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.
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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 disequilibrium, (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 disequilibrium 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>
<thead>
<tr>
<th>Table 1: Cooperative learning groups vs. traditional learning groups</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cooperative Learning Groups</strong></td>
</tr>
<tr>
<td>Positive interdependence</td>
</tr>
<tr>
<td>Individual accountability</td>
</tr>
<tr>
<td>Heterogeneous</td>
</tr>
<tr>
<td>Shared leadership</td>
</tr>
<tr>
<td>Shared responsibility for each other</td>
</tr>
<tr>
<td>Task and maintenance emphasized</td>
</tr>
<tr>
<td>Social skills directly taught</td>
</tr>
<tr>
<td>Teachers observe and intervene</td>
</tr>
<tr>
<td>Groups process their effectiveness</td>
</tr>
</tbody>
</table>

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

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

Figure 1: The format for the “Information Box”

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade Level</td>
<td>Either “2” or “3”</td>
</tr>
<tr>
<td>Sessions</td>
<td>Number of sessions, as well as length of each in minutes</td>
</tr>
<tr>
<td>Seasonality</td>
<td>Fall, Winter, or Spring, if appropriate</td>
</tr>
<tr>
<td>Instructional Mode(s)</td>
<td>Groups, discussion or hands-on design</td>
</tr>
<tr>
<td>Team Size</td>
<td>Individual students, small groups, or whole class</td>
</tr>
<tr>
<td>WPS Benchmarks</td>
<td>Listed by code</td>
</tr>
<tr>
<td>MA Frameworks</td>
<td>Listed by code</td>
</tr>
<tr>
<td>Key Words</td>
<td>List of engineering, technology, and science words</td>
</tr>
</tbody>
</table>
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.

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 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.
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.
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 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

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

- 0% No
- 13% Little Bit
- 87% Yes

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

2. Have you used the engineering design process to build any projects at home?

- 64% Yes
- 31% No
- 5% Little Bit

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

3. Do you think you want to be an engineer when you get older?

- 47% Yes
- 31% No
- 22% Maybe
- 5% Little Bit


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](image)

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.
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.

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 receive 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

<table>
<thead>
<tr>
<th>Materials</th>
<th>Quantity</th>
<th>Location</th>
<th>Classroom Cost ($) ~20 students</th>
</tr>
</thead>
<tbody>
<tr>
<td>A large container w/lid</td>
<td>1</td>
<td>Pet Center</td>
<td>22.99</td>
</tr>
<tr>
<td>Plants</td>
<td>As necessary</td>
<td>Home Improv. Store, Nursery</td>
<td></td>
</tr>
<tr>
<td>Gravel</td>
<td>½ Gallon</td>
<td>Pet Center</td>
<td>2.49</td>
</tr>
<tr>
<td>Sand</td>
<td>½ Gallon</td>
<td>Home Improv. Store</td>
<td>3.66</td>
</tr>
<tr>
<td>Soil</td>
<td>½ Gallon</td>
<td>Home Improv. Store, Nursery</td>
<td>1.57</td>
</tr>
<tr>
<td>Bark</td>
<td>¼ Bag</td>
<td>Home Improv. Store, Nursery</td>
<td>3.88</td>
</tr>
<tr>
<td>Charcoal</td>
<td>¼ Bag</td>
<td>Hardware store, food store</td>
<td>13.00</td>
</tr>
<tr>
<td>Jar w/ lid or ½ pint dish</td>
<td>1</td>
<td>Pet Center</td>
<td>3.49</td>
</tr>
<tr>
<td>Trowel</td>
<td>1</td>
<td>Home Improv. Store, Nursery</td>
<td>5.72</td>
</tr>
<tr>
<td>Plant mister</td>
<td>1</td>
<td>Home Improv. Store, Nursery</td>
<td>1.68</td>
</tr>
<tr>
<td>Small animals: Toad &amp; Salamander</td>
<td>2</td>
<td>Outside</td>
<td>0.00</td>
</tr>
<tr>
<td>Food: Crickets</td>
<td>Undefined</td>
<td>Pet Center</td>
<td>0.10/each</td>
</tr>
<tr>
<td>Food: Salamander Food</td>
<td>1</td>
<td>Pet Center</td>
<td>2.49</td>
</tr>
<tr>
<td>Heat lamp</td>
<td>1</td>
<td>Pet Center</td>
<td>13.99</td>
</tr>
<tr>
<td>Heat lamp bulb</td>
<td>1</td>
<td>Pet Center</td>
<td>9.49</td>
</tr>
<tr>
<td>Water dish (plastic tub)</td>
<td>1</td>
<td>Pet Center</td>
<td>3.49</td>
</tr>
<tr>
<td>Small animals: Chameleons</td>
<td>2</td>
<td>Pet Center</td>
<td>30.00</td>
</tr>
<tr>
<td>A large container</td>
<td>1</td>
<td>Pet Center</td>
<td>14.99</td>
</tr>
<tr>
<td>Plants</td>
<td></td>
<td>Home Improv. Store, Nursery</td>
<td></td>
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<tr>
<td>Aquarium Salt</td>
<td>1/2 tsp per gallon</td>
<td>Pet Center</td>
<td>2.79</td>
</tr>
<tr>
<td>Water filter</td>
<td>1 w/ replacement filters</td>
<td>Pet Center</td>
<td>12.24</td>
</tr>
<tr>
<td>Small animals: Fish</td>
<td>2</td>
<td>Pet Center</td>
<td>0.58</td>
</tr>
<tr>
<td>Food: Tropical Fish Food</td>
<td>1</td>
<td>Pet Center</td>
<td>2.49</td>
</tr>
<tr>
<td>Glass baking dish</td>
<td>1</td>
<td>Home &amp; Kitchen Center, Target</td>
<td>12.99</td>
</tr>
<tr>
<td>Item</td>
<td>Quantity</td>
<td>Location</td>
<td>Cost</td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
<td>----------</td>
<td>---------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Rocks, wood</td>
<td>Undefined</td>
<td>Home Improv. Store, Nursery</td>
<td>5.74</td>
</tr>
<tr>
<td>Small animals: Fiddler/Hermit Crabs</td>
<td>2</td>
<td>Pet Center</td>
<td>5.00</td>
</tr>
<tr>
<td>Food for crabs</td>
<td>1</td>
<td>Pet Center</td>
<td>4.99</td>
</tr>
<tr>
<td>Food: feeder fish</td>
<td>Undefined</td>
<td>Pet Center</td>
<td></td>
</tr>
<tr>
<td>12-inch ruler</td>
<td>1 per student/group</td>
<td>Classroom supply</td>
<td>0.00</td>
</tr>
<tr>
<td>Aluminum foil</td>
<td>1 roll</td>
<td>Grocery store</td>
<td>0.79</td>
</tr>
<tr>
<td>Clear tape</td>
<td>1 roll</td>
<td>Drugstore, office supply store</td>
<td>2.04</td>
</tr>
<tr>
<td>Duct tape</td>
<td>1 roll</td>
<td>Hardware store</td>
<td>3.95</td>
</tr>
<tr>
<td>Lightweight cardboard</td>
<td>Several pieces per group</td>
<td>Recycled</td>
<td>0.00</td>
</tr>
<tr>
<td>Milk cartons (1 or ½ Gal.)</td>
<td>1 per student/team</td>
<td>Recycled</td>
<td>0.00</td>
</tr>
<tr>
<td>Permanent markers</td>
<td>Several sets</td>
<td>School supply</td>
<td>0.00</td>
</tr>
<tr>
<td>Plastic drinking straws</td>
<td>1 package</td>
<td>Grocery store, dollar store</td>
<td>1.75</td>
</tr>
<tr>
<td>Plastic wrap</td>
<td>1 roll</td>
<td>Grocery store</td>
<td>0.99</td>
</tr>
<tr>
<td>Popsicle sticks/tongue depressors</td>
<td>1 package</td>
<td>Craft supply store</td>
<td>3.95</td>
</tr>
<tr>
<td>Scissors</td>
<td>1 pair per group</td>
<td>School supply</td>
<td>0.00</td>
</tr>
<tr>
<td>Scraps of colored paper/fabric</td>
<td>Undefined</td>
<td>Recycled</td>
<td>0.00</td>
</tr>
<tr>
<td>String</td>
<td>1 roll</td>
<td>Hardware store, toy store</td>
<td>1.00</td>
</tr>
<tr>
<td>Pipe Cleaners</td>
<td>1 package</td>
<td>Craft Supply Store</td>
<td>1.00</td>
</tr>
<tr>
<td>Cardboard Base (~6 in sqr)</td>
<td>1 per student</td>
<td>Recycled</td>
<td>0.00</td>
</tr>
<tr>
<td>Soda Cans</td>
<td>~2 per student</td>
<td>Recycled</td>
<td>0.00</td>
</tr>
<tr>
<td>Lever/Crane Kit</td>
<td>1</td>
<td>PIEE</td>
<td>0.00</td>
</tr>
<tr>
<td>Large food container</td>
<td>1</td>
<td>Kitchen stores</td>
<td>12.99</td>
</tr>
<tr>
<td>A variety of crushed cookies</td>
<td>2 cups each</td>
<td>Food stores</td>
<td>4.00</td>
</tr>
<tr>
<td>A variety of cookies/crackers/candies</td>
<td>2 types</td>
<td>Food stores</td>
<td>4.47</td>
</tr>
<tr>
<td>Jell-O, with crackers/candies</td>
<td>1</td>
<td>Food stores</td>
<td>0.63</td>
</tr>
<tr>
<td>Large laminated grid sheet/whiteboard/chalkboard</td>
<td>1</td>
<td>School supply</td>
<td>0.00</td>
</tr>
<tr>
<td>Toothpicks</td>
<td>1 package</td>
<td>Grocery store, dollar store</td>
<td>0.99</td>
</tr>
<tr>
<td>Plastic Cutlery</td>
<td>1 package</td>
<td>Grocery store, dollar store</td>
<td>4.00</td>
</tr>
<tr>
<td>Paper plates</td>
<td>1 package</td>
<td>Grocery store, dollar store</td>
<td>1.49</td>
</tr>
<tr>
<td>Napkins</td>
<td>1 package</td>
<td>Grocery store, dollar store</td>
<td>1.88</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>225.76</strong></td>
</tr>
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</table>
Table 4: List of Delta Education prices for comparable grade two kits, separated by applicable lesson plans

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

<table>
<thead>
<tr>
<th>Materials</th>
<th>Quantity</th>
<th>Price per Class $</th>
<th>Description</th>
<th>Brand</th>
<th>Store</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Cycle Part 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear Plastic Container</td>
<td>1</td>
<td>1.97</td>
<td>6.5qt</td>
<td>Rubbermaid</td>
<td>Wal-Mart</td>
</tr>
<tr>
<td>Blue Food Coloring</td>
<td>1</td>
<td>2.99</td>
<td>4-multi color</td>
<td>Betty Crocker</td>
<td>Stop and Shop</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Plastic Wrap</td>
<td>1</td>
<td>1.39</td>
<td>100 square feet</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tape</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>Classroom</td>
<td></td>
</tr>
<tr>
<td>Lamp with 100 Watt Bulb</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Icepack</td>
<td>1</td>
<td>0.99</td>
<td>Small</td>
<td>Rubbermaid</td>
<td>Wal-Mart</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>7.34</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>What is a centimeter?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metric Ruler</td>
<td>20</td>
<td>5.40</td>
<td>12in</td>
<td>Wal-Mart</td>
<td>Wal-Mart</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>5.40</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Cycle Part 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paper</td>
<td>1</td>
<td>2.84</td>
<td>500 sheets</td>
<td>Georgia-Pacific</td>
<td>Wal-Mart</td>
</tr>
<tr>
<td>Clear Cups</td>
<td>1</td>
<td>1.99</td>
<td>18-10 oz(clear)</td>
<td>Stop and Shop</td>
<td>Stop and Shop</td>
</tr>
<tr>
<td>Cold Water</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Room Temperature Water</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hot Water</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ice Cubes</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Item</td>
<td>Quantity</td>
<td>Price</td>
<td>Unit / Description</td>
<td>Supplier 1</td>
<td>Supplier 2</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------</td>
<td>--------</td>
<td>--------------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td><strong>Sound Machine</strong></td>
<td></td>
<td>4.83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry Kidney Beans</td>
<td>1</td>
<td>0.89</td>
<td>16 oz</td>
<td>Goya</td>
<td>Stop and Shop</td>
</tr>
<tr>
<td>Paper Plates</td>
<td>1</td>
<td>3.99</td>
<td>9 in</td>
<td>Stop and Shop</td>
<td>Stop and Shop</td>
</tr>
<tr>
<td>Rubber Bands</td>
<td>1</td>
<td>0.46</td>
<td>3in x 1/8in</td>
<td>Alliance</td>
<td>Wal-Mart</td>
</tr>
<tr>
<td>Popsicle Sticks</td>
<td>100</td>
<td>2.88</td>
<td>1-box</td>
<td>Waddle Wedoo</td>
<td>AC Moore</td>
</tr>
<tr>
<td>Small Round Cardboard Box</td>
<td>20</td>
<td>19.40</td>
<td></td>
<td>-</td>
<td>Nicole</td>
</tr>
<tr>
<td>Rubber Bands</td>
<td>1</td>
<td>-</td>
<td></td>
<td>-</td>
<td>Classroom</td>
</tr>
<tr>
<td>Medium Sized Sheet of Paper</td>
<td>1</td>
<td>3.79</td>
<td>12in x 18in</td>
<td>Art Street</td>
<td>Michaels</td>
</tr>
<tr>
<td>Wax Paper</td>
<td>1</td>
<td>1.29</td>
<td>75 square feet</td>
<td>Stop and Shop</td>
<td>Stop and Shop</td>
</tr>
<tr>
<td><strong>Rock Candy</strong></td>
<td></td>
<td>32.70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar</td>
<td>1</td>
<td>2.59</td>
<td>5 lb</td>
<td>Stop and Shop</td>
<td>Stop and Shop</td>
</tr>
<tr>
<td>Water</td>
<td>-</td>
<td>-</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Food Coloring</td>
<td>1</td>
<td>2.99</td>
<td>4-multi color</td>
<td>Betty Crocker</td>
<td>Stop and Shop</td>
</tr>
<tr>
<td>Wooden Spoon</td>
<td>-</td>
<td>-</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wax Paper</td>
<td>1</td>
<td>1.29</td>
<td>75 square feet</td>
<td>Stop and Shop</td>
<td>Stop and Shop</td>
</tr>
<tr>
<td>Large Pot</td>
<td>1</td>
<td>19.99</td>
<td>20 qt</td>
<td>Ekco</td>
<td>Stop and Shop</td>
</tr>
<tr>
<td>Pencils</td>
<td>24</td>
<td>0.97</td>
<td>1-package</td>
<td>Papermate</td>
<td>Wal-Mart</td>
</tr>
<tr>
<td>Embroidery Floss</td>
<td>3</td>
<td>0.87</td>
<td>8.7yd</td>
<td>DMC</td>
<td>Stop and Shop</td>
</tr>
<tr>
<td>Heating Source</td>
<td>-</td>
<td>-</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Measuring Spoons</td>
<td>1</td>
<td>1.47</td>
<td>1/8-1 cup</td>
<td>Wal-Mart</td>
<td>Wal-Mart</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1.24</td>
<td>1/8 tsp-1tbsp</td>
<td>Wal-Mart</td>
<td>Wal-Mart</td>
</tr>
<tr>
<td><strong>Reason for Seasons</strong></td>
<td></td>
<td>31.41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue Clay</td>
<td>1**</td>
<td>1.00</td>
<td>12 oz (rainbow)</td>
<td>Roseart</td>
<td>Michaels</td>
</tr>
<tr>
<td>Yellow Clay</td>
<td>1**</td>
<td>1.00</td>
<td>12 oz (rainbow)</td>
<td>Roseart</td>
<td>Michaels</td>
</tr>
<tr>
<td>Large Sheet of Paper</td>
<td>1</td>
<td>5.99</td>
<td>30-22&quot;x16&quot;</td>
<td>Crayola Floor Plan</td>
<td>Michaels</td>
</tr>
<tr>
<td>Toothpicks</td>
<td>1</td>
<td>0.59</td>
<td>750-flat wood</td>
<td>Stop and Shop</td>
<td>Stop and Shop</td>
</tr>
<tr>
<td>Embroidery Floss</td>
<td>3</td>
<td>0.87</td>
<td>8.7 yd</td>
<td>DMC</td>
<td>Stop and Shop</td>
</tr>
<tr>
<td>Globe</td>
<td></td>
<td>9.45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>UNIT</th>
<th>LESSON</th>
<th>SUMMARY</th>
<th>MSTEC FRAMEWORKS</th>
<th>WPS BENCHMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Living and Non-Living Things</td>
<td>2.A.1: Terrarium Lesson</td>
<td>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.</td>
<td>K-2.TE.1.1</td>
<td>02.SC.IS.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>K-2.TE.1.2</td>
<td>02.SC.IS.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>K-2.TE.1.3</td>
<td>02.SC.IS.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>02.SC.IS.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>02.SC.IS.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>02.SC.TE.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>02.SC.TE.02</td>
</tr>
<tr>
<td></td>
<td>2.A.2: Birdhouse</td>
<td>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</td>
<td>K-2.TE.1.1</td>
<td>02.SC.IS.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>K-2.TE.1.2</td>
<td>02.SC.IS.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>K-2.TE.1.3</td>
<td>02.SC.IS.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>02.SC.IS.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>02.SC.IS.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>02.SC.TE.01</td>
</tr>
</tbody>
</table>
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 |

| 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 |
Table 7: Lesson summaries for grade three

<table>
<thead>
<tr>
<th>UNIT</th>
<th>LESSON</th>
<th>SUMMARY</th>
<th>MSTEC FRAMEWORKS</th>
<th>WPS BENCHMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Introduction to Engineering</td>
<td>3.A.1 Sparky’s Engineer</td>
<td>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.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B: The Engineering Design Process</td>
<td>3.B.1 Tree House</td>
<td>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.</td>
<td>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</td>
<td>03.SC.TE.01 03.SC.TE.02 03.SC.TE.03 03.SC.TE.04 03.SC.TE.05 03.SC.IS.03</td>
</tr>
<tr>
<td>C: Materials</td>
<td>3.C.1 Materials to Build</td>
<td>This lesson introduces students to materials and their properties; students will have the opportunity to manipulate and discuss these properties.</td>
<td>3-5.TE.1.1 3-5.TE.2.2 3-5.PS.1.1</td>
<td>03.SC.TE.01 03.SC.TE.04 03.SC.PS.02</td>
</tr>
<tr>
<td></td>
<td>3.C.2 Properties of Materials</td>
<td>This lesson expands students’ knowledge of material properties by familiarizing them with different types of materials and their applications in real-world situations.</td>
<td>3-5.TE.1.1 3-5.TE.2.1 3-5.PS.1.1</td>
<td>03.SC.TE.01 03.SC.TE.04 03.SC.PS.02</td>
</tr>
<tr>
<td>3.C.3 Sound Machine</td>
<td>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.</td>
<td>3-5.TE.1.1</td>
<td>3-5.TE.1.2</td>
<td>3-5.PS.1.1</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>3.C.4 Minerals Observe and Identify</td>
<td>This lesson provides students with the opportunity to observe various properties of minerals and to record their observations in a notebook.</td>
<td>3-5.TE.1.1</td>
<td>3-5.ES.0.1</td>
<td>3-5.ES.0.2</td>
</tr>
<tr>
<td>3.C.4 Rocks Observing Properties</td>
<td>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.”</td>
<td>3-5.TE.1.1</td>
<td>3-5.ES.0.3</td>
<td>03.SC.TE.01</td>
</tr>
<tr>
<td>3.C.6 Making a Rock and Mineral Collection</td>
<td>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.</td>
<td>3-5.TE.1.1</td>
<td>3-5.TE.2.1</td>
<td>3-5.ES.0.1</td>
</tr>
<tr>
<td>3.C.7 Soil Water Retention</td>
<td>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.</td>
<td>3-5.TE.2.2</td>
<td>3-5.TE.2.3</td>
<td>3-5.ES.0.5</td>
</tr>
<tr>
<td>3.C.8 Soil Composition</td>
<td>The objective of this lesson is to extend students’ understanding of the composition of</td>
<td>3-5.ES.0.4</td>
<td>03.TE.SC.05</td>
<td>03.SC.IS.01</td>
</tr>
</tbody>
</table>
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.

| 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.

<table>
<thead>
<tr>
<th>3-5.LS.0.3</th>
<th>03.SC.LS.07</th>
</tr>
</thead>
</table>

### E: Maple Sugaring

<table>
<thead>
<tr>
<th>3.1.1 Maple Trees Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
</tr>
<tr>
<td>3-5.TE.2.1</td>
</tr>
<tr>
<td>3-5.LS.0.2</td>
</tr>
<tr>
<td>03.SC.TE.04</td>
</tr>
<tr>
<td>03.SC.LS.06</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3.1.2 Collecting Maple Sap</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
</tr>
<tr>
<td>3-5.TE.21</td>
</tr>
<tr>
<td>3-5.LS.02</td>
</tr>
<tr>
<td>03.SC.TE.03</td>
</tr>
<tr>
<td>03.SC.LS.06</td>
</tr>
</tbody>
</table>

### F: Solids, Liquids and Gasses

<table>
<thead>
<tr>
<th>3.1.1 Water Cycle Part 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
</tr>
<tr>
<td>3-5.TE.2.2</td>
</tr>
<tr>
<td>3-5.PS.0.3</td>
</tr>
<tr>
<td>03.SC.TE.04</td>
</tr>
<tr>
<td>03.SC.PS.05</td>
</tr>
<tr>
<td>03.SC.PS.06</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3.1.2 Water Cycle Part 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>After seeing a demonstration of the water cycle (see lesson 3.1.1 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.</td>
</tr>
<tr>
<td>3-5.TE.2.2</td>
</tr>
<tr>
<td>3-5.PS.0.3</td>
</tr>
<tr>
<td>03.SC.TE.04</td>
</tr>
<tr>
<td>03.SC.PS.06</td>
</tr>
<tr>
<td>03.SC.IS.04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3.1.3 Rock Candy</th>
</tr>
</thead>
<tbody>
<tr>
<td>This lesson introduces children to the creation of sugar crystals, which occurs when water evaporates from a saturated sugar-water solution.</td>
</tr>
<tr>
<td>3-5.TE.2.2</td>
</tr>
<tr>
<td>3-5.PS.0.3</td>
</tr>
<tr>
<td>03.SC.TE.04</td>
</tr>
<tr>
<td>03.SC.TE.05</td>
</tr>
<tr>
<td>03.SC.PS.03</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>G: Graphing and the Metric System</th>
<th>03.SC.PS.06</th>
<th>03.SC.IS.06</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.G.1 What is a Graph?</td>
<td>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.</td>
<td>3-5.TE.2.2</td>
</tr>
<tr>
<td>3.G.2 What is a Centimeter?</td>
<td>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.</td>
<td>-</td>
</tr>
</tbody>
</table>
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.
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).
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.
Works Cited


Brazeau-Ward, L. (2003) I’m confused, is it dyslexia or is it learning disability? Canadian Dyslexia Centre (CDC) Inc.


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

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

Table 9: Grading rubric for the grade three Engineering Review

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