feet long. Many backyard and hobby sugarmakers use smaller arrangements, or boil down their sap on the kitchen stove.

“An evaporator pan is divided into partitions, so that the sap is continuously flowing through the pan. Fresh sap enters at the back of the pan, where a float valve keeps the sap about an inch deep. As the water is boiled off, two things happen: First, the liquid becomes sweeter, and begins to move towards the front of the pan, traveling through the partitions. Secondly, more fresh sap is allowed into the rear of the pan. In this way the water is constantly being evaporated away, the liquid is becoming sweeter as it moves towards the front of the pan, and the float valve in the rear is always allowing more sap to be added to keep the level about an inch deep. It takes about forty gallons of this slightly sweet sap, boiled down, to make one gallon of pure maple syrup.

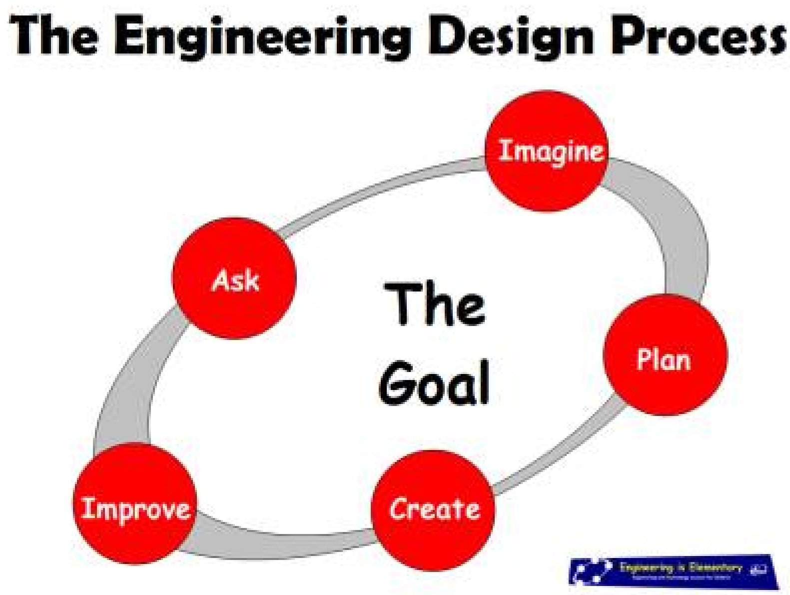
“The sugarmaker concentrates his attention to the front of the evaporator where the boiling sap is turning a golden color as it approaches being maple syrup. From time to time he will check the temperature of the boiling liquid. When it reaches seven and a half degrees above the boiling point of water, it has reached proper density and has become maple syrup. Another way of checking for the proper density or sugar content is to place a scoop into the boiling syrup. If the drops along the bottom edge of the scoop begin to hold together like a sheet or apron, then the sugarmaker knows the syrup is done. Coming from the tree, maple sap is approximately 98% water and 2% sugar. When the syrup is finished, it is only 33% water and 67% sugar.

“At this stage a valve on the front of the pan is opened and some of the finished boiling syrup is drawn off the pan and is filtered. After filtering, the syrup is bottled and is ready for sale or ready for a fresh pile of warm pancakes.

“The length of the sugaring season is totally dependent upon the weather. It may last only a few weeks, or as long as six or eight weeks. As the days become increasingly warmer, and the nights rarely get below freezing, the buds on the branches of the maple trees begin to swell, marking the end of the season. Chemical changes take place within the tree as baby leaves begin to form within the buds. At this time the sap is no longer suitable for boiling down into syrup. Sugarmakers know it is now time to clean up all the buckets, spouts, tanks, and miles of tubing with plenty of hot water so that the equipment can be put into storage and ready for the next winter.”

Appendix B: Instructor's Notes – The Engineering Design Process

"The Engineering Design Process for Children" and associated text comes directly from: http://www.mos.org/doc/1559 (accessed 7 October 2005).



"The Engineering Design Process is a series of steps that engineers use to guide them as they solve problems. Many variations of the model exist. While having a guide is useful for novices who are learning about engineering, it is important to note that practicing engineers do not adhere to a rigid step-by-step interpretation of the process. Rather there are as many variations of the model as there are engineers. Because our curriculum project focuses on young children, we have created a simple process that depicts fewer steps than other renditions and that uses terminology that children can understand. The engineering design process is cyclical and can begin at any step. In real life, engineers often work on just one or two steps and then pass along their work to another team."

"A few questions can guide students through each of the steps:

“ASK

- What do I want to do?
- What is the problem?
- What have others done?

“IMAGINE

- What could be some solutions?
- Brainstorm ideas.
- Pick one to start with that you think will work the best.

“PLAN

- Draw a diagram of your idea.
- Make lists of materials you will need to make it.
- Decide how it works. How will you test it?

“CREATE

- Build a prototype.
- Test it.
- Talk about what works, what doesn't, and what could work better.

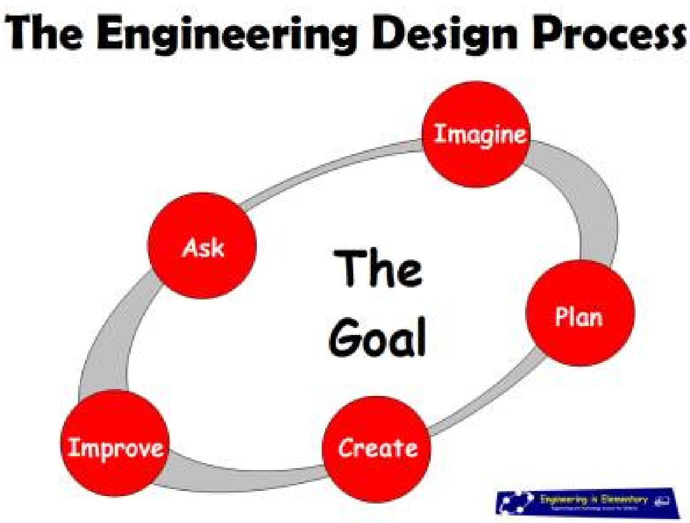
“IMPROVE

- Talk about how you could improve your product.
- Draw new designs.
- Make your product the best it can be!”

Designing a Container to Collect Maple Sap

Name: ______________________ Date: _________________

Engineers design tools and technologies that help people do work faster and better. You have learned about maple sugaring and you know that maple sap flows out of a maple tree by means of a spout. Pretend that you are an engineer who is designing a container to collect maple sap.



The Engineering Design Process for Children: http://www.mos.org/doc/1559 (accessed 21 January 2006)

1. **Ask:** What will you design? ____
2. **Imagine:** Close your eyes. Visualize your design.
3. **Plan:** Place a check in the box beside the materials that you would like to use.

- ☐ Plastic pail
- ☐ Sponge
- ☐ Metal pail
- ☐ Wooden pail
- ☐ Copper tubing
- ☐ Plastic milk jug, 1 gallon size
- ☐ Soft plastic tubing
- ☐ Plastic milk jug, ½ gallon size
- ☐ Paper bag, large size
- ☐ Glass tubing

4. **Create:** In the space below, draw picture of your design. Label the materials that you would use to make each part.

5. **Improve:** How can you improve your design? For example, could you change part of the design so that the container could hold more sap? Or attach to a maple tree more easily?

3.F.1 The Water Cycle: Part 1

Students will learn to demonstrate the various phases of the water cycle

Grade Level	3
Sessions	(1): 1 at 40-50 minutes
Seasonality	None
Instructional Mode(s)	Whole Class
Team Size	N/A
WPS Benchmarks	03.SC.TE.04, 03.SC.PS.05, 03.SC.PS.06
MA Frameworks	3-5.TE.2.2, 3-5.PS.0.3
Key Words	Condensation, Evaporation, Gas, Liquid, Precipitation, Solid, Water Cycle

Summary

This lesson reinforces basic concepts learned about the water cycle. Children will revisit the various phases of water (ice, water, water vapor) and will recall facts that they have learned about the characteristics of solids, liquids, and gases. After confirming that students have a solid understanding of evaporation, condensation, and precipitation, the instructor will create a simple working model of the Water Cycle.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

7. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
8. 03.SC.PS.05 Describe how water can be changed from one state to another by adding or taking away heat.
9. 03.SC.PS.06 Do simple investigations with evaporation, condensation, freezing and melting. Confirm that water expands upon freezing.

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6. 3-5.TE.2.2 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
7. 3-5.PS.3 Describe how water can be changed from one state to another by adding or taking away heat.

Additional Learning Objectives

4. Students will correctly use the terms evaporation, precipitation, and condensation.

Required Background Knowledge

1. A good understanding of solids, liquids and gases.
2. A good understanding of how evaporation, condensation, and precipitation relate to the water cycle.

Essential Questions

5. What is a phase?
6. What is evaporation?
7. What is condensation?
8. What is precipitation?
9. What are the three phases of water present in the water cycle?
10. What are the four stages of the water cycle?
11. What happens when heat is added to water?
12. What happens when heat is taken away from water?

Introduction / Motivation

The instructor might begin the lesson by reviewing a visible chart or diagram of the water cycle. (S)he might then lead the class in a discussion about specific examples of solids, liquids, and gases and list these examples in a visible location.

Procedure

The instructor will:

4. Write the four stages of the water cycle on the board (see Appendix A: Instructor's Notes).
5. Review *condensation*, *evaporation*, and *precipitation* (see Vocabulary with Definitions).
6. Construct a model of the water cycle (see Materials List).
   - Fill the plastic container with several cups of warm water and add a few drops of blue food coloring.
   - Cover the plastic container with plastic wrap and tape it firmly in place.
   - Place a frozen icepack on top of the plastic wrap.
   - Let the cycle sit for about ten minutes until the water cycle begins.
7. While waiting for the water cycle to begin, lead students through questions 1 through 8 on the attached worksheet.

8. Allow students to observe the water cycle.
   - Explain the three phases of water (gas, liquid, and solid).
   - Show where condensation, evaporation, and precipitation are occurring.
9. Explain the three phases of water to the students: the icepack is a solid; the rain (condensation below icepack) is a liquid; and the water vapor (invisible, but eventually condenses into liquid droplets) is a gas.
10. Lead students through questions 9 through 15 on the attached worksheet.

Materials List

Materials per class	**Amount**	**Location**
Clear Plastic Container	One	Home
Blue Food Coloring	Several drops	Home, grocery store
Plastic Wrap	One piece	Classroom, grocery store
Tape	One roll	Classroom, drugstore
Warm Water	Two – Three cups	Tap, coffeemaker, microwave oven
Icepack	One	Home, grocery store

Materials per student	**Amount**	**Location**
The Water Cycle Worksheet	One	End of lesson plan – print or photocopy

Vocabulary with Definitions

10. *Condensation* – the process by which a gas changes into a liquid, usually by cooling.
11. *Evaporation* – the process by which a solid (ex. ice) or liquid (ex. water) changes into a gaseous phase (ex. water vapor), usually by taking in heat.
12. *Gas* – a substance that has neither independent shape nor volume but tends to expand indefinitely.
13. *List* – a group of words, organized by category.
14. *Liquid* – a fluid without an independent shape but with a definite volume (unlike a gas).
15. *Precipitation* – any form of water that falls to the Earth's surface from clouds; examples include: rain, snow, sleet, and hail.
16. *Solid* – a substance that has a definite shape and volume.
17. *Water Cycle* – the repetition of evaporation and condensation that distributes Earth's water throughout the planet.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

3. Collect student worksheets and determine whether the students understand:
    a. The water cycle
    b. The various phases of water (gas, liquid, solid)
    c. The differences among solids, liquids and gases
    d. The terms *precipitation*, *condensation*, and *evaporation*.

Lesson Extensions

3. Teach lesson 3.F.2 Water Cycle 2.

Attachments

4. Appendix A: Instructor's Notes
5. The Water Cycle

Troubleshooting Tips

1. Explain to students that in nature, the sun warms the water in oceans, lakes and streams. The sun provides the *energy* that water needs to change phase from liquid (water) to gas (water vapor). In the classroom, the Water Cycle demonstration uses warm water because it evaporates rather quickly. In nature, both warm and cool water evaporate, but warm water evaporates faster.

Safety Issues

1. None

Additional Resources

2. Brummett, D.C, Lind, K.K, Barman, C.R., DiSpezio, M.A., and Ostlund, K.L. Destinations in Science. Addison-Wesley; Reading, MA. 1995.

Appendix A: Instructor's Notes

The following information is from the Addison-Wesley textbook, Destinations in Science, pages D16, D17, D22, and D23.

The Water Cycle:

- "Energy from the sun heats water in the oceans, lakes, rivers and streams. The water evaporates and becomes water vapor that moves into the air."
- "Water vapor rises high into the air. High above the earth's surface, the air cools. Water vapor condenses into tiny water droplets to form clouds."
- "Billions of tiny drops come together to form larger drops of water. When the drops become too heavy, they fall to the earth's surface as rain, snow or hail."
- "At the surface, some water falls into rivers, lakes and oceans. Some soaks into the ground. Rivers and ground water flow downhill into oceans or lakes."

The Water Cycle

Name: ________________________________ Date: _________________

Directions: Answer the questions below. Think about words that you have learned, such as: water vapor, water, ice, condensation, evaporation, and precipitation.

Visualize how your bathroom looks after you take a hot bath or shower.

1. How does the air feel? ____

2. How does the mirror look? ____

Imagine that you are outside on a hot summer day. You are drinking a cold glass of lemonade with ice cubes.

3. What happens to the *outside* of the glass of lemonade? _____________________

   ____

   ____

Imagine that a pot of water is **heated** on a stove.

4. What is the ***state*** or ***phase*** of the water in the pot? _________________________

5. What is the ***state*** or ***phase*** of the water leaving the pot? ____________________

6. What is the special word for the process of water leaving the pot? ____________

   ____

Imagine that it is December and water, in the form of snow, falls from the sky.

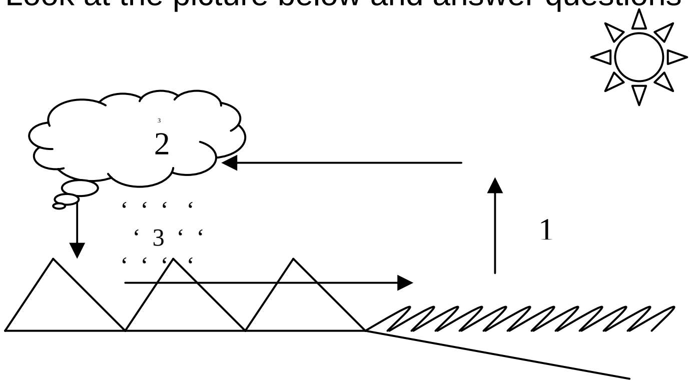
7. What is the special word for when water, **in any form**, falls from the sky? *Hint: the answer is not "snow"!* ____

8. What is the ***state*** or ***phase*** of the snow? ________________________________

In the boxes below, draw pictures that illustrate the different ***states*** or ***phases*** of water. The last one is very tricky!

Solid Water	Liquid Water	Water Vapor

Look at the picture below and answer questions 9, 10 and 11.



9. At which number in the diagram does condensation occur? ____________________

10. At which number in the diagram does evaporation occur? ____________________

11. At which number in the diagram does precipitation occur? ____________________

Think about the water cycle demonstration that you saw.

12. Was the water in the bottom of the container *warm* or *cold*? ____________________

13. In nature, can both *warm* and *cold* water evaporate? ____________________

14. What did the water in the bottom of the container *represent*? ____________________

____

15. Where did you see the “raindrops”? ____________________________________

16. Did you *see* water vapor? Why or why not? ______________________________

____

3.F.2 The Water Cycle: Part 2

Diagramming the water cycle and demonstrating the expansion of frozen water

Grade Level	3
Sessions	(3): 1 at 30-40 minutes, 2 at 40-50 minutes
Seasonality	None
Instructional Mode(s)	Whole Class
Team Size	N/A
WPS Benchmarks	03.SC.TE.04, 03.SC.PS.06, 03.SC.IS.04
MA Frameworks	3-5.TE.2.2, 3-5.PS.0.3
Key Words	Condensation, Diagram, Evaporation, Water Cycle

Summary

After seeing the water cycle, the students will diagram and label the water cycle on their own. The students will also confirm that water expands when cooled.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2. 03.SC.PS.06 Do simple investigations with evaporation, condensation, freezing and melting. Confirm that water expands upon freezing.
3. 03.SC.IS.04 Conduct multiple trials to test a prediction. Compare the results of an investigation or experiment with the prediction.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.2.2 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2. 3-5.PS.3 Describe how water can be changed from one state to another by adding or taking away heat.

Additional Learning Objectives

1. Students will have a full understanding of the water cycle.
2. Students will be able to describe what happens to water when it is cooled.

Required Background Knowledge

1. Some knowledge of solids, liquids and gases is needed.

2. Students must have seen the water cycle and be familiar with how water changes phase upon addition or subtraction of heat (see lesson 3.F.1 Water Cycle 1).

Essential Questions

1. What is a diagram?
2. What are the four stages of the water cycle?
3. When does condensation occur?
4. When does evaporation occur?
5. What happens when water is cooled?

Introduction / Motivation

The instructor might begin the lesson by reviewing the water cycle and writing the stages on the board. (S)he might demonstrate the water cycle again, emphasizing condensation and evaporation. Another option to begin the lesson is to ask the students if they know how rain and snow happen.

Procedure

The Instructor will:

Part 1: (40-50 minutes)

1. Ask each student to bring two empty, disposable water bottles from home with their initials on them.
2. Provide each student with a sheet of paper.
3. Ask the students to create a labeled diagram of the water cycle; ensure that students include arrows.
4. The diagram should include clouds, the ocean, land, and the sun, as well as the words “evaporation”, “condensation” and “precipitation” (“rain” or “snow”) written in the correct locations.
5. Ask students to label their diagrams with words representing the different phases of water (“gas”, “liquid” and “solid”).
6. If time permits, ask students to color their diagrams.

Part 2: (40-50 minutes)

1. In a visible location, place three, clear, plastic cups: one filled with cold water, one filled with room temperature water, and one filled with hot water (see Materials List).
2. Ask students to use their worksheets (see The Phases of Water) to write a prediction about what will happen when ice is put into each of the three cups.
3. Place one ice cube in each cup.
4. Allow students to observe the cups.
5. Ask students to record their observations on The Phases of Water worksheet.
6. Explain to students why and how the ice cube quickly melted in the cup with the hot water.
7. Ask each student to fill his or her two water bottles *almost* to the top. The bottles should not be completely full or they will explode in the freezer.
8. Ask students to measure the height, in centimeters, of the *water* inside each water bottle; students should record this information on The Phases of Water worksheet.
9. Ask students to predict what will happen when one of the bottles is put into the freezer with the cap on, and the other is left at room temperature with the cap off. They should record their predictions on The Phases of Water worksheet.
10. Leave one of each student's water bottles in a room-temperature location where it will not be disturbed. *Leave the cap off of the bottle so that evaporation can occur.*
11. Collect the other water bottle, place it in the freezer, and leave it overnight.

Part 3: (30-40 minutes)

1. Ask students to collect both of their water bottles.
2. Ask each student to measure and record the height, in centimeters, of water in each water bottle.
3. Discuss what happened to the water.
    a. Some of the water in the water bottle left at room temperature should have evaporated; therefore, the height of the water decreased.
    b. The frozen water should have expanded; therefore, the height of the water increased.
4. Have the students complete the rest of The Phases of Water worksheet.

Materials List

Materials per Class	**Amount**	**Location**

Clear Plastic Cups	Three	Home
Cold Water	Varies	Classroom
Room Temperature Water	Varies	Classroom
Hot Water	Varies	Classroom
Ice Cubes	Three	Home, school

Materials per Student	**Amount**	**Location**
The Phases of Water Worksheet	One	End of lesson plan – print or photocopy
Paper	One Sheet	Classroom
Disposable Plastic Water Bottles	Two	Students' homes
Metric Ruler	One	Classroom

Vocabulary with Definitions

1. *Condensation* – the process by which a gas changes into a liquid, usually by cooling.
2. *Cycle* – a regularly repeated sequence of events.
3. *Diagram* – a symbolic representation of information that shows and explains relationships.
4. *Evaporation* – the process by which a solid (ex. ice) or liquid (ex. water) changes into a gaseous phase (ex. water vapor), usually by taking in heat.
5. *Water Cycle* – the cycle of evaporation and condensation that controls the distribution of the Earth's water as it evaporates from bodies of water, condenses, precipitates, and returns to those bodies of water.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Collect student worksheets to determine whether students understand (a) how to make a diagram and (b) the water cycle.

Lesson Extensions

None

Attachments

1. The Phases of Water

Troubleshooting Tips

1. The students may need assistance when measuring the height of the water.

Safety Issues

1. Use caution with hot water.

Additional Resources

None

The Phases of Water

Name: ______________________________ Date:_______________________

Directions: On a separate sheet of paper, use the following words to make a diagram of the water cycle. Label your diagram and include arrows that show the direction of the water cycle.

Ocean	Sun	Clouds	Land
Condensation	Evaporation	Rain	Water Vapor

What do you predict will happen when the ice is put into the <u>cold water</u>?

____

____

____

What do you predict will happen when the ice is put into the <u>room temperature water</u>?

____

____

____

What do you predict will happen when the ice is put into the hot water?

____

____

____

Draw the ice as you saw it in each of the cups:

Cold water

Room Temperature Water

Hot Water

The Water Bottle Experiment

Day 1: Before the water bottle is put into the freezer

1. Height of the water in the room temperature water bottle: ________ cm
2. Height of the water in the freezer water bottle: ________ cm

What do you predict will happen to the water that is kept at room temperature?

____

____

What do you predict will happen to the water that is frozen?

____

____

Day 2: After the water bottle was put into the freezer:

1. Height of the water in the room temperature water bottle: ________ cm
2. Height of the water in the freezer water bottle: ________ cm

3. What happened to the water that was kept at room temperature?

____

____

4. What happened to the water that was frozen?

____

3.F.3 Rock Candy: Solids, Liquids, Gases

The creation of sugar crystals: exploring evaporation, crystallization, and the metric system

Grade Level	3
Sessions	(2): 1 at 50-60 minutes, 1 at 50-80 minutes
Seasonality	None
Instructional Mode(s)	Whole Class, Small Groups
Team Size	2 students
WPS Benchmarks	03.SC.TE.04, 03.SC.TE.05, 03.SC.PS.03, 03.SC.PS.06, 03.SC.IS.06
MA Frameworks	3-5.TE.2.2, 3-5.PS.0.3
Key Words	Condensation, Crystallization, Evaporation, Seeding

Summary

This lesson introduces children to the creation of sugar crystals, which occurs when water evaporates from a saturated sugar-water solution. Students will have the opportunity to explore the metric measuring system and will practice writing laboratory reports. Students will experience evaporation first-hand and will learn that sugar dissolves in hot water.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2. 03.SC.TE.05 Develop a knowledge and understanding of the metric measurement system.
3. 03.SC.PS.03 Compare and contrast solids, liquids, and gases based on the basic properties of each of these states of matter.
4. 03.SC.PS.06 Do simple investigations with evaporation, condensation, freezing and melting. Confirm that water expands upon freezing.
5. 03.SC.IS.06 Record data and communicate findings to others using graphs, charts, maps, models, oral and written reports.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.2.2 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2. 3-5.PS.0.3 Describe how water can be changed from one state to another by adding or taking away heat.

Additional Learning Objectives

1. Students will work with the metric system to measure volume and mass.
2. Students will discover that when sugar is added to cold water a mixture (water and undissolved sugar) is formed; however, when sugar is added to hot water, a solution is formed (water and dissolved sugar).
3. Students will apply their knowledge of evaporation and condensation.
4. Students will become familiar with writing a laboratory report.

Required Background Knowledge

1. Basic knowledge of the properties of solids, liquids and solids.
2. Basic understanding of evaporation and condensation.
3. Basic knowledge of physical and chemical changes.
4. Basic knowledge of the metric system.

Essential Questions

1. What is the difference between adding sugar to cold and hot water?
2. What happened to the sugar-water solution after seven days?
3. What is the phase of water after the water is evaporated?
4. What is the phase of the sugar after the water is evaporated?
5. What are the different parts of a laboratory report?

Introduction / Motivation

The instructor might begin the lesson by asking the students what they remember about the properties of solids, liquids and gases. The instructor might then ask how many students have eaten rock candy and which flavor is their favorite.

Procedure

The Instructor will:

Part 1: (50-80 minutes)

1. Divide the students into pairs (optional).
2. Lead students through the “Purpose” section of the Laboratory Report worksheet.
3. Hand out one paper cup and one craft stick to each member of the group.

4. Put a small amount of cold water and sugar into each cup and have the students mix it with their craft stick (a total of 240 ml (1 cup) of sugar will be used, divided up among all students in the class).
5. Ask students to record their observations in the “Results” section of their worksheets.
6. Hand out another paper cup and a small piece of string to each student. Ask each student to take a pencil out of his or her desk.
7. Put a large pot, a wooden spoon and measuring spoons on a table in front of the classroom.
8. Ask each student to add 45 ml (3 tbsp) of sugar to the pot.
9. Carefully add the hot water (see Materials List for quantity) to the pot and, using a wooden spoon, mix, until all sugar is dissolved.
    - Either use a heat source in the classroom or heat the water before the lesson (this can be done using a coffee machine).
10. Add food coloring (optional).
11. Ask students to record their observations of the sugar and hot water mixture in the “Results” section of the worksheet.
12. Have each student tie their piece of string to the middle of their pencil.
13. Give each student/group a small amount of sugar on a paper towel.
14. Have each student/group soak their string in water and then roll it in sugar; this process is called “seeding” (See Vocabulary with Definitions).
15. Have each group or student put their string into the second paper cup, ensuring that the string *almost* touches the bottom of the cup. The pencil should lie across the top of the cup.
16. Have each pair of students come to the front of the classroom. Carefully pour the very warm sugar water into their paper cups (about ¾ full). ***Ensure that the mixture is not too HOT; very hot water will seriously injure students.***
17. Place a small piece of plastic wrap over the top of each cup – this will prevent dust and dirt from contaminating the students’ candy.
18. Have each student weigh his/her cup and record the weight in the “Results” section of the worksheet.
19. Put the cups in a place where they will not be disturbed and let them sit for about seven days.

20. Have the students record the weight of their cups each day in the “Results” section of the Laboratory Report worksheet.

Part 2: (50 – 60 minutes)

1. *Complete this part of the lesson once students’ candy has crystallized.*
2. Ask the students to reform previous pairs and hand out paper towels to each pair.
3. Have each student/group weigh their cup one last time and record the weight in the results section of the Laboratory Report worksheet.
4. Have each student observe his or her rock candy and draw what he or she sees in the “Results” section of the Laboratory Report worksheet.
5. Discuss what happened to the water (it evaporated) (See Vocabulary with Definitions).
6. Discuss the water droplets on the plastic wrap (it condensed) (See Vocabulary with Definitions).
7. Have the students carefully remove the sugar crystals and put them on the paper towel. The students may need help when removing the sugar crystals.
8. Have each group measure the length of their largest crystal (in centimeters) and have them record it in the “Results” section of the Laboratory Report worksheet and on the blackboard.
9. Make one bar graph of the measurements of all the groups’ largest crystals, whether by free hand or using graph paper.
10. In the “Results” section of the Laboratory Report worksheet, have the students graph their data for the mass of the crystal over the seven days.
    a. The students may need help filling out the scale for the y-axis.
11. Ask each student to complete the “Materials” and “Procedure” sections of the Laboratory Report worksheet: students may need help with these parts.
12. Lead the students through the “Discussion and Conclusions” sections of the Laboratory Report worksheet.
13. Let the students eat and enjoy their treats!

Materials List

Materials per class	Amount	Location
Sugar	30 ml (2 Tbsp) multiplied by number of students Additional 480 ml (2 cups) (separated)	Grocery store
Water	7.5 ml (1 ½ tsp) of hot water multiplied by number of students Additional 240mL (1 cup) of cold water	Classroom
Food Coloring (optional)	Several drops	Home
Wooden Spoon	One	Home
Plastic Wrap	One roll	Home
Large Pot	One	Home
String	One roll	Home, craft store
Heat Source	One	Classroom, home, teacher's room
Measuring Cups and Spoons	One 240 ml (1 cup) One 15 ml (1 Tbsp) One 2.5 ml (½ tsp)	Home
Scale or Balance	Several	Classroom

Materials per student	Amount	Location
Laboratory Report Worksheet	One	End of lesson plan – print or photocopy
Craft Sticks	Two	Craft store
Paper Cup	Two	Grocery store
Pencil	One	Classroom

Vocabulary with Definitions

1. *Condensation* – the process by which a gas changes into a liquid, usually by cooling.
2. *Crystallization* – the process by which a material solidifies into a definite, regular shape.
3. *Evaporation* – the process by which a solid (ex. ice) or liquid (ex. water) changes into a gas (ex. water vapor), which is usually done when the solid or liquid is heated.
4. *Metric* – a unit of measurement that is based on the meter.
5. *Seeding* – adding water and a small amount of sugar directly to the string to activate crystal growth.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Collect student worksheets to determine whether students understand (a) evaporation, (b) crystallization, and (c) correct use of the metric system.

Lesson Extensions

1. Ask students to pick their favorite sandwich and write a laboratory report describing how to make the sandwich.
2. Help students make a volcano out of paper maché and lava out of baking soda, vinegar, and food coloring. Demonstrate phase changes as the liquid (vinegar) and solid (baking soda) change to gaseous form (bubbles in lava).

Attachments

1. Laboratory Report

Troubleshooting Tips

1. Water should be sufficiently hot to dissolve the sugar, but cool enough so as not to pose danger to the students.
2. When taking the rock candy out of the jar, the string might come out without the crystals; recommend that students remove the rock candy from the cups slowly and carefully.

Safety Issues

1. Ensure that students do not touch the hot water.

Additional Resources

None

Laboratory Report

Name: ______________________________ Date: ______________________

Laboratory Report: Many scientists and college students use laboratory reports to organize experiments.

Directions: You will write your own laboratory report when you create rock candy. Rock candy is really the crystallized form of sugar. Complete each section below when your teacher instructs you to do so.

1. **Purpose:** Write one sentence about what you are going to do in this experiment.

____

____

____

2. **Materials:** List all materials that were used in the rock candy experiment.

1 Wooden Spoon____________________

____

____

____

____

____

____

____

____

____

Procedure: Complete the remaining steps that were taken to make the sugar crystals.

Step 1: Each student put ____________ milliliters of sugar into the pot.

Step 2: Add the hot ______________________ to the pot.

Step 3: Using a _________________________, mix, until all sugar is ___________.

Step 4: Tie a string to the middle of a pencil.

Step 5: Soak the string in water and then roll it in sugar; this process is called

______________________.

Step 6: Put the string into the cup and fill the cup with the ___________________.

Step 7: Put ___________ ___________ over the top of the cup.

Step 8: Weigh the ____________ and the crystals each day for seven days and record the mass in the "Results" section of the Laboratory Report worksheet.

Step 9: After 7 days, ___________ the rock candy and ___________ what I saw.

Step 10: Carefully remove the sugar crystals from the cup and put them onto a paper towel.

Step 11: __________ the largest __________ and record its mass.

Step 12: Make a __________ of the ______________ versus __________ of the cup and crystals.

3. Results: Answer the following questions:

What did you observe when the sugar was mixed with cold water?

____

____

____

What did you observe when the sugar was mixed with the hot water?

____

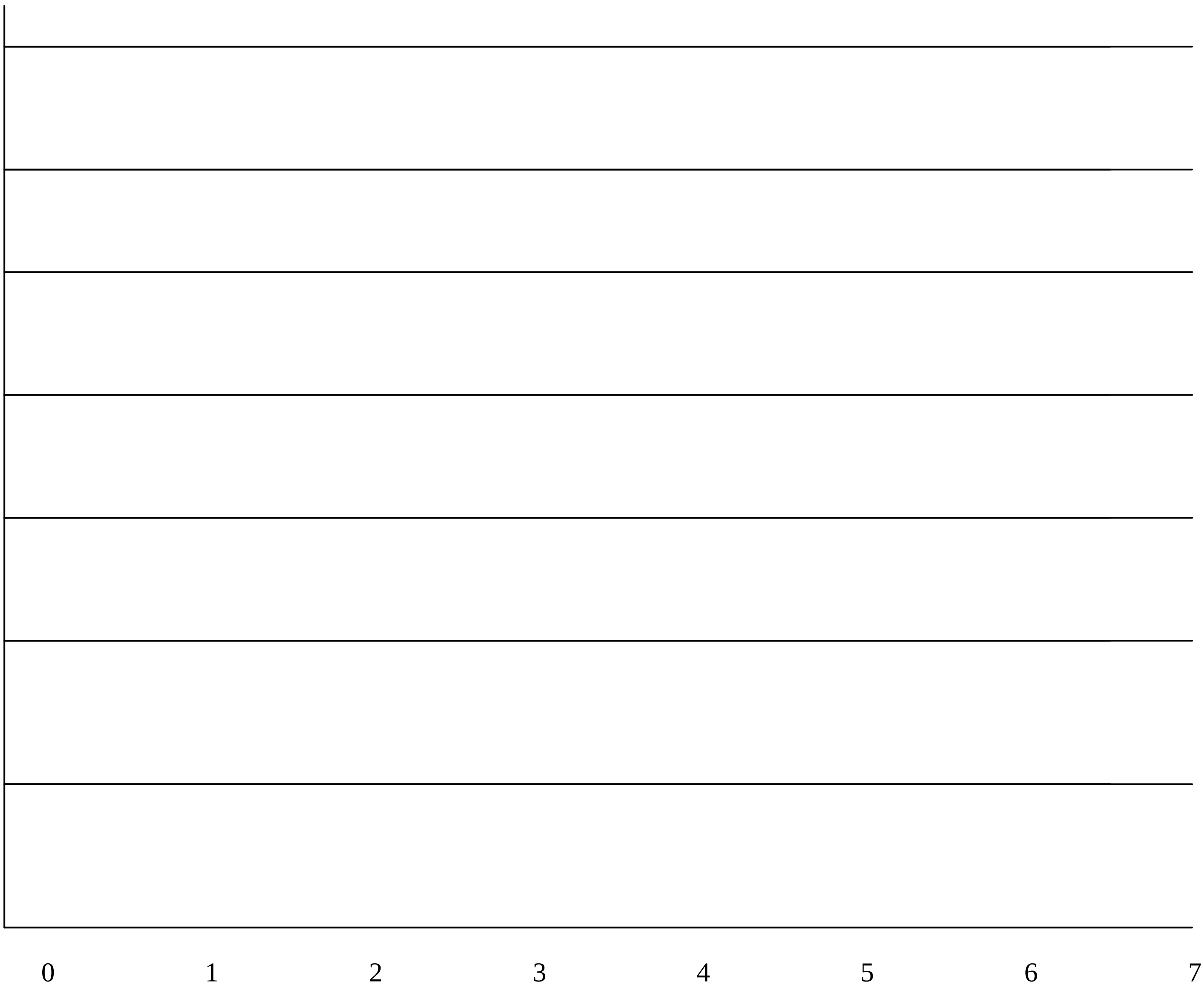
____

Over a seven-day period, fill in the following table:

Day	Mass of the jar and crystals (grams)
1	
2	
3	
4	
5	
6	
7	

Make a bar graph, where the x-axis represents the number of days and the y-axis represents the mass of the jar and crystals. Your teacher will help you fill out the title for the y-axis and the x-axis.

Crystal Growth



What is the length of your largest crystal? _______________ centimeters

Draw your sugar crystal:

3. **Discussion and Conclusions:** Answer the following questions:

What happened to the water in the cup?

____

____

What are the crystals made of?

____

____

What is condensation and when did you observe it?

____

____

What is evaporation and when did you observe it?

Did you enjoy making the sugar crystals?

3.C.1 Phases of the Moon

Exploring phases of the moon

Grade Level	3
Sessions	1 x 50 minutes
Seasonality	N/A
Instructional Mode(s)	Whole class, Teams
Team Size	2-4 students
WPS Benchmarks	03.SC.TE.04, 03.SC.TE.02
MA Frameworks	3-5.ES.15
Key Words	Phases of the moon, solar system

Summary

This lesson will provide students with the new perspective on the different shapes that the moon takes as it lights the sky each night. After seeing a demonstration and building a model, the students should be able to identify the phases of the moon.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.02 Identify and explain the appropriate materials and tools to construct a given prototype safely
2. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagram, graphic organizers, and lists.

Additional Learning Objectives

1. At the conclusion of this lesson, the students will be able to identify the phases of the moon.
2. At the conclusion of this lesson, students will recognize that the moon revolves on an axis as it orbits the earth.
3. At the conclusion of this lesson, students will recognize that the light from the moon is a reflection from the sun.
4. At the conclusion of this lesson, the students will have a basic understanding of the Engineering Design Process

Required Background Knowledge

1. Basic familiarity with the moon in the night sky and why the appearance of the moon changes.

Essential Questions

1. What is a new moon?
2. What is a crescent moon?
3. What is a half/quarter moon?
4. What is a gibbous moon?
5. What is a full moon?
6. What is waning?
7. What is waxing?
8. What is a blue moon?

Introduction / Motivation

The instructor might ask students if they have ever noticed differences in the size, shape, or position of the moon. (S)he might also ask the students if they know why these variations occur (5 minutes).

Procedure

Part 1: Demonstration

The instructor will:

1. Choose three students, have one represent the moon, one the sun and the other the Earth (refer to figure below)

2. Ask the moon walk a few steps around the Earth
3. Ask the class how much of (student's name) can you see now?
    - Example: can you see all of (student's name), half of (student's name), some of (student's name) or none of (student's name)?

Part 2: Design and Construction by Students

1. Split the class into groups with 2 to 4 students in each group
2. Hand each group:
   - One small Styrofoam ball
   - One medium Styrofoam ball
   - One large Styrofoam ball
   - Three 4”X1/8” dowels (before the lesson, the instructor must cut the dowels into four inch pieces using scissors)
   - One 1X12X5” Styrofoam block
3. Have each group design a model of the sun, moon and Earth on the worksheet in attachment 1 that uses the materials that are given to them, where the moon will be able to rotate around the Earth (See Appendix 1 for an example).
4. Approve each group’s design before they start building
5. Have the students use the materials to construct their model (refer to attachment 1 for an example)
6. Turn off the lights or find a dark or low-lit area.
7. Visit each group and remove the sun from its dowel. Hold the flashlight horizontally above the dowel and aim it towards the Earth
8. Ask a student to move the moon slowly around the Earth. The students should observe the different phases
9. If the model shows the phases incorrectly, ask students to modify/redesign their model (See Appendix 1)
10. Define each phase of the moon and draw a diagram on the black/whiteboard
    - Explain each phase
    - Explain waxing
    - Explain waning
11. Have each student complete the Moon Phase Flipbook worksheet if time allows.

Materials List

Materials per class	Amount	Location
1.5-inch Styrofoam ball (small)	One for each group	Craft store

3-inch Styrofoam ball (medium)	One for each group	Craft store
4-inch Styrofoam ball (large)	One for each group	Craft store
1X12X18” Styrofoam block	Cut into squares (one for each group)	Craft store
36”X1/8” dowel	One for every three groups	Craft store
Flashlight	One	Drugstore, office supply store
Stapler (Optional)	One	Classroom
Masking Tape (Optional)	One Roll	Drugstore, office supply store

Materials per student	**Amount**	**Location**
Crayons (Optional)	One	Drugstore, supermarket
Flipbook Worksheet (Optional)	One	Attachment 2
Manilla Paper (Optional)	One	Office Supply Store

Vocabulary with Definitions

1. *Blue Moon* – the second full moon in a single month
2. *Crescent Moon* – between a half moon and a new moon; appears as a banana-shape
3. *Full Moon* – the moon when it appears as an entire circle
4. *Gibbous Moon* – the moon when it appears as more than halfway lit, but less than fully lit; appears as a circle with a banana-shaped section of the edge missing
5. *Half Moon* – the moon when it appears as a half circle; sometimes called a quarter moon because this Moon has completed one quarter of an orbit around the Earth from either the full or new position and one quarter of the moon's surface is visible from Earth
6. *New Moon* – the moon when it is no longer visible from Earth; cannot be seen
7. *Phase* – a given form of the moon that occurs regularly

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Note class participation during demonstration of the moon phases.
2. Note student’s ability to model their design after what was demonstrated in class.

Lesson Extensions

1. If time allows, instructor might want to utilize the Phases of the Moon Flipbook Worksheet.
2. The instructor might use this lesson as an introduction to the behavior of the other planets in the solar system.

Attachments

1. Phases of the Moon: Model design worksheet
2. Phases of the Moon Flipbook

Troubleshooting Tips

1. Emphasize to students that the moon, the earth, and the sun are *all* rotating simultaneously.
2. If the student does not move the moon around the Earth slowly enough, then the phases will not correctly be observed

Safety Issues

1. Students should exercise caution when using scissors to cut out flipbook sheets.
2. Masking tape should be used to cover the staples in the flipbook's binding.

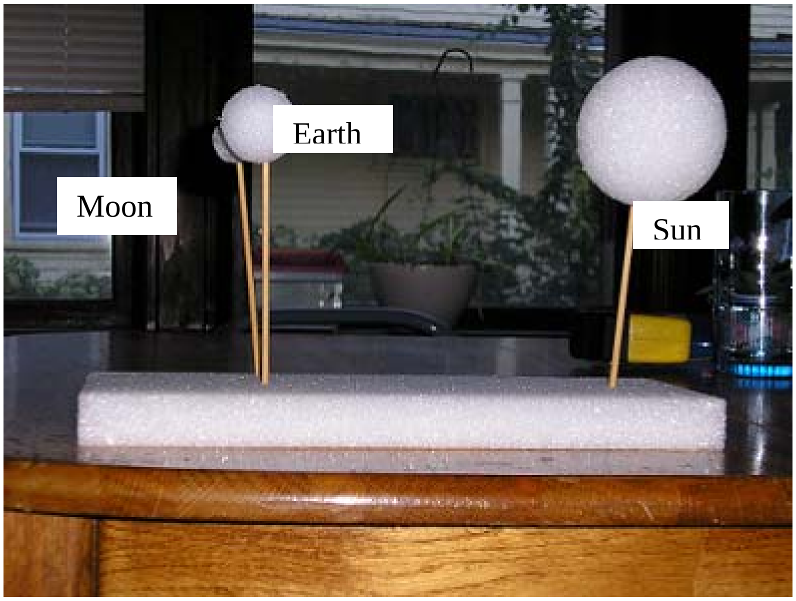
Additional Resources

1. Moon Calculator: http://imagiware.com/astro/moon.cgi (accessed 12 September 2005)

Appendix A: Diagrams and Examples

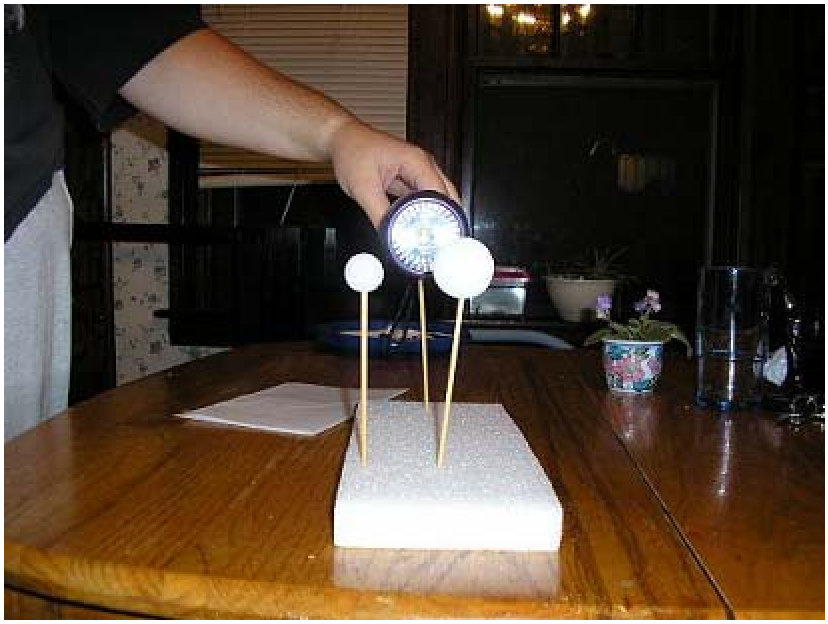
The following diagram demonstrates a working model that shows the phases of the moon:

Side View:

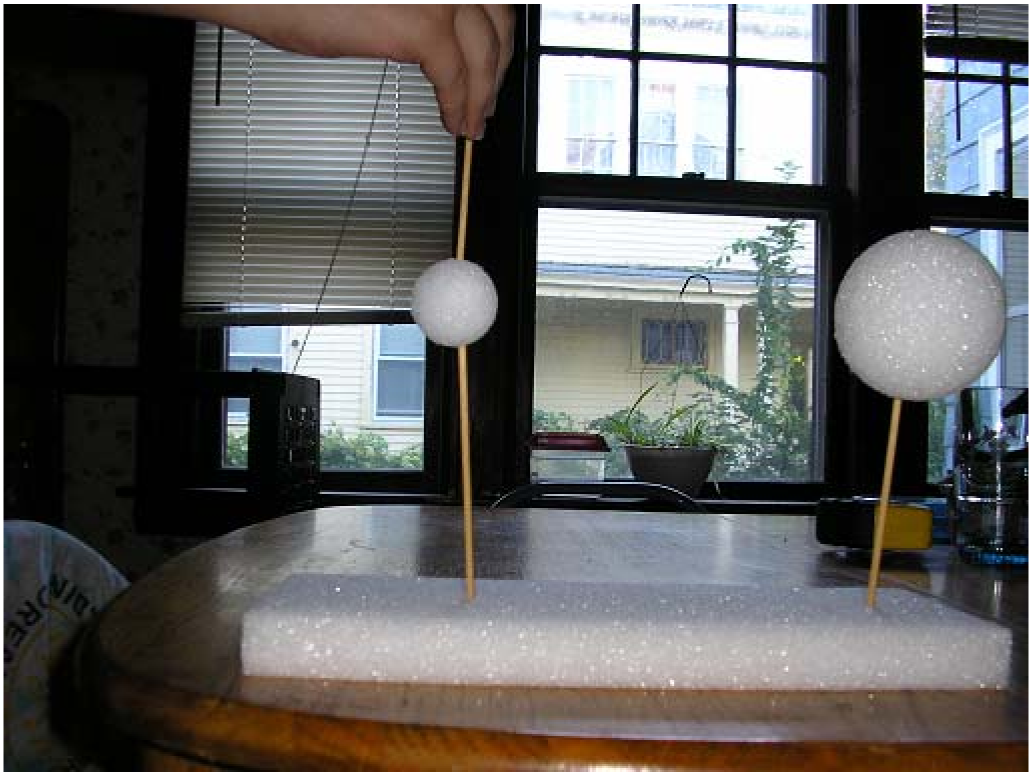


Front view:

Front view with flashlight:

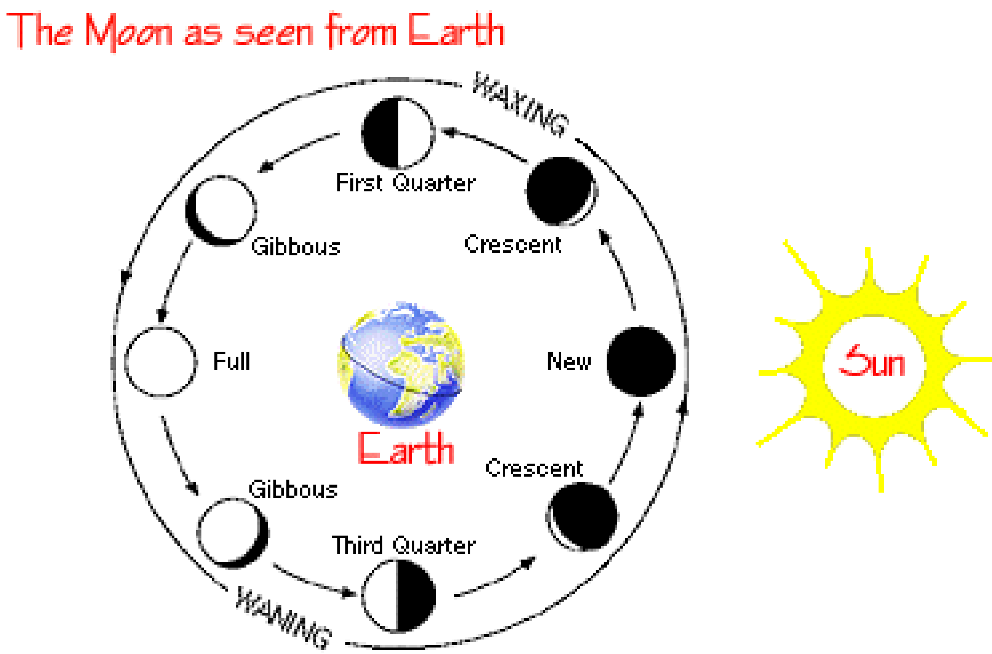


The following is how it should look as the moon is being rotated around the sun:



Appendix B: Phases Illustrated

Phases of the moon shown from the Earth and from above the solar system:

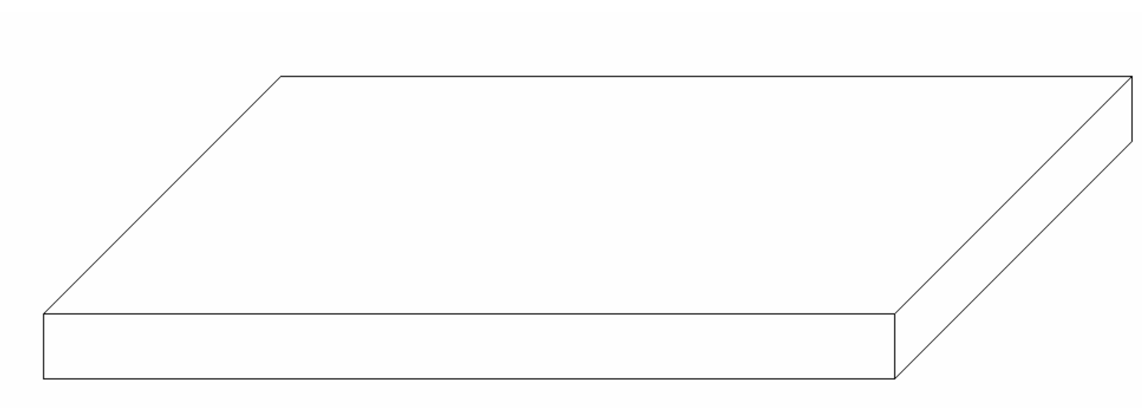


Figures taken directly from http://starchild.gsfc.nasa.gov/docs/StarChild/shadow/questions/question3.html (accessed 5 January 2006).

Name:____________________ Date:_____________

Phases of the Moon: Model Design Worksheet

Using the materials provided, design a model that can be used to show the phases of the moon. When you finish your design, ask your teacher to approve it before you begin to build your model.



3.Z.4-6 Toys in Space

A hands-on activity that challenges students to explore the behavior of Toys in Space

Grade Level	3
Sessions	(3): 3 at 40-60 minutes
Seasonality	None
Instructional Mode(s)	Whole Class, Small Groups
Team Size	2-4 students
WPS Benchmarks	03.SC.TE.02, 03.SC.IS.01, 03.SC.IS.04
MA Frameworks	None
Key Words	Freefall, Gravity, Microgravity, Space, Toys

Summary

The objectives of this lesson are (a) to further the students' understanding of gravity and (b) to emphasize how gravity affects objects on Earth and in space. Students will predict and observe how certain toys act in the different environments; they will then adapt their favorite toy for use in space. Following this lesson, students should better understand the concept of "gravity" and the utilization of the engineering design process.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.02 Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.
2. 03.SC.IS.01 Ask questions and make predictions that can be tested.
3. 03.SC.IS.04 Conduct multiple trials to test a prediction. Compare the results of an investigation or experiment with the prediction.

2001 Massachusetts Frameworks for Grade 3

1. 3-5.TE.1.2 Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.
2. 3-5.TE.2.3 Identify relevant design features (e.g., size, shape, weight) for building a prototype of a solution to a given problem.

Additional Learning Objectives

1. Students will improve fine-motor skills through construction of functional structures.

Required Background Knowledge

1. Working knowledge of gravity, microgravity, and the solar system.

Essential Questions

1. What is gravity?
2. Does gravity exist in space?
3. Is the effect of gravity the same in space as it is on Earth?
4. What is freefall?
5. What is microgravity?
6. Why do objects appear to float in space?

Introduction / Motivation

Explain to students that this lesson focuses on gravity and its effects on objects on Earth and in outer space. Consider creating a large chart that categorizes these differing effects. Explain that astronauts appear to float because they are in a state of "freefall" (see Vocabulary with Definitions) around the Earth. Freefall causes the microgravity effect that gives the illusion that gravity does not exist in outer space. Ask students to imagine parachuting from an airplane with a group of friends. After jumping from the plane, but before opening the parachutes, everyone would be in a state of freefall, headed toward Earth at the same speed. From the others' perspective, each friend would appear to be floating. Astronauts in a space shuttle "see" each other floating in much the same way. A space shuttle orbits, or freely falls around, the Earth and therefore everything in the space shuttle also orbits the Earth and *appears* to float.

Procedure

The instructor will:

Part 1: (35 minutes)

1. Read to students the NASA article, "The Physics of Toys" (see below, p 9). The article describes the "Toys in Space Project", known as the Testing Of Youth Science

(TOYS), and focuses on the Space Shuttle Discovery's mission to test the operation of various toys in space.

2. Provide each student with a copy of the attached worksheet called "Toys in Space 1 – Microgravity". Lead students through questions 1 and 2.
3. To illustrate freefall, poke a small hole in the side of an empty soda can, near the base, and cover the hole with your thumb. Fill the can with water. While holding the can over a catch basin in the floor, ask students to think about what will happen when you remove your thumb and to question 3 on their worksheets.
4. Remove your thumb and let students observe the stream of water.
5. Ask students to answer question 4.
6. Cover the hole again with your thumb and refill the can with water (if necessary). Ask students to predict what will happen when you remove your thumb from the hole *as* you drop the can into a catch basin (question 5).
7. Drop the can and then ask the students to observe whether water leaked from the hole (question 6).
8. Explain to the students that the soda can and water fell *in relation to each other*.

Part 2: (40 – 60 minutes)

1. Explain to students that in 1993, ten toys were tested in space by astronauts of the Discovery crew, and that today, students will make their own predictions with respect to toys on Earth versus toys in space.
2. Ask students what they remember about microgravity.
3. Create groups of 3 to 4 students.
4. Provide students with copies of the worksheet "Toys in Space 2 – Toys".
5. Students will focus on the "ball and cup", "klacker balls", and the basketball and hoop. Show students the toys and allow them to handle the toys for 3-5 minutes (adjust as needed).
6. Ask students to explain how gravity affects these toys' operation on their worksheet (question 1).
7. Ask students to predict how these toys would behave in space (question 2).
8. Repeat this procedure with questions 3-8.

9. As a class, have students explain their predictions by interacting with the toys and demonstrating their ideas to the class: be sure the students are using the concept of microgravity experienced in space
10. Tell the students that they will now watch selected clips of how the toys actually worked in space. Explain to the students that the clips they are about to watch are actual footage from space with real astronauts from the 1993 project TOYS.
11. The video includes: Klacker Balls (16.35 minutes), Ball and Cup (18.59 min), and the Basketball and Hoop (23.01 min).
12. After watching the clips, discuss how the toys worked in space, in light of the students' predictions.

Part 3: (40 – 60minutes)

1. Explain to students that they will now be the astronauts and will choose a toy to test in space. Remind students that they will be in a space shuttle and that their toys cannot require electricity!
2. Ask students to use their worksheets, "Toys in Space 3 – Your Toy", to draw and label a sketch of this toy and to explain how the toy works on earth.
3. The students should explain whether this toy would work the same way on a space shuttle and how it would operate in microgravity.
4. Students should then utilize the engineering design process to adapt this toy to operate in space (individually or in groups).
5. Students should describe in sentences how they would adapt their toy.
6. Students should create a labeled sketch of their new toy on their worksheet.
7. Students may share their work with the class. Each student/group might explain which toy they chose to bring into space and how they adapted it?

Materials List

Materials per Class	**Amount**	**Location**
Klacker Balls	Two	Toy store
Ball in Cup	Two	Toy store
Basketball Hoop	One	Toy store
Small Dowel	One per group	Craft store
String	One per group	Craft store

Black Marker	One per group	Classroom
Tape	As Necessary	Classroom

Materials per Student	**Amount**	**Location**
Microgravity worksheet	One	End of lesson plan – print or photocopy
How do Toys Work in Space? worksheet	One	End of lesson plan – print or photocopy
Creating My Own Toy worksheet	One	End of lesson plan – print or photocopy
Small Paper Cup	One	Lunch room
Ping-Pong ball	One	Toy store
Length of Yarn, approx. 3-ft	One	Craft store
Toothpick	One	Grocery store
Scissors	One	Classroom

Vocabulary with Definitions

1. *Freefall* – the condition of acceleration which is due only to gravity. Objects undergoing freefall experience only one force: their own weight.
2. *Gravity* – The natural force of attraction exerted by a celestial body, such as Earth, upon objects near their surface. These objects are drawn toward the center of the celestial body.
3. *Microgravity* – Very little gravitational force, like that experienced by of a free-falling object, an object in orbit, or an object in outer space.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Observe student groups at work.
2. Collect student worksheets.
3. Listen to oral responses and class discussions.

Lesson Extensions

None

Attachments

1. Toys in Space
2. Appendix A: Instructor's Notes – NASA Article: The Physics of Toys
3. Microgravity
4. How do Toys Work in Space?
5. Creating My Own Toy

Troubleshooting Tips

None

Safety Issues

None

Additional Resources

None

Appendix A: Instructor's Notes – NASA Article: The Physics of Toys

Taken from: http://quest.arc.nasa.gov/space/teachers/liftoff/toys.html (13 Nov 2005).

NASA Article: The Physics Of Toys

Would you like to play, or do **physics**? When you play with toys in space you can do both.

Astronauts on several Space Shuttle missions took some toys into space to see how they work in **microgravity**. They found the toys that push off the floor would move faster. Toys that moved through the air or water by themselves did not do as well. The toys that would travel in a straight line on Earth did not in space. The astronauts played with wind-up toys, racecars on tracks, and fish that swim in water. They had fun while studying science.

Mario Runco was the Space Shuttle mission specialist. He flew on the shuttle STS-54. That crew played with the toys. The mission was called "The Physics of Space." Astronauts and children just like you got to play a part.

The elementary schools where each astronaut went when they were small got to have a live video link with the Shuttle. The children played with the same toys on the ground. They **predicted** what they thought the toys would do in space. The fun part was watching the astronauts do things to the toys the kids asked them to do. They checked their predictions and talked about why the toys acted the way they did. They could see if they were right or wrong. The students did an experiment using the scientific method with the help of astronauts in space. Science can be fun!

Name ________________________ Date ___________________

Microgravity

1. What is gravity?

____

____

____

What is gravity like on the Earth?	What is gravity like in Space?

2. What is microgravity? When would you experience microgravity?

____

____

____

3. What *will happen* to the water when your teacher holds the can?

4. What *happened* to the water when your teacher held the can?

5. What *will happen* to the water when your teacher drops the can?

6. What *happened* to the water when your teacher dropped the can?

Name ___________________________ Date ___________________

How do Toys Work in Space?

1. Explain how the ball and cup works on Earth. How does gravity affect this toy?

____

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____

____

2. Predict how the ball and cup would work in space. How would gravity affect this toy in space?

____

____

____

____

3. How do klacker balls work on Earth. How does gravity affect this toy?

4. Predict how klacker balls would work in space. How would gravity affect this toy in space?

5. How did the klacker balls behave in space?

6. Explain how a basketball and hoop work on Earth. How does gravity affect this toy?

7. Predict how a basketball and hoop would work in space. How does gravity affect this toy in space?

8. How did the basketball hoop behave in space?

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9. Construct your own ball in cup.
    a. Tie one end of the string to the holes in the ball with several knots
    b. Tie the other end of the string to a toothpick and tape it to the side of the cup.
    c. Try to catch the ball in the cup

10. Why does the ball stay in the cup after it is caught? (Hint: What keeps you from floating in the classroom?)

____

Name ________________________ Date ___________________

Creating My Own Toy

1. Draw and label your favorite toy in the box below.

2. Describe how gravity affects this toy on Earth.

____

____

____

3. Predict how gravity will affect this toy in space.

4. Explain how you could change this toy to make it work in space the way it works on Earth. (Hint: Think about gravity.)

5. Draw and label your *modified* toy in the box below.

3.Z.5-7 Reasons for Seasons

Exploring the effect of the Earth's tilt and rotation on the changing seasons

Grade Level	3
Sessions	(3): 1 at 50 minutes, 1 at 40-60 minutes, 1 at 50-80 minutes
Seasonality	None
Instructional Mode(s)	Whole Class, Small Groups
Team Size	2-4 students
WPS Benchmarks	03.SC.TE.04, 03.SC.IS.01
MA Frameworks	3-5.TE.1.1, 3-5.TE.1.2, 3-5.TE.2.1, 3-5.TE.2.2
Key Words	Earth's orbit, Northern Hemisphere, Summer Solstice, Winter Solstice, Vernal Equinox, Autumnal Equinox, Engineering Design Process, Materials, Model

Summary

This lesson introduces children to the sun, the Earth, and the relationship between the two that causes the seasons to change. The lesson will familiarize students with the idea that the Northern and Southern Hemispheres experience different seasons. In addition to these science themes, the lesson will provide students with an opportunity to (a) conceptualize the uses of various materials, (b) represent a problem in a number of ways, (c) predict seasonal changes based on a model of the Earth and sun, and (d) use the Engineering Design Process to create a scientific drawing.

Learning Objectives

2002 Worcester Public Schools (WPS) Benchmarks for Grade 3

1. 03.SC.TE.04 Describe different ways in which a problem can be represented, e.g., sketches, diagram, graphic organizers, and lists.
2. 03.SC.IS.01 Ask questions and make predictions that can be tested.

Additional Learning Objectives

1. Students will understand that the tilt of planet Earth causes seasonal change.
2. Students will understand that materials can be manipulated in various ways to best make use of their inherent properties.
3. Students will work with other members of a group to problem-solve, design, and construct a model that represents a larger concept.
4. Students will use the Engineering Design Process to create a scientific drawing that accurately represents the reasons for seasonal change on Earth.

Required Background Knowledge

None

Essential Questions

1. What are the four seasons in Massachusetts?
2. What causes the different seasons?
3. Does the Southern Hemisphere experience the same seasons at the same time as the Northern Hemisphere? Why or Why not?
4. What shape is the Earth's path, or *orbit*, around the sun?
5. What inherent properties of a given material (clay, toothpick, string) make the material useful for a particular purpose?
6. What other materials might students find appropriate to use when constructing a model of the Earth and sun?

Introduction / Motivation

The instructor may begin the lesson by asking students to recall the Engineering Design Process used in model tree house construction. Students may then describe their favorite season or list the seasons that one would experience in the Northern Hemisphere.

Procedure

Part 1: (50 minutes)

1. Ask students to bring to class an object representing their favorite season (optional). Discuss.
2. Pass out the KWL Worksheet (attached).
3. Ask students to complete the "K" and "W" portions of a KWL chart.
4. Discuss the responses as a class.
5. Read <u>Reasons for Seasons</u> by Gail Gibbons; discuss key ideas throughout.
6. Use a tilted globe to demonstrate the Earth's path around the sun.
   - Choose one child to represent the sun.
   - Move the globe around the child (sun).
   - Stop at various points with the globe tilted correctly at a slight angle.
7. Ask students to identify seasons at the various points. The students will need to imagine themselves in the Northern or Southern Hemisphere.

8. In a visible location, draw the Earth's path around the sun and label seasons at various positions.
9. Ask students to complete the "L" portion of their KWL worksheets.

Part 2: (50 – 60 minutes)

1. Review the Engineering Design Process (EDP) and explain how the students will be using the EDP to complete the next part of the lesson (5 minutes).
2. Divide students into small groups (4 students).
3. Show students the materials and tools available (see Materials List) for the model of the Earth's orbit around the sun.
4. Provide each student with a copy of the attached worksheet (see "Reasons for Seasons").
5. Lead students through worksheet questions 1 and 2 (10 minutes).
6. Explain question 3; emphasize the selection of materials and encourage groups to discuss ideas about seasonal change. Ask students to complete the "Materials" chart (5 – 10 minutes). Discuss responses as a class; students should have the same general ideas with respect to material selection.
7. Provide each group with materials. Allow students to work cooperatively to create a model of the Earth's path around the sun (20 minutes).
8. Lead students through question 4 (10 – 15 minutes). Collect drawings and note misconceptions.

Part 3: (20 – 30 minutes)

1. Work as a class to represent the movement of Earth around the sun, discussing seasonal change at various points along the Earth's path (via clay model, blackboard/whiteboard drawing, role-playing with a globe, etc.) (10 – 15 minutes).
2. Allow students time to revise their drawings; once they drawings are correct, students may color the drawings (10 – 15 minutes).

Materials List

Materials per class	Amount	Location
Blue Clay	One	Craft Store
Yellow Clay	One	Craft Store

Large Sheet of Paper	One per group	Classroom, office supply store
Toothpicks	One per group	Craft Store
String	One per group	Craft Store
Globe	One	Classroom

Materials per student	Amount	Location
Reasons for Seasons worksheet	One	End of lesson plan – print or photocopy

Vocabulary with Definitions

Part 1:

1. *Autumnal Equinox* – When the sun appears in the sky for twelve hours, marking the first day of fall for the Northern Hemisphere (September 22nd or 23rd).
2. *Axis* – The imaginary line that passes through Earth, joining the North and South Poles.*
3. *Elliptical Orbit* – The oval-shaped path taken by the Earth as it moves around the sun.
4. *Equator* – The imaginary line that wraps around the Earth and divides the northern half of Earth from the southern half.*
5. *North Pole* – Northern-most point on Earth.*
6. *Northern Hemisphere* – The half of Earth that lies north of the equator.*
7. *South Pole* – Southern-most point on Earth.*
8. *Southern Hemisphere* – The half of Earth that lies south of the equator.*
9. *Summer Solstice* – Marks the longest day of the year in the Northern Hemisphere; the North Pole is tipped toward the sun and the South Pole is tipped away (June 21st).*
10. *Vernal Equinox* – When the sun appears in the sky for twelve hours, marking the first day of spring for the Northern Hemisphere (March 19th, 20th, or 21st).
11. *Winter Solstice* – When the North Pole is tipped away from the sun and the South Pole is tipped towards it (December 21st or 22nd).*

*Definitions taken from The Reason for Seasons, Gail Gibbons.

Part 2:

1. *Aeronautical Engineer* – A type of engineer who designs machines that fly, such as airplanes and spaceships.
2. *Property* – A characteristic, or trait, that sets one item apart from another.

Assessment / Evaluation of Students

The instructor may assess the students in any/all of the following manners:

1. Observe student groups at work; ask students to demonstrate and explain their models.
2. Collect student worksheets; note misconceptions and clarify during follow-up lesson.
3. Listen to oral responses and class discussions.

Lesson Extensions

1. Have the students complete My Favorite Season Worksheet after reading the story.
2. Lead students through construction of a model of the Solar System.
3. Ask students to draw pictures of the sun's rays, as they strike the Earth at different locations. Students might then label each drawing with the name of the corresponding season.

Attachments

1. KWL Worksheet
2. Reason for Seasons
3. Appendix A: Instructor's Notes

Troubleshooting Tips

1. Students may require help creating the Earth's axis; it can be difficult to push toothpicks through clay.

Safety Issues

1. Toothpicks are sharp

Additional Resources

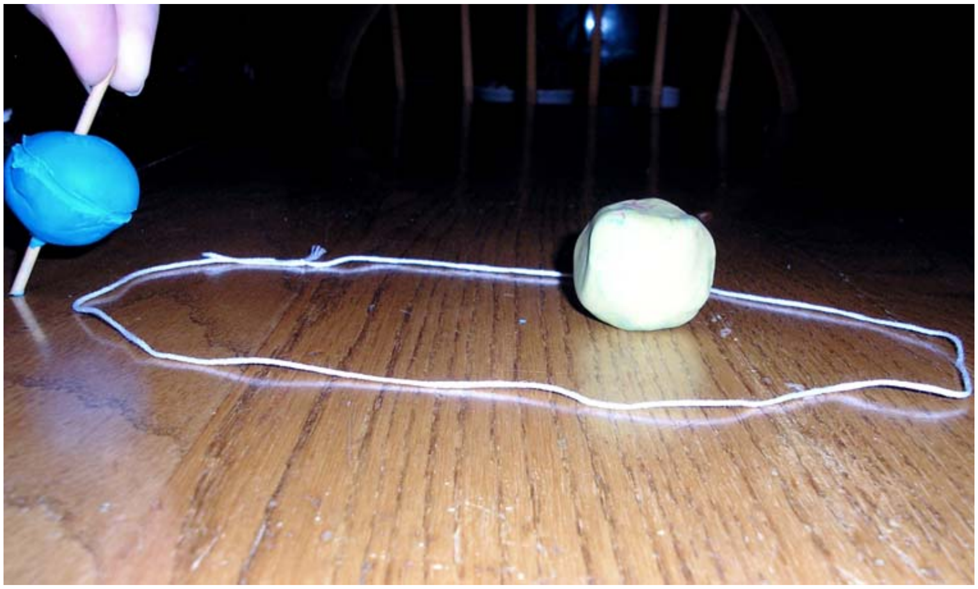
1. The Engineering Design Process for Children: http://www.mos.org/doc/1559 (accessed 7 October 2005).
2. The Seasons: http://csep10.phys.utk.edu/astr161/lect/time/seasons.html (accessed 10 November 2005).
3. The Equinoxes: http://www.space.com/spacewatch/050318_equinox.html (accessed 14 November 2005).

Appendix A: Instructor's Notes

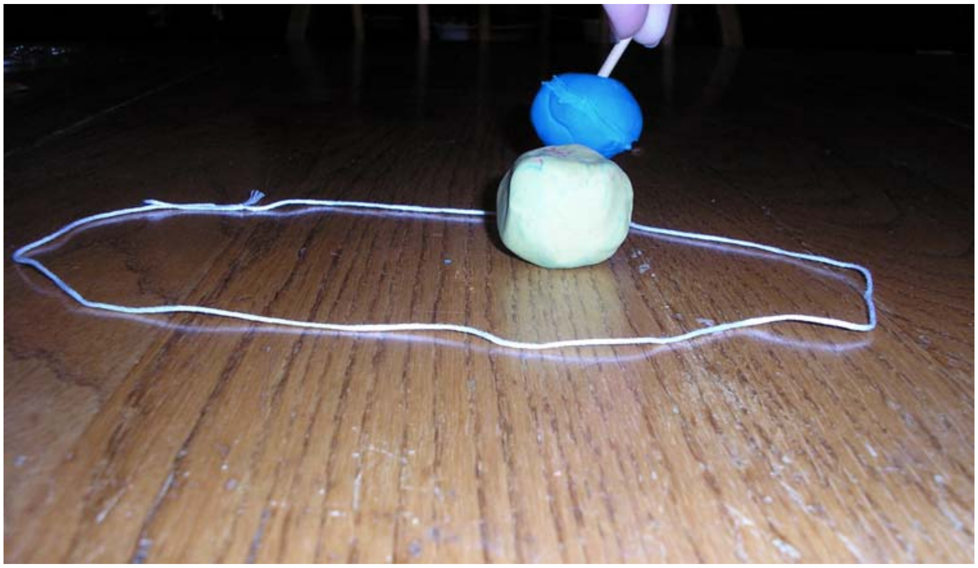
Clarifying Common Misconceptions:

1. Different seasons are *not* caused by the variation in Earth's distance from the sun.
2. The Earth is *closer* to the sun when it is *winter* in the Northern Hemisphere! However, the North Pole is pointed away from the sun and so the Northern Hemisphere experiences less direct sunlight, fewer hours of sunlight, and thus, the season called "winter".
3. The Northern Hemisphere of Earth experiences *summer* when the planet is farthest from the sun; at that time, its axis points towards the sun and the Northern Hemisphere receives more hours of sunlight than it does in the winter. The sun's rays are also more direct.
4. The Earth's tilt (23.5°) and elliptical path (orbit) around the sun cause seasonal change.
5. The axis of the Earth always points in the same direction: 23.5°, towards the North Star, *Polaris*.
6. The Earth spins on its axis once every twenty-four hours, which equals one day. This means that Earth is spinning at a speed of about 1000 miles per hour.

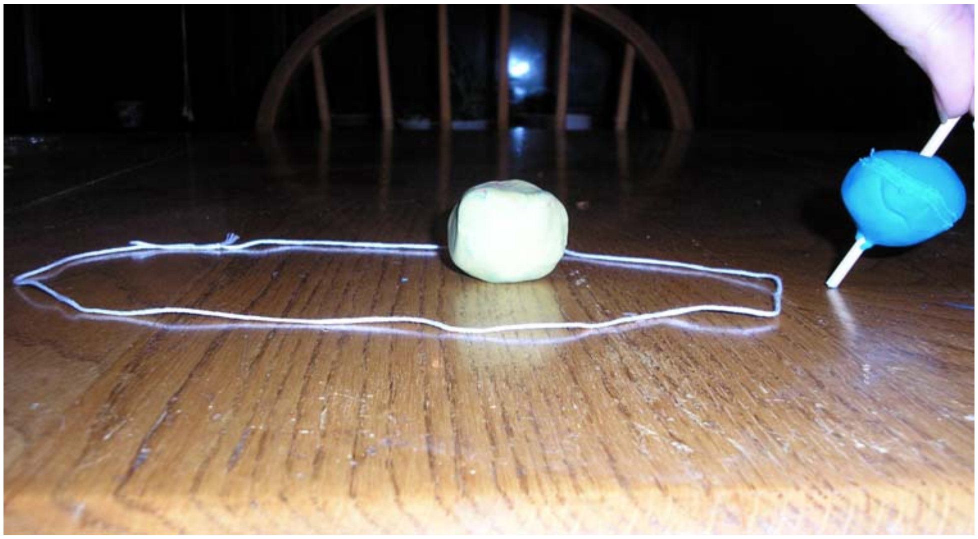
Examples of Student Models



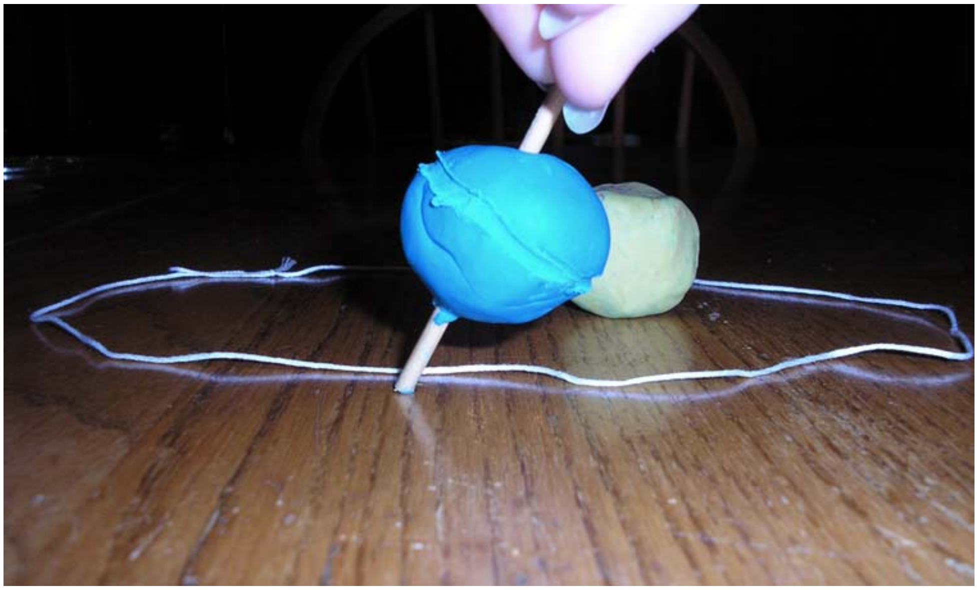
(Summer)



(Autumn)



(Winter)



(Spring)

Reason for Seasons

Name: ______________________ Date: __________________

Seasons in the Northern Hemisphere

1. **Ask**

How does the Earth's tilt cause the different seasons?

____

____

____

____

____

____

2. **Imagine**

An aeronautical engineer designs spaceships, airplanes and helicopters. Imagine that you are an aeronautical engineer studying the Earth's orbit around the sun. What season does the Northern Hemisphere experience when the Earth's axis points toward the sun?

____

Why? ____

____

____

____

____

What season does the Northern Hemisphere experience when the Earth's axis is tilted away from the sun?

____

Why? ____

____

____

____

____

3. **Plan**

Read the list of materials below. Think about which materials you would like to use to model the Earth's path around the sun. Beside the materials that you **will** use, write **what** each materials represents.

Material	What does the material represent?
Blue Clay	
Yellow Clay	
String	
Toothpick	

Collect the materials that you need and then construct your model. Use the tip of the toothpick to carefully draw the equator on your model of Earth. Test your model to determine whether you predicted the correct seasons at each position.

4. **Create**

Use the model you have just created to help you **visualize** the way that Earth travels around the Sun. Use a pencil to create a scientific drawing that shows **why** seasons change.

a. Draw a picture of the Earth's **orbit**. The orbit is the path the Earth takes around the sun.
b. Draw and label the sun.
c. Draw the Earth at four different positions in its orbit.
d. Show how the Earth is tilted at the different locations: draw the Earth's axis.
e. Draw the Earth's equator on each of the four pictures of Earth.
f. Imagine that you are standing in the Northern Hemisphere; use a blue marker or crayon to predict and label the season that you would experience at each of the four positions.
g. Imagine that you are standing in the Southern Hemisphere; use a red marker or crayon to predict and label the season that you would experience at each of the four positions.

5. **Improve**

Does your drawing show all four seasons? If not, how can you improve the drawing to show each season?

What materials could you use to improve your model?

My Favorite Season

Name: ______________________ Date: _________________

There are four seasons: spring, summer, fall and winter. Which one is your favorite? Write two paragraphs describing your favorite season. On the back of this paper, draw a picture to illustrate your favorite season.

KWL Worksheet

Name: ____ Date: ____________________________________

What do you **Know** about the seasons?	What do you **Want** to know about the seasons?	What did you **Learn** about the seasons?